Demo Abstract: An Integrated Tool of Applying Stochastic Network Calculus for Network Performance Analysis

Michael A. Beck*, Sebastian Henningsen†, Qian Xu*, Jianping Wang*, Kui Wu‡, Xian Liu§
*Department of Computer Science, City University of Hong Kong
{mabeck | jianwang}@cityu.edu.hk, Qian.XU@my.cityu.edu.hk
†Department of Computer Science, Humboldt University of Berlin, Germany, sebastian.henningsen@hu-berlin.de
‡Department of Computer Science, University of Victoria, Canada, wkui@uvic.ca
§Huawei Technologies Ltd. Co., lene.liuxian@huawei.com

***Abstract*—With the recent emergence of online network performance measuring tools, Internet users are now able to measure their received service levels. Such user-initiated network performance measurements push the ISPs to an ever-high standard, requiring them to know the worst-case performance of its admitted flows, whether and where to accommodate a new flow request, without violating the service agreement level (SLA). Stochastic Network Calculus (SNC) has been developed to derive performance bounds of a network system for many years in the research community. However, it has not been practically adopted by ISPs due to the lack of a tool supporting features such as end-to-end analysis or optimal parameter tuning. In this demo, we extended the DISCO Stochastic Network Calculator. We also compare the analytical results obtained from the tool with the simulation results obtained in NS-3 to validate the tightness of the performance bounds.**

I. Introduction

A network operator is frequently confronted with the following basic question: Can I admit a new flow (customer) to an existing system? Usually this question is embedded into additional constraints: By what extend will the admittance impact the performance of already existent flows? Can all required performance guarantees be uphold? What guarantees can I provide for the new flow under these constraints? How and where do I need to upgrade the network to allow the new flow? In these scenarios, ISPs are mostly interested in the system's worst case behavior, particularly, end-to-end delay and backlogs. We can formulate such performance bounds either deterministically, as in $\mathfrak{d}(t) < T$, or stochastically, as in $\mathbb{P}(\mathfrak{d}(t) > T) \leq \varepsilon_T$, where $\mathfrak{d}(t)$ denotes the delay of the system at time t. Here we call T the delay-bound for the system, which either always holds (the deterministic case) or with a high probability ε_T (the stochastic case).

Queuing theory traditionally derives performance measures in means or averages. These, however, do not suit well for a worst-case analysis as described above. To address this problem, ideas from effective bandwidths and systems theory have been merged to what is known as Stochastic Network Calculus today (SNC) (see for example [6]). This theory provides stochastic performance bounds of the form $\mathbb{P}(\mathfrak{d}(t) > T) \leq \varepsilon$.

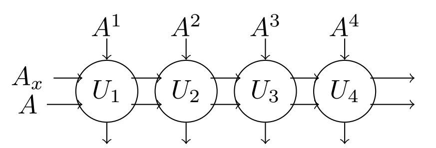

Figure 1. A ladder topology for 4 nodes. The flow of interest in this scenario is denoted by A. The cross-flow A_x takes the same path as A, while the "rung"-flows A^i contest for resources on one node only.

Whereas there has been considerable progress on the theoretic side of SNC [4], it has not been applied broadly in real-world communication networks yet. One reason for this imbalance is the lack of any tool support, to ease the application of SNC. In this demo we present the further extension of the DISCO SNC Calculator (further just called the Calculator), which was first published as a prototype in [3]. Since its release, the Calculator has been refurbished into a flexible and extensible framework for stochastic worst case analysis. In this demo we: (1) present new features of the Calculator (Section II) and (2) use the tool to compare SNC bounds to simulation results obtained by NS-3 [7] (Section III).

II. Features

The most interesting feature of SNC is the capability of reducing complex queueing networks to simpler ones. Hence, by nesting basic transformation theorems we can tackle any kind of feedforward networks. However, deriving these bounds – although a concatenation of easy separate steps – becomes more complex the more convoluted the analyzed topology is.

When we apply SNC, we are also faced with a second problem of determining optimal parameters for bound analysis. Recall the stochastic performance bound $\mathbb{P}(\mathfrak{d}(t) > T) \leq \varepsilon_T$, where $\mathfrak{d}(t)$ describes the end-to-end delay. Using SNC the quantity ε_T does in general not appear as a single value, but rather as a function of a number of parameters, say $\varepsilon(p_1, \ldots, p_k)$. The number of parameters k depends on the topology of the network analyzed and on the steps performed to reduce the network's complexity. It is crucial to find optimal

