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Discrete map for traffic simulation

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D.V. Belkov, E.N. Edemskaya Discrete map for traffic simulation. *One of the most important mathematical discoveries of the past few decades is that random behavior can arise in deterministic nonlinear systems with just a few degrees of freedom. This discovery gives new hope to providing simple mathematical models for analyzing systems. The analysis of the network traffic is actually reduced to the task of processing the time series. The theory of non-linear dynamics provides a potential to study, identification and prediction of the time series that have some specific properties. Recent studies of real traffic data in modern computer networks have shown that traffic exhibits self-similar (fractal) properties. The use of traditional models in networks characterized by self-similar processes can lead to incorrect conclusions about the performance of analyzed networks. Many analytical studies have shown that self-similar network traffic can have a detrimental impact on network performance, including amplified queuing delays and packet loss rates in broadband wide area networks The understanding of the self-similar nature in traffic is an important issue. One of the most important tasks of network research is to construct adequate models for the concerned traffic flows. The objective of our work is deterministic traffic simulation. The task of this work is design of one dimension discrete map for traffic simulation. Discrete maps can produce broad traffic models in the sense that sometimes even one parameter is enough to produce the range of behavior that appears in packet traffic. The discrete map for network traffic simulation is offered in this work. In this article the researches are executed in the Matlab environment. For the study two realization of network traffic is chosen. They are got in the university of city Napoly (Italy). In obedience to a license information is freely accessible for the analysis. Studied time series are the measuring of TCP-packet jitter. In first case (TCP_j512) packets have a volume a 512 byte, in the second (TCP_j1024) is a 1024 byte. The measuring were conducted every 10 milliseconds, over 2000 counting out is got. A sender had 802.11b connection, a recipient is UMTS-access, speed of transmission 100 pps. In the article for the simulation of these time series it is suggested to use the discrete map, that built on the basis of the map "tent" and Zaborovsky map. The simulation of TCP-packets jitter of wireless network is executed. Phase trajectories of models and real processes have same type. The offered discrete displaying can be used for bursty traffic simulation.*

Introduction

Recent studies of real traffic data in modern computer networks have shown that traffic exhibits self-similar (fractal) properties over a wide range of time scales [1,2]. The properties of self-similar traffic are different from properties of traditional models based on Poisson, Markov-modulated Poisson, and related processes. The use of traditional models in networks characterized by self-similar processes can lead to incorrect conclusions about the performance of analyzed networks. The use of traditional models leads to over-estimation of the performance quality of computer networks, insufficient allocation of communication and data processing resources, and difficulties in ensuring the quality of service expected by network users.

Many analytical studies have shown that self-similar network traffic can have a detrimental impact on network performance, including amplified queuing delays and packet loss rates in broadband wide area networks. Praxson and Floyd found that wide-area network traffic consists of more bursts than Poisson models predict over many time scales. This difference has implications for congestion control mechanisms and performance. Crovella and Bestavros found evidence and possible causes of self-similarity in World Wide Web traffic, such as WWW document file size data.

The possibilities of dynamic systems in simulation of the network traffic are studied in a series of research works by Erramilli.

The understanding of the self-similar nature in traffic is an important issue. One of the most important tasks of network research is to construct adequate models for the concerned traffic flows. New self-similar traffic models are necessary to reveal the dynamics of individual streams of data and how they give rise to the self-similar characteristics observed in real-world situations. Such models must be analytically tractable or algorithmic to enable simulation studies. The performance of communication networks with the self-similar characteristics of traffic must be studied to determine the consequences of self-similarity of data streams on queuing performance [3-5].

The understanding traffic behavior is important in network dimensioning and performance prediction. There is a basic need for a comprehensive and detailed study of fractal traffic theory. Many significant results have been obtained in a number of approaches published in this field, there are still many open questions to be answered.

The objective of our work is deterministic traffic simulation. The task of this work is design of one dimension discrete map for traffic simulation. Discrete maps can produce broad traffic models in the sense that sometimes even one parameter is enough to produce the range of behavior that appears in packet traffic. Dynamic networks such as ATM are capable of interesting time behavior. That means that over particular time intervals, the traffic pressure on the network is varied. A discrete map is a reasonable model of incident traffic, which makes possible to model the dynamic behavior of a packet network under study by using non-linear equations. Chaotic models of nonlinear dynamics have been used as alternatives for stochastic models in many branches of science [6,7].

