Quality and Cost of Deterministic Network Calculus – Design and Evaluation of an Accurate and Fast Analysis

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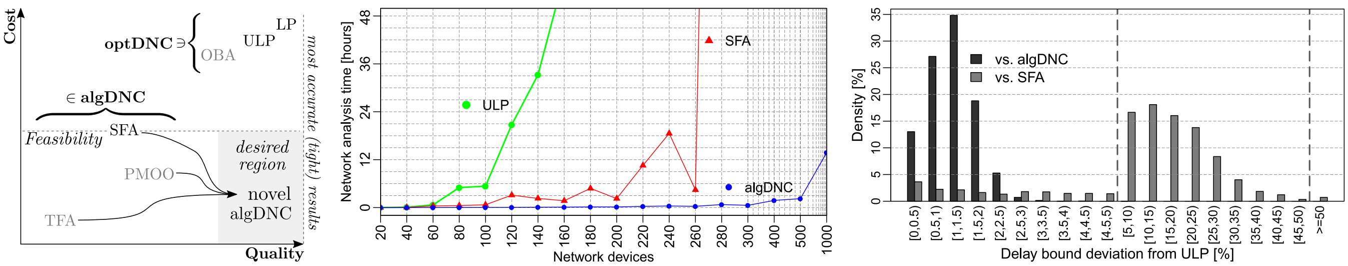

(a) Unifying algebraic DNC analyses. **(b) Cost of analyses, measured in computation runtimes.** **(c) Deviation of delay bounds from optimization analysis ULP.**

Figure 1: Evaluation of quality and cost of deterministic network calculus analyses. Among algebraic (algDNC) and optimization (optDNC) analyses, only our novel algDNC achieves the desired tradeoff (a). For the networks feasible to analyze with optDNC's ULP analysis (b), our delay bounds only deviate by 1.142% on average; a decisive improvement over previous SFA (c).

ABSTRACT

Networks are integral parts of modern safety-critical systems and certification demands the provision of guarantees for data transmissions. Deterministic Network Calculus (DNC) can compute a worst-case bound on a data flow's end-to-end delay. Accuracy of DNC results has been improved steadily, resulting in two DNC branches: the classical algebraic analysis (algDNC) and the more recent optimization-based analysis (optDNC). The optimization-based branch provides a theoretical solution for tight bounds. Its computational cost grows, however, (possibly super-)exponentially with the network size. Consequently, a heuristic optimization formulation trading accuracy against computational costs was proposed. In this paper [1], we challenge optimization-based DNC with a novel algebraic DNC algorithm. We show that:

(1) no current optimization formulation scales well with the network size and
(2) algebraic DNC can be considerably improved in both aspects, accuracy and computational cost.

To that end, we contribute a novel DNC algorithm that transfers the optimization's search for best attainable delay bounds to algebraic DNC. It achieves a high degree of accuracy and our novel efficiency improvements reduce the cost of the analysis dramatically. In extensive numerical experiments, we observe that our delay bounds deviate from the optimization-based ones by only 1.142% on average while computation times simultaneously decrease by several orders of magnitude.

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Figure 1 presents the findings of our paper [1]: We combined the strengths of the algDNC analyses TFA, SFA, and PMOO to create a novel algDNC analysis that attains accurate delay bounds with feasible computational effort (Figure 1a). Against previous belief, we showed that optDNC's most efficient heuristic, ULP, is computationally infeasible even for moderately sized networks. For larger networks, we also showed that the algebraic SFA is more costly than expected, becoming barely feasible to execute. For our novel algDNC analysis, we provide efficiency improvements that make it scale considerably better with the network size, its computation times are several orders of magnitude smaller. (Figure 1b). Nonetheless, it provides highly accurate results that are crucially improving over SFA. Our algebraically derived delay bounds are competitive with optDNC's ULP (Figure 1c).

CCS CONCEPTS

• **Networks → Network performance evaluation**; *Network performance analysis*; Network performance modeling; • **Computing methodologies → Symbolic and algebraic algorithms**; *Symbolic calculus algorithms*; Optimization algorithms;

KEYWORDS

Delay bounds; deterministic network calculus; worst-case analysis

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[1] Steffen Bondorf, Paul Nikolaus, and Jens B. Schmitt. 2016. Quality and Cost of Deterministic Network Calculus – Design and Evaluation of an Accurate and Fast Analysis. *arXiv:1603.02094 [cs.NI]* (March 2016).