Ruru: High-speed, Flow-level Latency Measurement and Visualization of Live Internet Traffic

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ABSTRACT

End-to-end latency is becoming an important metric for many emerging applications (e.g., 5G low-latency services) over the Internet. To better understand end-to-end latency, we present Ruru[1], a DPDK-based pipeline that exploits recent advances in high-speed packet processing and visualization. We present an operational deployment of Ruru over an international high-speed link running between Auckland and Los Angeles, and show how Ruru can be used for latency anomaly detection and network planning.

CCS Concepts

•**Networks** → **Network monitoring;**

1. INTRODUCTION

With the increasing number of real-time applications (e.g., online games using virtual reality, multi-site financial transaction processing, etc.), and the radically new business models and use cases introduced by the 5G mobile architecture (e.g., robotics, tactile Internet, etc.) requiring interactive back-and-forth communication, user-perceived *end-to-end latency* is becoming an all-important factor for both users and network providers [1][2]. At the same time, unpredictable end-to-end latency has been a recurring source of frustration and disappointment over the past thirty years which has been tolerated by users instead of being understood and improved [4]. Current network monitoring tools such as, e.g., SNMP, Netflow, or PerfSonar[2] (used by WAN operators), only provide aggregate statistics of network traffic over relatively long timescales (e.g., average traffic load over five-minute intervals) which cannot provide insights into traffic dynamics over short timescales appropriate for events such as flow-level micro-congestion or sudden latency changes. Furthermore, they usually focus on the low layers of the stack and mostly provide information that does not necessarily represent individual user-perceived performance [3].

In order to understand the nature of latency over the Internet and to support emerging latency-sensitive applications, we have designed Ruru, a real-time, passive latency monitoring system deployed at REANNZ, New Zealand's Research and Education network provider. Ruru runs on a commodity server using a DPDK-enabled network interface card (that provides a userspace, polling-based driver to bypass the slow interrupt-based kernel space of the host operating system) and uses a simple software module to calculate latency for all individual TCP flows. Ruru also maps the source and destination IP addresses of each flow to geographical locations as well as to AS numbers, and visualizes these measurements on-the-fly on a 3D WebGL-enabled map interface. In addition, Ruru aggregates statistics by source and destination locations, and AS numbers for further analysis.

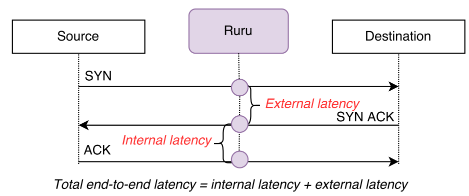

Figure 1: Ruru latency calculation

2. DESIGN AND ARCHITECTURE

Ruru DPDK packet analysis: The Ruru pipeline (shown in Figure 2) analyzes all traffic going through the NIC. For scalability and performance, we configure symmetric Receiver Side Scaling (RSS) at the start of the pipeline to dispatch incoming packets to multiple DPDK receiver queues. As show in the architecture diagram, these queues will later be used by different DPDK processing threads that are allocated on separate CPU cores. After pre-parsing all TCP packet headers, we record three sub-microsecond timestamps in hash tables (indexed by the RSS hash) for three packets per flow: first SYN, the following SYN-ACK, and the first ACK, as shown in Figure 1. These three timestamps (SYN, SYN-ACK, ACK) allow us to calculate the end-to-end latency from the source to Ruru (we call this internal latency) as well as from Ruru to the destination (noted as external

*Work had been done while Richard Cziva was an intern at REANNZ.
[1]Ruru is a native New Zealand owl.
[2]http://perfsonar.net