Traffic simulation

The theories of chaos and fractals are among the more broadly applicable developments in all of science over the last three decades. From a modeler's viewpoint, their appeal lies in the promise of capturing complexity in a concise manner. Ideas from chaos and fractals have been successfully used to model complex, bursty phenomena in virtually every branch of science. Recent measurement studies do in fact reveal that actual packet traffic has features that can more efficiently be described in terms of fractal processes, rather than conventional stochastic processes. Fundamentally, chaos and fractals are independent and unrelated concepts. However fractal geometry is invoked to describe the irregular trajectories of chaotic systems in state space; and chaotic systems are often used as convenient generators of fractal processes.

It is known that chaotic systems have the following main properties: non-linearity, determinacy and sensitivity to the initial conditions. Besides, chaotic time series looks like a stochastic process. The attractor of a non-linear chaotic system is frequently fractal. If it is possible to detect the feature of deterministic chaos in the traffic, we will obtain a new model of the traffic and a new algorithm of its prediction due to the chaos deterministic nature. The traffic model of TCP protocol can be both a simple periodic process and, under some conditions, have a complex behavior compatible with the concept of deterministic chaos. In particular, the researchers obtained a trajectory of the system in phase space that they referred to the class of strange attractors. An attractor is a cluster set of trajectories in the phase space of the system to which all the trajectories from a neighborhood of this set tend [6].

We assume that a packet traffic is deterministic. For example, the figure 1 shows a phase space plot between successive inter-arrival times (t_{i+1} vs. t_i) for Ethernet type data [3]. One can easily observe the existence of clusters, diagonal lines, vertical and horizontal lines. These shapes on the plot indicate the existence of determinism in packet traffic. This aspect of packet traffic is justified by the existence of deterministically spaced packets and their superposition. Discrete maps may allow for a more concise description of these structures, which can significantly influence queuing behaviors.

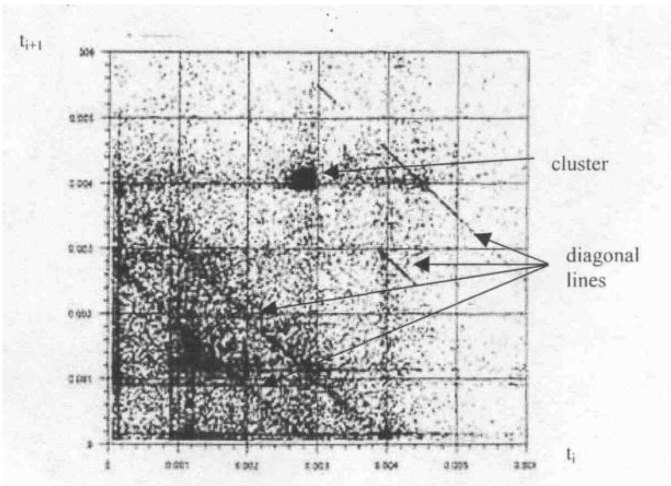

Figure 1. - Phase space plot of successive inter-arrival times [3]

In our article the researches are executed in the Matlab environment. For the study two realization of network traffic is chosen. They are got in the university of city Napoly (Italy). In obedience to a license information is freely accessible for the analysis. Studied time series are the measuring of TCP-packet jitter. In first case (TCP_j512) packets have a volume a 512 byte, in the second (TCP_j1024) is a 1024 byte. The measuring were conducted every 10 milliseconds, over 2000 counting out is got. A sender had 802.11b connection, a recipient is UMTS-access, speed of transmission 100 pps [8]. In the article for the simulation of these time series it is suggested to use the discrete map, that built on the basis of the map “tent” [9] and Zaborovsky map [10].

The map “tent” looks like $x_i = \begin{cases} x_{i-1}/a, 0 < x_{i-1} < a \\ (1-x_{i-1})/(1-a), a < x_{i-1} \le 1 \end{cases}$, $x_0 = 0.1$.

