The Analyzer of the Computer Network State Using Stochastic Network Calculus

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Introduction

There are a number of network engineering problems for which we have to predict the packets delay and backlog during transmission through the network. These characteristics are critical for the voice and video traffic [1], information exchange between stock markets and banks. Another example of these characteristics importance is the optimal route generation for traffic flows in the network.

Using a stochastic representation of the traffic arrivals and the service process, it becomes possible to simulate the network operation more accurately [1] [2]. Moreover, SNC can be applied in some cases that cannot be covered by the DNC method. For example, simulations when the traffic arrivals rate is corresponding to a Poisson distribution [3] or when the intensity of traffic arrivals is temporarily greater than the rate of the service process.

Stochastic network calculus

The traffic arrivals can be represented in form of the Exponentially Bounded Burstiness (EBB) model in the following way:

$$P[A(\tau,t) > \rho(t-\tau) + b] \leq \varepsilon(b) \quad (1)$$

The service process can be represented in form of the Exponentially Bounded Functions (EBF) model that is similar to the EBB model for the traffic arrivals except the opposite inequality sign in (1).

According to [1], from EBB and EBF models SNC method can derive the backlog bound b that satisfies the following condition:

$$P[B(t) > b] \leq \varepsilon'$$

where ε' is the probability that the backlog will exceed the bound b in a real network. Similarly, the delay bound ω can be derived that satisfies the following:

$$P[W(t) > \omega] \leq \varepsilon'$$

where ε' is the probability that the delay will exceed the bound ω in real network.

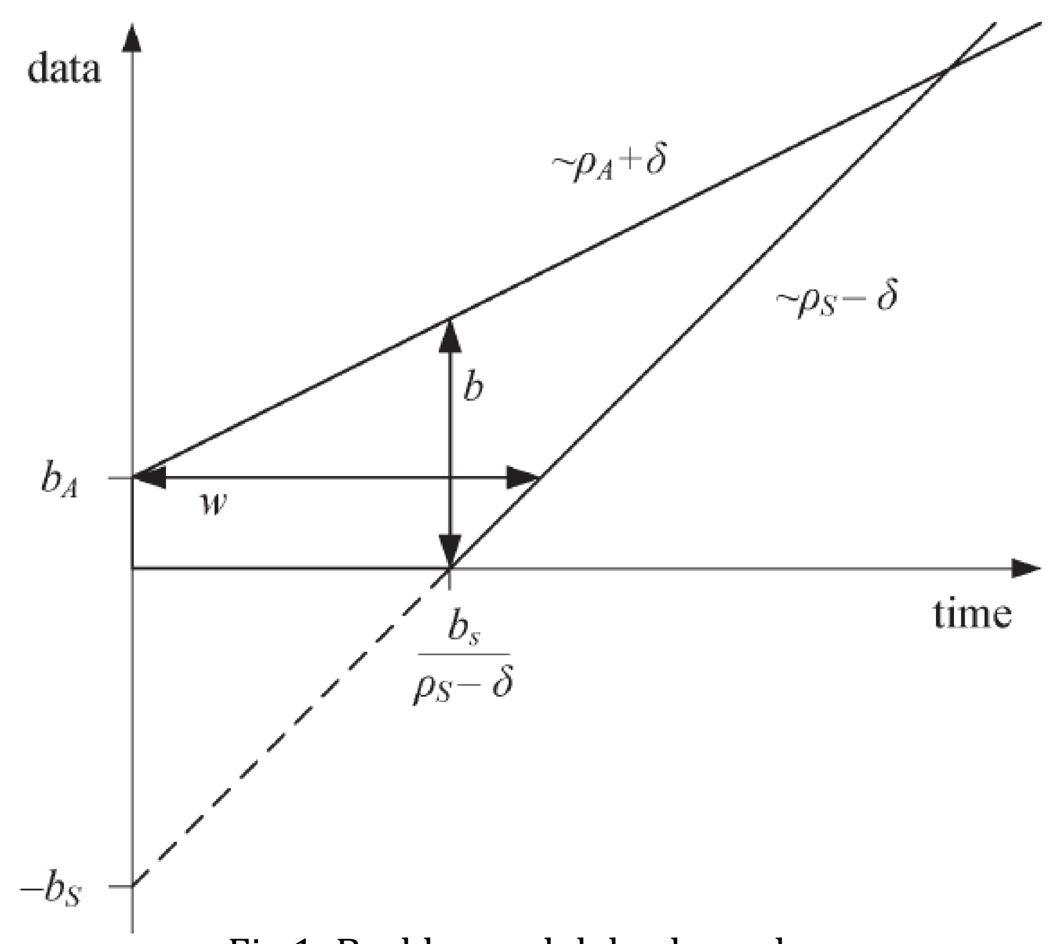

Fig.1: Backlog and delay bound

Experimental study

The bounds computation using the SNC method was implemented in Python3. The input parameters are: the servers number, the rate and the burst parameters for each server (represents $S(\tau,t)$), the network topology, traffic arrivals distribution and its parameters (represents $A(\tau,t)$). The program starts its work with the convolution of service processes. Further, due to the convolution overall network will be represented with the one server, parameters of which are computed from all servers' parameters with the convolution algorithm. Then the arrival rate ρA is computed using the traffic arrivals parameters. Finally, the delay and backlog bounds are obtained by the SNC and DNC methods.

It is worth to note that the backlog and delay formulas for SNC, given in [1], depend of the free parameter $\theta \geq 0$. Therefore, there is an additional step in the program's work to find the optimal value for θ at which the minimum delay and backlog bounds are reached.

