

MODELING AND EFFECTIVE BANDWIDTH ALLOCATION FOR INTERNET TRAFFIC

So Young Park¹ and Gang Uk Hwang¹

1) *Division of Applied Mathematics, KAIST, Daejeon 305-701, KOREA*

Corresponding Author : So Young Park, sphinx@kaist.ac.kr

ABSTRACT

In this study, we analyze the stochastic characteristics of internet traffic from measured internet traffic trace. From our analysis, it can be shown that nonhomogeneous Poisson process and Gaussian process are good candidates to model internet traffic mathematically. Based on our results, we compute the effective bandwidth for the measured internet traffic and show the validity of the computed effective bandwidth through simulation studies with the NS-2 simulator.

INTRODUCTION

Since too little bandwidth capacity may not provide the sufficient performance and too much bandwidth capacity may lead to a waste of resources, we should obtain an effective bandwidth. Traditionally, methods obtaining bandwidth for IP traffic do not use the detailed statistical characteristics of the traffic. However, these methods cannot provide performance guarantees. Therefore, studies about a model of IP traffic are needed to obtain the effective bandwidth. During the last few years, there has been these studies. Especially, it is shown that current network traffic can be well represented by the Poisson model for sub-second time scales in [1], and that the Gaussian model can be also used to describe a network traffic [2].

In this study, we confirm that internet traffic can be well represented by the nonhomogeneous Poisson model and the Gaussian model. To compute the effective bandwidth, we use the bandwidth formula for Gaussian traffic [2] and a lower bound for the tail of the queue length distribution of the fractional Brownian motion(FBM) [3], a special case of the Gaussian model.

MODELING AND ANALYSIS

In this study, we measure packet inter-arrival times and packet sizes in an IP network and analyze the stochastic characteristics of IP traffic. In our analysis, we use the Q-Q (Quantile-Quantile) plot to analyze the packet inter-arrival time distribution and show that an exponential distribution is the most appropriate when we consider an IP traffic trace of length around 100 ms. To check whether the packet inter-arrival times are independent, we apply the autocorrelation method and show that the packet inter-arrival times are independent. When we have an IP traffic trace of length greater than 100 ms, we observed that the arrival rates are changing in time but almost fixed in each sub-interval of length 100 ms. These observation shows that IP traffic can be modeled by a nonhomogeneous Poisson process.

We also consider a Gaussian process to model IP traffic. For doing this, we check the normality of the measured IP traffic. Our analysis shows that the Gaussian process seems to capture the stochastic characteristics of IP traffic well.

Next, we compute the effective bandwidth for IP traffic based on our Gaussian model. The formula of the effective bandwidth based on a Gaussian process is given as follows:

$$C(T, \varepsilon) = \mu + \frac{1}{T} \sqrt{(-2 \log \varepsilon) \cdot v(T)} \quad (1)$$

where T is an interval of length, ε is the target loss probability and μ is the mean arrival rate. Using formula (1) we simulate a queueing system where the measured packet inter-arrival times are used as the arrival process and the measured packet sizes are used to determine the service process. In our simulation we use the NS-2 simulator. Our numerical results show that using formula (1) does not provide a good prediction on system performance. The reason for this is that, we think, a Gaussian process is quite general, so that it does not capture the detailed stochastic characteristics of IP traffic. To solve this problem, we consider the fractional Brownian motion, which is a special case of a Gaussian process. To use the the fractional Brownian motion, we need to estimate the Hurst parameter, and we estimate the Hurst parameter using the least-squares method. The formula of the effective bandwidth based on the fractional Brownian motion is given as follows:

$$P(q > x) \geq \exp \left(- \left[\frac{1}{2\sigma^2(1-H)^2} \left(\frac{(C-\mu)(1-H)}{H} \right)^{2H} x^2(1-H) \right] \right) \quad (2)$$

where x is a buffer size and H is a Hurst parameter. To check whether formula (2) provides a good prediction on system performance, we again use the NS-2 simulator to simulate a queueing system. Our simulation study shows that using the effective bandwidth based on the fractional Brownian motion provides a good prediction on system performance.

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