Zaborovsky map: $y_i = \frac{y_{i-1}}{b} + \frac{1}{y_{i-1}} - 1$, $y_0 = 1$.

Offered map (z/t map) looks like $z_i = \frac{{y_i}^c}{x_i}$. Control parameters a, b, c are constants. The figure 2 shows simulation chart. It is needed to adjust control parameters of the model and coefficients k_1, k_2, that to minimize error.

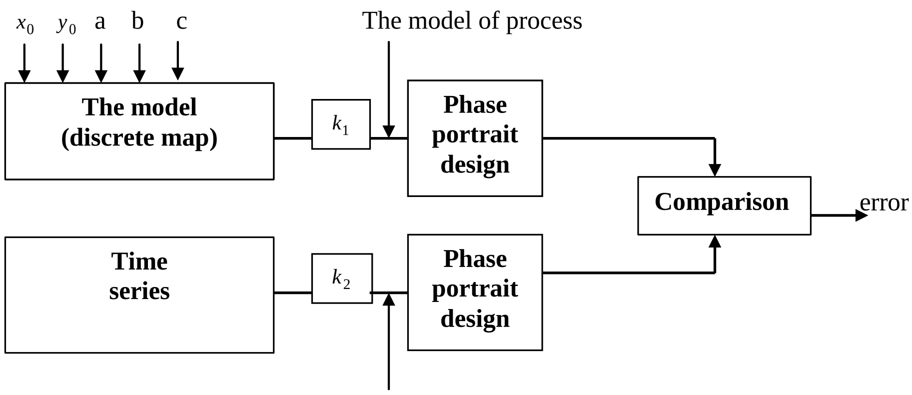

Figure 2. - Simulation chart

At the simulation of time series TCP_j512 we appropriated the values to the parameters: $x_0 = 0.1$, $y_0 = 1$, $a = 0.3$, $b = 3.8$, $c = 0.5$, $k_1 = 4.5$, $k_2 = 10^4$. The figures 3-6 show simulation results. Alike trajectories on phase portraits are marked by identical numbers.