The experimental study was carried out for the following values of the input parameters: n is number of servers, linear network topology, where every server is a work-conserving server with constant rate ci where $i \in [1,n]$, Marcoff On-Off traffic which described with <burst parameter, traffic rate in state On, state On probability> and the ε value. The bounds were computed for the same parameter values using stochastic and deterministic network calculus if it was possible.

Computations of delay and backlog bounds were made in two different ways, depending of the traffic rate and the server rate ratio. If the server rate is greater than the traffic rate, then the optimal value $\theta \to \infty$ and the backlog and delay bounds for both SNC and DNC methods are equal. The delay dependence of θ in this case can be observed in Fig.2, where the blue line denotes the SNC delay bound and red line denotes the DNC delay bound.

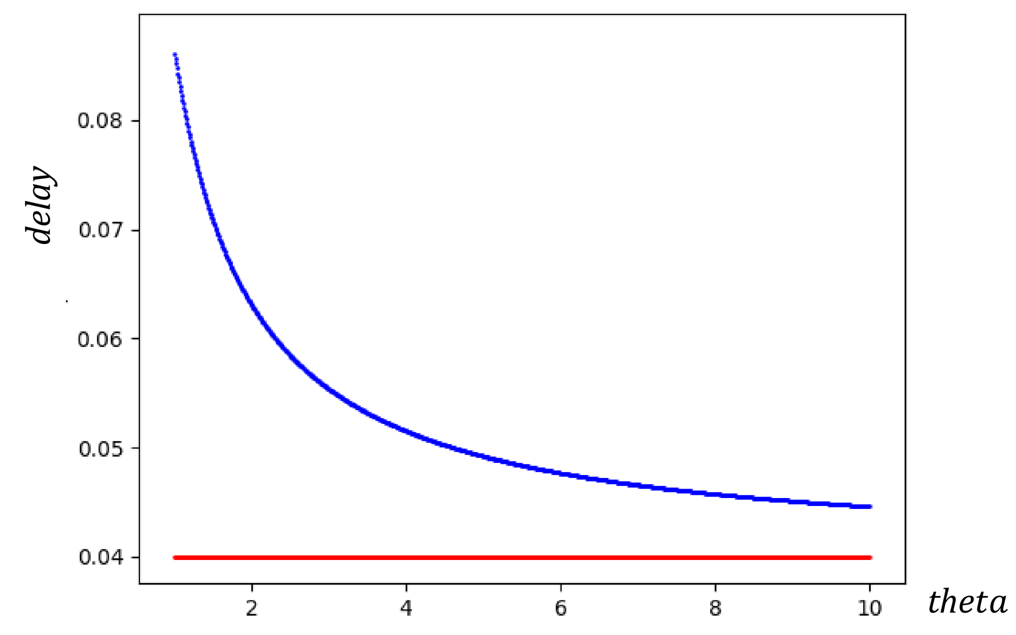

Fig.2: Delay dependence of θ for SNC and DNC methods

Otherwise, the server rate would be less than the traffic rate ($r \geq c$). Under this condition, it is possible to compute backlog and delay bounds only for SNC method by optimizing the free parameter θ. For optimization step, we used the «scipy.optimize» library, and in particular its minimize function, in which the Sequential Least Squares method was chosen to find the minimum. Fig. 3 depicts the particular example of the delay dependence of θ under the condition $r \geq c$ for SNC method.

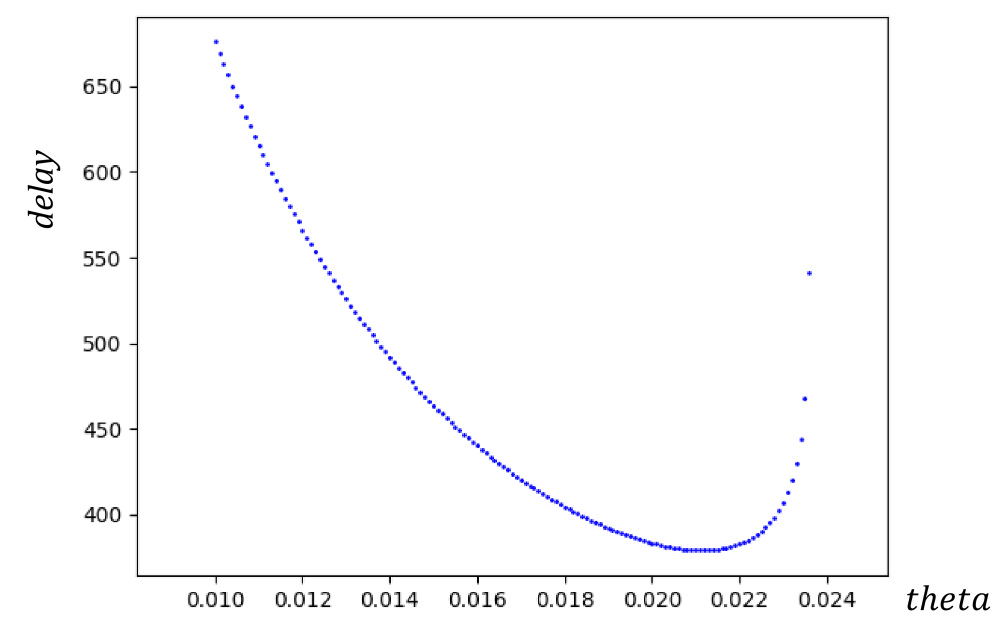

Fig.3: Delay dependence of θ under the condition $r \geq c$ for SNC method

Future works

Developed prototype will be extended to the case of multiple traffic flows (flow multiplexing will be applied). To prove the bounds correctness obtained with SNC method, it is planned to compare the SNC bounds with the results of the network simulation in NS3. The applicability of SNC method will be studied for the routes generation problem in software-defined networks.

Bibliography

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