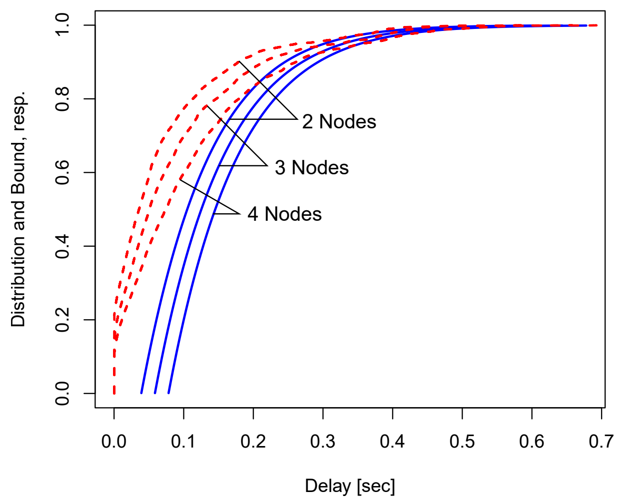

Figure 2. Delay obtained by NS-3 simulations (dashed red lines) and performance bounds (solid blue lines) computed by the tool for different ladder lengths.

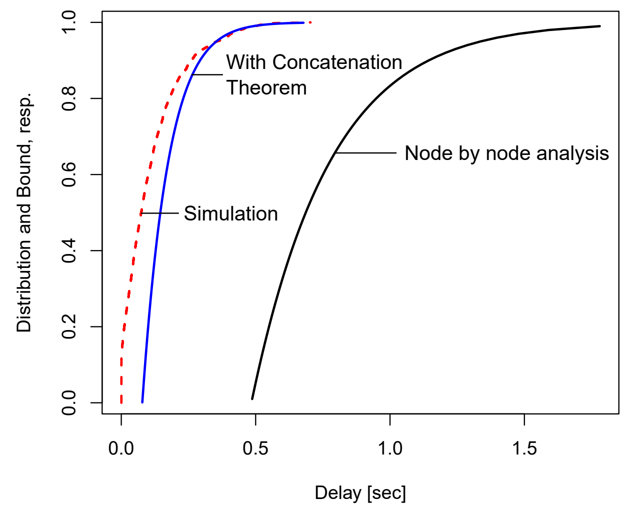

Figure 3. Demonstration of the concatenation theorem for a ladder-graph of length 4.

values for these parameters. Our tool addresses the above difficulties by automatically performing two steps: (1) From a given network it derives the function $\varepsilon(p_1, \ldots, p_k)$ on a symbolic level. With the help of the Calculator, this can either be done manually or automatically. (2) It feeds the function from step (1) into an optimizer that finds an optimal solution for these parameters under a given accuracy.

In this demo we have improved the prototype of Calculator [3] in several ways:

- We introduced a flexible interface to feed the tool with a given network configuration. As such the network does not need to be generated with the tool's methods, but can be read from a simple text-file.
- We have implemented an end-to-end analysis that uses the important concatenation theorem. This theorem vastly improves end-to-end performance bounds, see for example [5] for its derivation and impact. Currently this end-to-end analysis is restricted to ladder-networks (see Figure 1). These networks generalize tandem topologies, which are often the subject of research when it comes to SNC.
- We refactored the code into a flexible and extensible framework. This facilitates the process of implementing classes specific to the user's application scenario. These include traffic models, analysis-techniques, optimization-algorithms and scheduling disciplines. By the modular design one can, for example, implement a new traffic model to the tool, while not interfering with the process of calculating end-to-end performance bounds.

At [1] the reader can find a short demonstration of some features of our tool.

III. Evaluation

We use the Calculator to produce end-to-end delay bounds in a ladder topology (see Figure 1). Further we compare these bounds to delays obtained from NS3-simulations. In Figure 2, we plot the empirical delay-distribution obtained from simulations together with the function $f(T) = \varepsilon_T(p_1, \ldots, p_k)$ with optimized parameters $p_1, \ldots, p_k$. We see that the empirical distribution of the delay is well approximated by the curve obtained by SNC and our tool. In Figure 3, we show the impact of using the concatenation theorem for a proper end-to-end analysis. The black line is the bound obtained by ignoring the concatenation theorem. Note that in the prototype version [3], only the black curve was available as performance bound. Clearly the implementation of the concatenation theorem is imperative to achieve proper bounds on the end-to-end delay.

IV. Conclusion

The demo shows a perspective on what the Calculator is capable of. With the Calculator, network operators can predict the performance of a network system and identify its shortages or choke points. With further work in the future, the Calculator can be integrated into existing network management tools for real-time traffic control and resource provisioning.

The work presented in this demo is a continuing development as an open source tool. A GitHub repository can be found at [2].

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