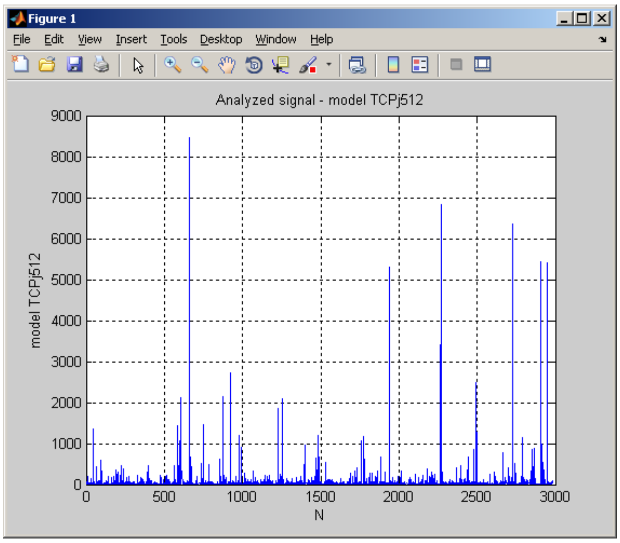

Figure 3. - The model of time series TCP_j512

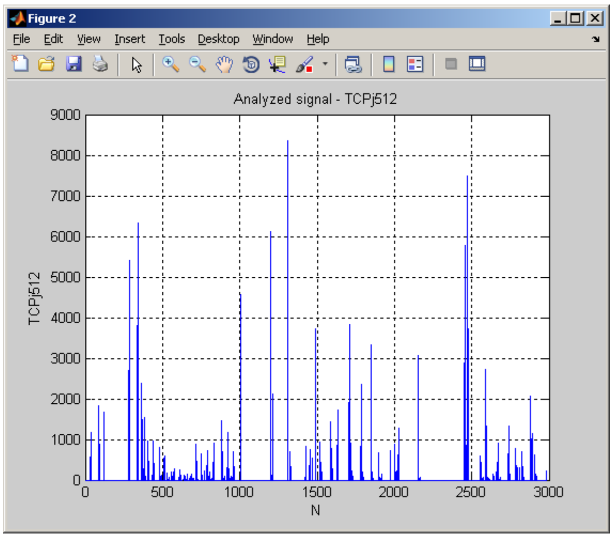

Figure 4. - Simulated process TCP_j512

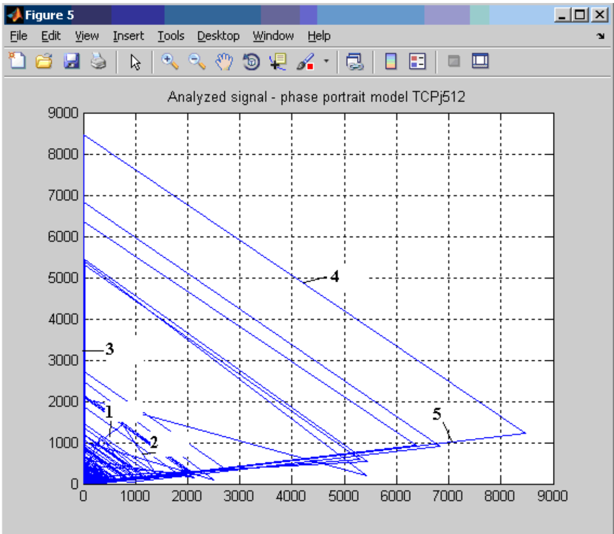

Figure 5. – Phase portrait of the model TCP_j512

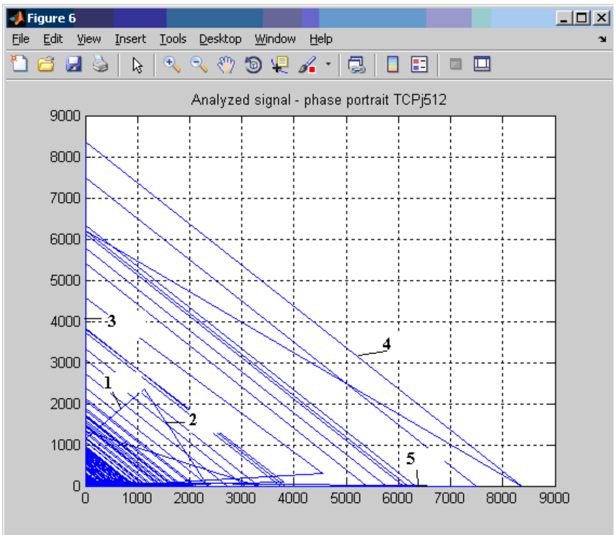

Figure 6. – Phase portrait TCP_j512

At the simulation of time series TCP_j1024 we appropriated the values to the parameters: $x_0 = 0.1$,

$y_0 = 1$, $a = 0.3$, $b = 3.8$, $c = 1$, $k_1 = 2.7$, $k_2 = 10^4$. The figures 7-10 show simulation results. Alike trajectories on phase portraits are marked by identical numbers.

