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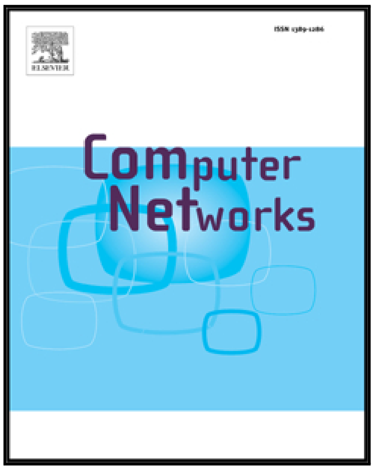

Software Defined Network Inference with Evolutionary Optimal Observation Matrices

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ACCEPTED MANUSCRIPT

Software Defined Network Inference with Evolutionary Optimal Observation Matrices

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Abstract

A key requirement for network management is the accurate and reliable monitoring of relevant network characteristics. In today's large-scale networks, this is a challenging task due to the scarcity of network measurement resources and the hard constraints that this imposes. This paper proposes a new framework, called SNIPER, which leverages the flexibility provided by Software-Defined Networking (SDN) to design the optimal observation or measurement matrix that can lead to the best achievable estimation accuracy using Matrix Completion (MC) techniques. To cope with the complexity of designing large-scale optimal observation matrices, we use the Evolutionary Optimization Algorithms (EOA) which directly target the ultimate estimation accuracy as the optimization objective function. We evaluate the performance of SNIPER using both synthetic and real network measurement traces from different network topologies and by considering two main applications for per-flow size and delay estimations. Our results show that SNIPER can be applied to a variety of network performance measurements under hard resource constraints. For example, by measuring only 8.8% of all per-flow path delays in Harvard network [1], congested paths can be detected with probability of 0.94. To demonstrate the feasibility of our framework, we also have implemented a prototype of SNIPER in Mininet.

Keywords: Passive and Active Network Measurement, Network Inference, Matrix Completion, Software Defined Networking.

1. Introduction

In large scale networks, the direct measurement of network's Internal Attributes of Interest (IAI), such as the per-flow size, delay, or packet loss is infeasible due to the complexity and high overhead of measurement process, and the limited availability of network measurement resources. In large-scale networks, the measurement resources, including the Ternary Content Addressable Memory (TCAM) entries, processing power, storage capacity and available bandwidth, are very limited, and hence, per-flow direct measurements are infeasible. To cope with scalability issues, Network Inference (NI) techniques can be leveraged to estimate various IAI based on partial passive and/or active measurements. However, NI problems are mainly formulated as Under-Determined Linear Inverse (UDLI) problems which are naturally ill-posed in the sense that the number of measurements are not sufficient to uniquely and accurately determine the solution. Hence, side (supplementary) information from different sources and perspectives must be incorporated into the problem formulation to improve the estimation accuracy [2] [3] [4].

Software-Defined Networking (SDN) provides data plane and control plane separation enabling capability to dynamically control and re-program network switches. Most current research has focused on leveraging SDN flexibility to implement complex network management and control applications, such as enhanced route control [5][6]. However, SDN can also enable adaptive and efficient implementation of passive and active network monitoring applications that can be controlled dynamically at run-time [7] [8] [9] [10]. This is important for many network management and security applications.

Network inference techniques can utilize the real-time programmability provided by the SDN to optimize and facilitate the process of collecting the required direct measurements and/or side information. In fact, the capabilities of SDN have been utilized in a variety of passive and active network monitoring applications. Most SDN based passive measurement studies are related to traffic monitoring and network security applications, such as, network

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