My research interest is in networked systems. I focused on network management and network performance optimization, including network diagnostics [1, 2, 3], network verification [**ying2017sla**, 4], mobile network architecture design [5, 6], and TCP optimization [7].

1 Network Diagnostics

1.1 PerfSight: Performance Diagnosis for Software Dataplanes[1]

The advent of network functions virtualization (NFV) means that data planes are no longer simply composed of routers and switches. Instead, they are very complex and involve a variety of sophisticated packet processing elements that reside on the OSes and software running on generic servers where network functions (NFs) are hosted. In this paper, we argue that these new "software data planes" are susceptible to at least three new classes of performance problems. To diagnose such problems, we design, implement and evaluate, PerfSight, a ground-up system that works by extracting comprehensive low-level information regarding packet processing and I/O performance of the various elements in the software data plane. PerfSight then analyzes the information gathered in various dimensions (e.g., across all VMs on a machine, or all VMs deployed by a tenant). By looking across aggregates, we show that it becomes possible to detect and diagnose key performance problems. Experimental results show that our framework can result in accurate detection of the root causes of key performance problems in software data planes, and it imposes very little overhead.

1.2 Management Plane Analytics[2]

While it is generally held that network management is tedious and error-prone, it is not well understood which specific management practices increase the risk of failures. Indeed, our survey of 51 network operators reveals a significant diversity of opinions, and our characterization of the management practices in the 850+ networks of a large online service provider shows significant diversity in prevalent practices. Motivated by these observations, we develop a management plane analytics (MPA) framework that an organization can use to: (i) infer which management practices impact network health, and (ii) develop a predictive model of health, based on observed practices, to improve network management. We overcome the challenges of sparse and skewed data by aggregating data from many networks, reducing data dimensionality, and oversampling minority cases. Our learned models predict network health with an accuracy of 76-89%, and our causal analysis uncovers some high impact practices that operators thought had a low impact on network health. Our tool is publicly available, so organizations can analyze their own management practices.

1.3 Virtual Network Diagnosis as a Service[3]

Today's cloud network platforms allow tenants to construct sophisticated virtual network topologies among their VMs on a shared physical network infrastructure. However, these platforms provide little support for tenants to diagnose problems in their virtual networks. Network virtualization hides the underlying infrastructure from tenants as well as prevents deploying existing network diagnosis tools. This paper makes a case for providing virtual network diagnosis as a service in the cloud. We identify a set of technical challenges in providing such a service and propose a Virtual Network Diagnosis (VND) framework. VND exposes abstract configuration and query interfaces for cloud tenants to troubleshoot their virtual networks. It controls software switches to collect flow traces, distributes traces storage, and executes distributed queries for different tenants for network diagnosis. It reduces the data collection and processing overhead by performing local flow capture and on-demand query execution. Our experiments validate VND's functionality and show its feasibility in terms of quick service response and acceptable overhead; our simulation proves the VND architecture scales to the size of a real data center network.

2 Network Verification

2.1 SLA-Verifier: Stateful and Quantitative Verification for Service Chaining[ying2017sla]

Network verification has been recently proposed to detect network misconfigurations. Existing work focuses on the reachability. This paper proposes a framework that verifies the Service Level Agreement (SLA) compliance of the network using static verification. This work proposes a quantitative model and a set of algorithms for verifying performance properties of a network with switches and middleboxes, i.e., service chains. We develop SLA-Verifier and evaluate its efficiency using simulation on real-world data and testbed experiments. To improve the SLA violation detection accuracy, our system uses verification results to optimize online monitoring.

2.2 Automatic Synthesis of NF Models by Program Analysis[4]

Network functions (NFs), like firewall, NAT, IDS, have been widely deployed in today's modern networks. However, currently there is no standard specification or modeling language that can accurately describe the complexity and diversity of NFs. Recently there have been research efforts to propose NF models. However, they are often generated manually and thus error-prone. This paper proposes a method to automatically synthesize NF models via program analysis. We develop a tool called NFactor, which conducts code refactoring and program slicing on NF source code, in order to generate its forwarding model. We demonstrate its usefulness on two NFs and evaluate its correctness.

3 Others

3.1 PRAN: Programmable Radio Access Networks[5]

With the continued exponential growth of mobile traffic and the rise of diverse applications, the current LTE radio access network (RAN) architecture of cellular operators face mounting challenges. Current RAN suffers from insufficient radio resource coordination, inefficient infrastructure utilization, and inflexible data paths. We present the high-level design of PRAN, which centralizes base stations' L1/L2 processing into a cluster of commodity servers. PRAN uses a flexible data path model to support new protocols; multiple base stations' L1/L2 processing tasks are scheduled on servers with performance guarantees; and a RAN scheduler coordinates the allocation of shared radio resources between operators and base stations. Our evaluation shows the feasibility of fast data path control and efficiency of resource pooling (a potential for a 30X reduction in resources).

3.2 SoftMoW: Recursive and Reconfigurable Cellular WAN Architecture[6]

The current LTE network architecture is organized into very large regions, each having a core network and a radio access network. The core network contains an Internet edge comprised of packet data network gateways (PGWs). The radio network consists of only base stations. There are minimal interactions among regions other than interference management at the edge. The current architecture has several problems. First, mobile application performance is seriously impacted by the lack of Internet egress points per region. Second, the continued exponential growth of mobile tracesc puts tremendous pressure on the scalability of PGWs. Third, the fast growth of signaling tracesc known as the signaling storm problem poses a major challenge to the scalability of the control plane. To address these problems, we present SoftMoW, a recursive and reconfigurable cellular WAN architecture that supports seamlessly inter-connected core networks, reconfigurable control plane, and global optimization.

To scale the control plane nation-wide, SoftMoW recursively builds up the hierarchical control plane with novel abstractions of both control plane and data plane entities. To enable scalable end-to-end path setup, SoftMoW presents a novel label swapping mechanism such that each controller only operates on its logical topology and each switch along the path only sees at most one label. SoftMoW supports new network-wide optimization functions such as optimal routing and inter-region handover minimization. We demonstrate that SoftMoW improves the performance, flexibility and scalability of cellular WAN using real LTE network traces with thousands of base stations and millions of subscribers. Our evaluation shows that path inflation and inter-region handovers can be reduced by up to 60% and 44% respectively.

3.3 Adaptive Data Transmission in the Cloud[7]

Data centers provide resources for a broad range of services, such as web search, email, websites, etc., each with different delay requirements. For example, a web search should cater to users' requests quickly, while data backup has no special requirement on completion time. Different applications also introduce flows with very different properties (e.g., size and duration).

The default method of transport in data centers, namely TCP, treats flows equally, forcing equal share of the bottleneck network bandwidth. This fairness property leads to poor outcomes for time-sensitive applications. A better solution is to allocate more bandwidth to time-sensitive applications. However, the state-of-the-art approaches that do this all require forklift changes to data center networking gear. In some cases, substantial changes need to be made to end-system stacks and applications as well.

In this paper, we argue that a simple modification to TCP can help better meet the requirements of latency-sensitive applications in the data center. No modification to end-systems, applications or networking gear is necessary. We motivate our Adaptive TCP (ATCP) design using measurements of real data center traffic. We analytically derive the parameters to use in our proposed modification to TCP. Finally, we use extensive simulations in NS2 to show the benefits of ATCP.

References

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