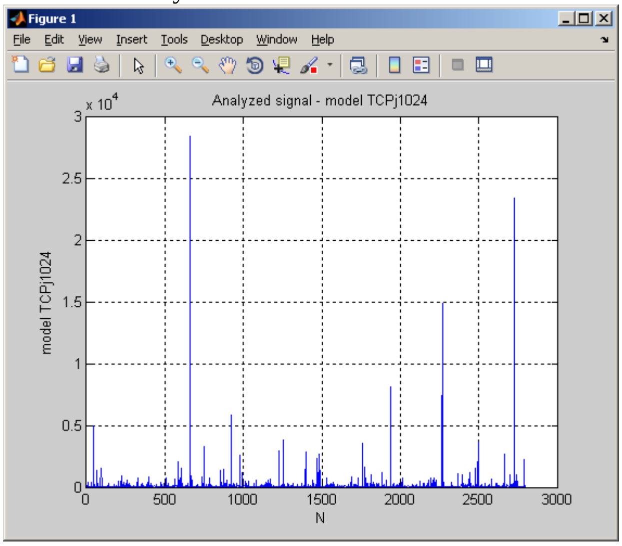

Figure 7. - The model of time series TCP_j1024

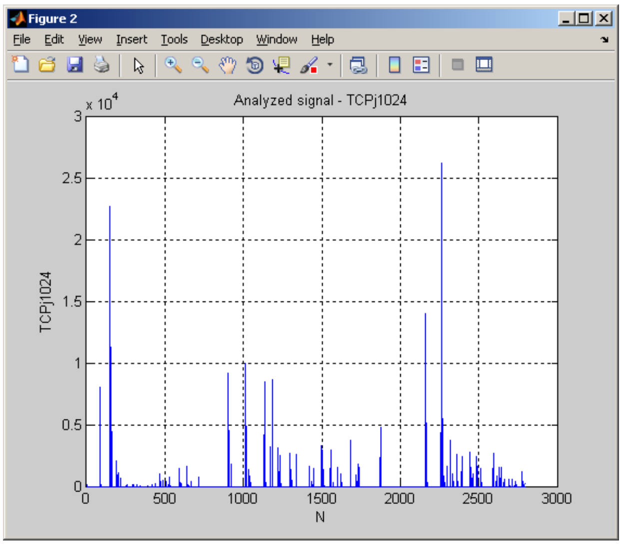

Figure 8. - Simulated process TCP_j1024

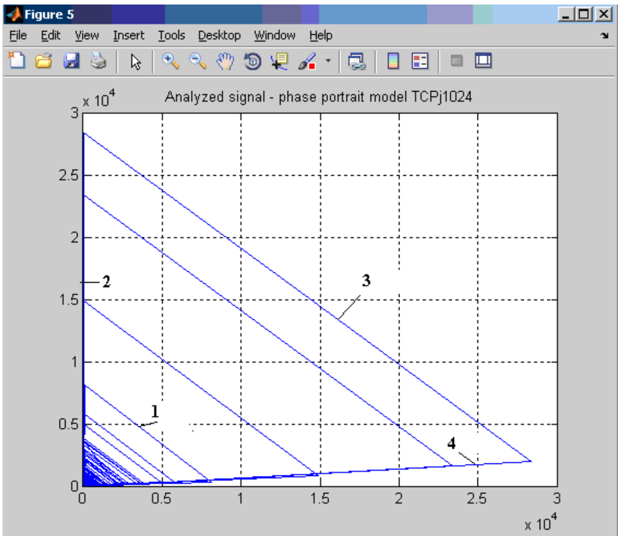

Figure 9. – Phase portrait of the model TCP_j1024

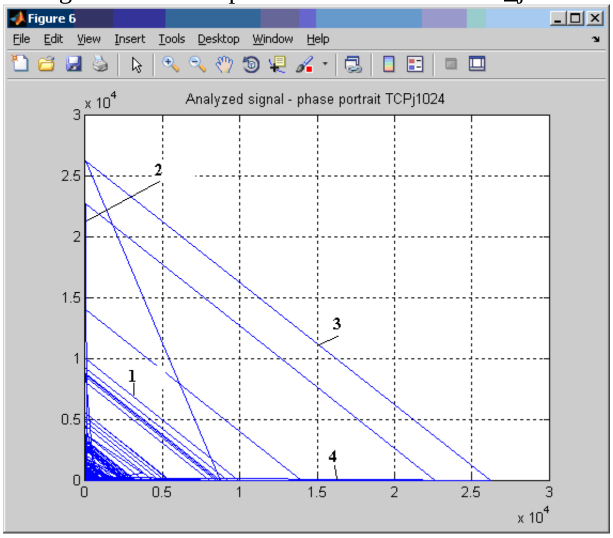

Figure 10. – Phase portrait TCP_j1024

Conclusions

The analysis of the network traffic is actually reduced to the task of processing the time series. The theory of non-linear dynamics provides a potential to study, identification and prediction of the time series that have some specific properties. The discrete map for network traffic simulation is offered in this work. The simulation of TCP-packets jitter of wireless network is executed. Phase trajectories of models and real processes have same type. The offered discrete displaying can be used for bursty traffic simulation.

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