Computer Science Journal of Moldova, vol.12, no.2(35), 2004

Foreword

The 1990s have seen a flurry of new discoveries on the properties of Internet traffic, beginning with the seminal paper by Leland et al. at ACM SIGCOMM '93 on the self-similar nature of local area network traffic. The Ethernet based findings have been confirmed in wide area network settings governed by IP, and self-similar burstiness has been shown to be the norm, rather than the exception, of data traffic. The three key accomplishments have consisted of the identification of the principal cause of traffic self-similarity – heavy-tailed file sizes – the performance impact of long-range dependence with respect to queueing, and multiple time scale traffic control which seeks to harness correlation structure at large time scales.

A topic that has received limited attention is the relationship between fractal burstiness and chaotic dynamics. Self-similarity and chaos are, in general, independent notions, and one need not be accompanied by the other. In numerous domains of interest, however, there is an intimate relationship between self-similarity and chaos – a classical example being chaotic dynamical systems that induce convergent sub-domains which are fractal (e.g., Mandelbrot set) – so that it is natural to ask if nontrivial connections exist in the context of network traffic.

A similar distinction exists between self-similarity and long-range dependence (also referred to as power-law behavior), which are oftentimes used interchangeably in traffic modeling due to their joint occurrence. Thus, the difference here is that for network traffic it is known that one rarely occurs without the other. The same cannot be said of self-similarity and chaos. The special issue on "Network Traffic and Chaos" co-edited by "Computer Science Journal of Moldova" and "International Journal of Chaos Theory and Applications" is aimed at exploring this question, both directly through the use of dynamical systems and indirectly by characterizing refined properties of network traffic.

The first three papers take a direct approach by relating the properties of network traffic to the properties of dynamical systems that are either chaotic or possess phase transitions. The paper by V. Anantharam explores the connection between fractal traffic, chaotic maps, and queueing, where a correspondence between expanding deterministic maps with strong mixing properties and stochastic processes is used to invoke a large deviation principle to facilitate queueing analysis. The paper provides a framework wherein traditional performance analysis can be affected to input traffic generated by the symbolic dynamics associated with deterministic maps.

M. Krunz and A. Alkhatib's paper uses chaotic dynamical systems as models of network traffic – in particular, variable bit rate (VBR) video traffic – in a framework similar to that of Anantharam's paper. The objective of Krunz and Alkhatib's paper, however, is to identify low-dimensional chaotic maps from given VBR video traces, which can serve as compact descriptions and traffic generators when trajectories are computed from different initial conditions.

The paper by K. Fukuda, H. Takayasu and M. Takayasu uses dynamical systems in the form of first-order autoregressive maps with noise, the dynamics of which is shown to model network traffic traces collected at Keio University. A distinguishing feature of Fukuda et al.'s work is the presence of phase transitions induced by three piecewise linear segments with different slopes – inducing different dwell times (exponential versus power-law) – which are shown to model three phases in measured network traffic: congested, intermediate and non-congested.

The last two papers take an indirect approach by providing refined characterizations of network traffic and performance. The paper by S. Ma and C. Ji studies wavelet based traffic modeling in an attempt to capture the multi scale resolution of self-similar traffic, where separation between long-range and short-range structure is affected. The key contribution lies in exploiting the weakened, i.e., summable correlation structure in the frequency domain, in order to achieve effective modeling in the frequency domain with applications to performance analysis.

M. Borella's paper takes a critical look at end-to-end packet delay on the Internet and their properties. Whereas previous measurement works have concentrated on throughput and packet loss, Borella's paper shows that network delay exhibits significant long-range dependence, in spite of the fact that network delay has a narrower range and variability. Borella uses wavelets to estimate the Hurst parameter of delay time series.

Alberto Apostolico and Kihong Park
Department of Computer Sciences, Purdue University