FlowSense: Monitoring Network Utilization with Zero Measurement Cost

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Abstract. Flow-based programmable networks must continuously monitor performance metrics, such as link utilization, in order to quickly adapt forwarding rules in response to changes in workload. However, existing monitoring solutions either require special instrumentation of the network or impose significant measurement overhead.

In this paper, we propose a push-based approach to performance monitoring in flow-based networks, where we let the network inform us of performance changes, rather than query it ourselves on demand. Our key insight is that control messages sent by switches to the controller carry information that allows us to estimate performance. In OpenFlow networks, PacketIn and FlowRemoved messages—sent by switches to the controller upon the arrival of a new flow or upon the expiration of a flow entry, respectively—enable us to compute the utilization of links between switches. We conduct a) experiments on a real testbed, and b) simulations with real enterprise traces, to show accuracy, and that it can refresh utilization information frequently (*e.g.*, at most every few seconds) given a constant stream of control messages. Since the number of control messages may be limited by the properties of traffic (*e.g.*, long flows trigger sparse FlowRemoved's) or by the choices made by operators (*e.g.*, proactive or wildcard rules eliminate or limit PacketIn's), we discuss how our proposed passive approach can be combined with active approaches with low overhead.

1 Introduction

Enterprises are deploying flow-based programmable networks to support diverse performance- or reliability-based application requirements such as deadline guarantees [8], quick failure recovery [4], or fast and reliable big data delivery [5,10]. In flow-based networks, a centralized controller locally computes the routes that satisfy a set of requirements and installs them remotely in the forwarding tables of switches. To ensure that traffic flows according to the pre-defined goals and to adapt rules quickly to workload or infrastructure changes, the network must continually monitor the utilization of every link.

Flow-based network utilization monitoring must be not only accurate and responsive in detecting variations, but it must also scale with minimal overhead on

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the network [3]. Existing monitoring techniques do not satisfy all of these goals simultaneously. Active monitoring techniques (*e.g.* SNMP polling) inject measurement probes and require careful scheduling to scalably monitor the entire network. Passive "capture-and-analyze" tools (*e.g.*, SPAN, netflow, tcpdump) need expensive instrumentation and infrastructure to gather and process measurements. Recently, several tools take advantage of the functionality provided by software-defined networks (SDNs), which allow the controller to poll switches for utilization-based statistics [11,6]. Though this eliminates the need for additional instrumentation, control packets used for polling still impose overhead.

In this paper, we propose a new approach for high accuracy utilization monitoring with *zero* measurement cost. Rather than rely on on-demand active polling of switch counters, we infer performance *by passively capturing and analyzing control messages between the switches and the centralized controller.* This is made possible by the physical separation of the control and data planes in SDNs. In particular, we use the control messages that notify the controller of changes in network traffic (*e.g.*, flow arrival, flow expiration). Such changes in traffic may result in changes in performance; by detecting the time and magnitude of these changes, the controller can monitor network utilization locally, without additional instrumentation or overhead.

To explore the feasibility of our control traffic based monitoring, we design FlowSense to measure link utilization (the bandwidth consumed by flows traversing the link) in OpenFlow networks [7]. FlowSense relies on PacketIn and FlowRemoved messages, sent by switches to the controller when a new flow arrives or when a flow entry expires. FlowRemoved messages contain information about the size and duration of flows matched against the entry. To compute utilization over an interval, the controller analyzes all PacketIn and FlowRemoved messages corresponding to the arrival of flows and to the expiration of the flows that were active during the interval.

Relying on control traffic to compute network utilization fails when there is little or no control traffic. This may happen due to the properties of data traffic (*e.g.*, long flows that lead to few flow expiration events) or due to measures taken by network operators (*e.g.*, to limit the amount of control traffic and preserve scalability, they install flow rules proactively that potentially never expire). In this paper, we study the feasibility of our monitoring approach, both in terms of effectiveness (*how accurate is it?*) and compatibility with current networks (*how is it affected by traffic patterns and network deployment scenarios?*).

To summarize, our primary contributions are two-fold. First, we introduce a push-based approach to flow-based network performance monitoring with zero measurement cost, where we let the network inform us of performance changes, rather than query it ourselves. We describe FlowSense, a system to measure link utilization that is simultaneously fast, accurate, and imposes no overhead. Using preliminary experiments on a small OpenFlow deployment, we show that the utilization computed using control plane messages closely resembles that measured on the data plane.