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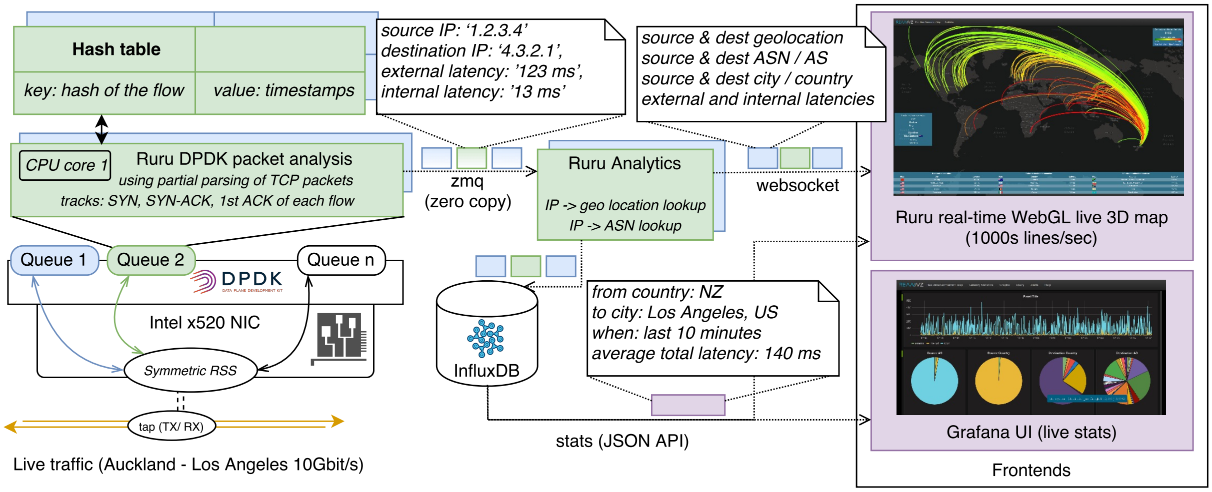

Figure 2: Ruru high-level architecture

latency). The sum of the two latency measurements gives us the total end-to-end latency from the source to the destination.

Ruru Analytics: The DPDK application publishes the latency measurements (source and destination IP addresses with the external and internal latency measurements) on zero-copy ZeroMQ sockets to other software modules (called Ruru Analytics) that retrieve geographical locations (coordinates, country and city information) and AS information for the source and destination IPs using multiple threads. We used geo-location and AS databases from IP2Location providing 98% country-level accuracy[3]. After this step, all original IP addresses are removed for privacy reasons and the geographically enriched measurements are sent to a time-series database (Influx DB) for long-term storage, as well as to the frontend (using WebSockets) that displays the results in real-time.

Frontends: In a web-browser, Ruru visualizes multiple thousands of connections per second on a live 3D map on-the-fly. To achieve such high performance (multiple thousands of 3D arcs drawn on a map with 30 fps using a recent graphic card), we have used the WebGL API with the MapGL wrapper to render 3D objects on top of a world map by directly using the graphic card of the client machine. Apart from the live map, the Grafana UI also shows statistics and graphs of the measured end-to-end latency (e.g., min, max, median, mean) for a required time interval (InfluxDB takes care of indexing data on geo-location and AS information).

Due to the modular nature of the pipeline, and the use of ZeroMQ sockets allowing efficient and fast interconnect of modules, Ruru can be easily extended with additional functionality. For instance, one could add a filter module to filter measurements in the pipeline based on some criteria (e.g., geo-location).

3. USE CASES AND DEMO

Ruru has been deployed on a Dell PowerEdge commodity server, tapping a 10Gbit/s international link carrying real user traffic between Auckland (NZ) and Los Angeles (US) (this link is one of REANNZ's two international commodity links out of NZ) since December 2016. While in operation, Ruru has been used for anomaly detection and was able to find very fine-grained micro-glitches in latency that no other monitoring system had previously identified. For example, we have found that a periodic firewall update was causing a 4000 ms latency increase on all connections that were started within a specific, very short time period each night. This 4000 ms increase had not been noticed by conventional measurement tools (e.g., SNMP polls), however, it was clearly shown in our Grafana UI. Other types of anomalies (e.g., unusual number of TCP connections between two locations or SYN floods) can also be identified in real-time with simple Ruru modules. Ruru can also be used to visually alert operators to latency anomalies by inspecting the live 3D map and observe how the color of the arcs changes between certain locations: red lines in areas where most lines are green show increased latency for some connections.

The demo will present Ruru with live, high-speed production traffic. Ruru is entirely open-source[4]. A video on our demo can be viewed here: https://youtu.be/EJzCn4TL3oI.

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[3]http://lite.ip2location.com

[4]http://github.com/reannz/ruru