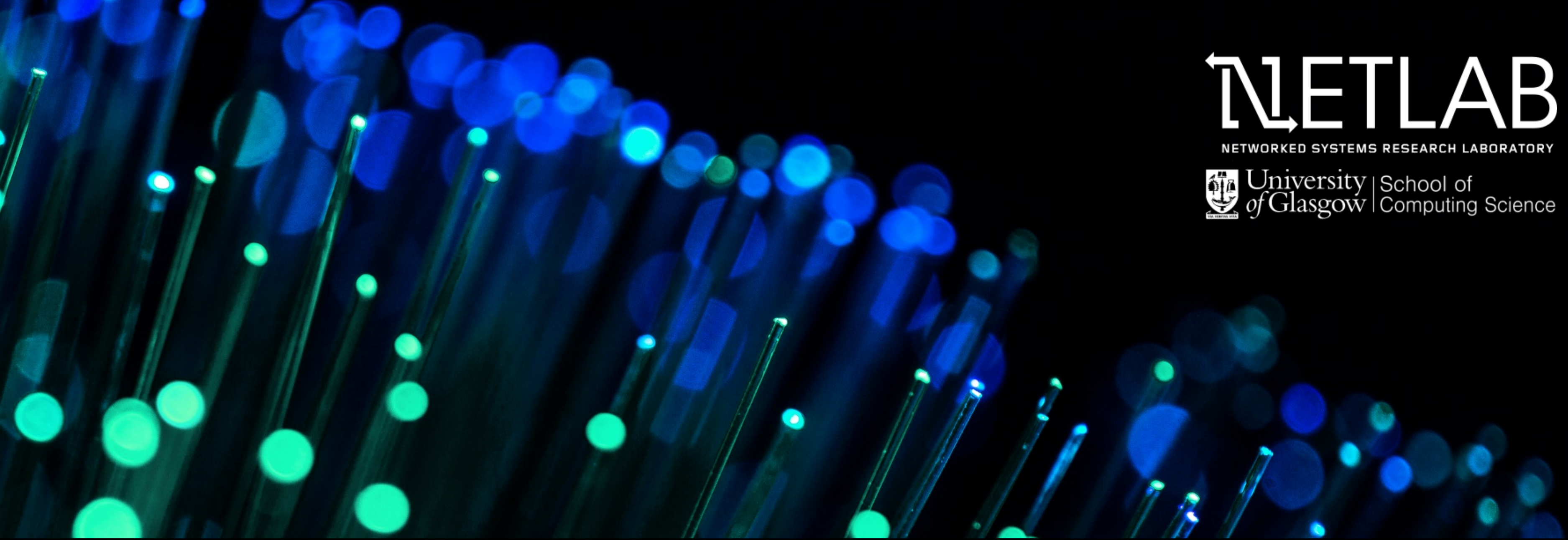

NETLAB
NETWORKED SYSTEMS RESEARCH LABORATORY
University of Glasgow | School of Computing Science

Ruru: Real-Time Wide-Area TCP Latency Monitoring

Richard Cziva | University of Glasgow | Richard.Cziva@glasgow.ac.uk | RIPE 75 | 22 October 2017, Dubai, UAE

About Netlab

- University of Glasgow, United Kingdom
  - Fourth oldest university in the English-speaking world and one of Scotland's four ancient universities. Founded in 1451.
- Networked System Research Laboratory "Netlab", School of Computing Science
  - Website: https://netlab.dcs.gla.ac.uk
  - Team: 3 academics, 4 researchers, 7 PhD students
  - Director: Dr. Dimitrios P Pezaros
- Research on SDN, NFV, mobile edge, network security and data plane programmability, resilient infrastructure …
- Project partners include: BT Google airbnb AIRBUS GROUP Microsoft ARM


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REANNZ

- New Zealand's NREN
- Connecting universities and research labs
- International links to Sydney, Los Angeles
- Based in Wellington, NZ

Ruru (morepork):
A native New Zealand bird

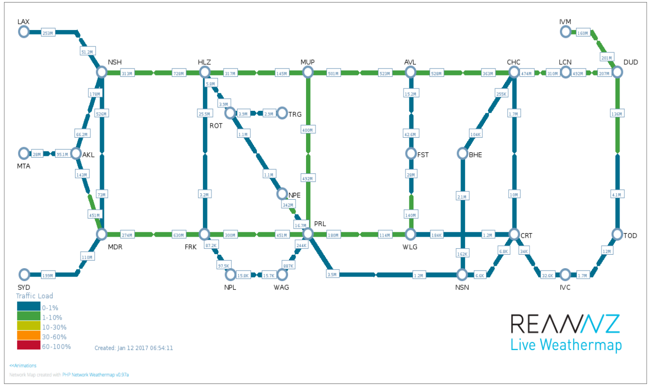
“a watchful guardian”

Image from: http://www.doc.govt.nz

Motivation

As a network operator, the goal is to understand the performance of the network we provide for our customers.

- Most of today’s network monitoring tools are either
  - Too coarse-grained (e.g., port statistics collected every 5 minutes)
  - Or rely on synthetic, generated traffic (e.g., PerfSonar)
- **Individual user-perceived performance (especially real-time end-to-end latency) has not been monitored yet**
  - No easy-to-use, free tools were available
  - Techniques were too slow, constrained, proprietary
  - Would require special hardware – expensive, not customized
  - **Results were not visual / analyzed**



REANNZ live weathermap

Why *end-to-end latency*?

- Increasing number of real-time applications (e.g., online games using virtual reality, multi-site financial transaction processing, etc.)
- 5G mobile architecture use-cases (e.g., robotics, tactile Internet) require interactive back-and-forth communication
- New Zealand's isolated geographical location

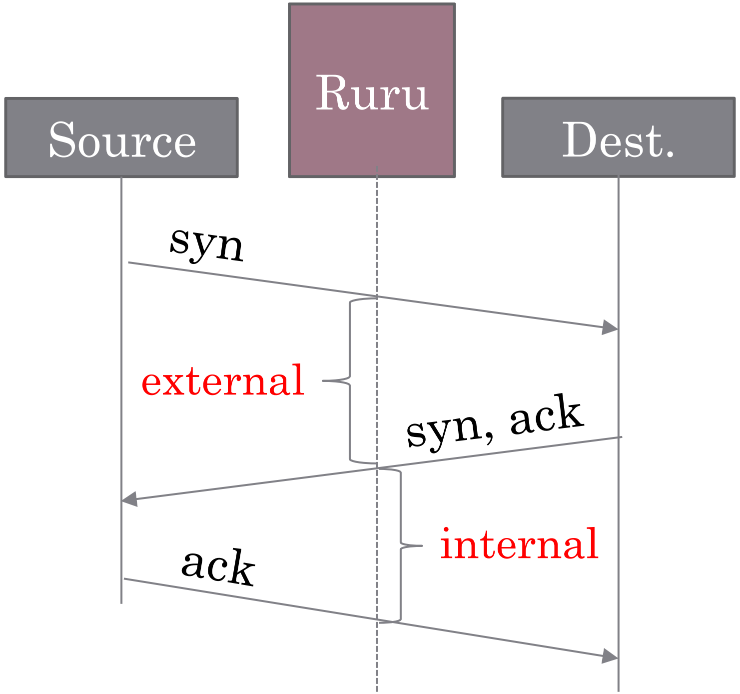
As a result, user-perceived end-to-end latency is becoming an all-important factor for both users and network providers

What is Ruru?

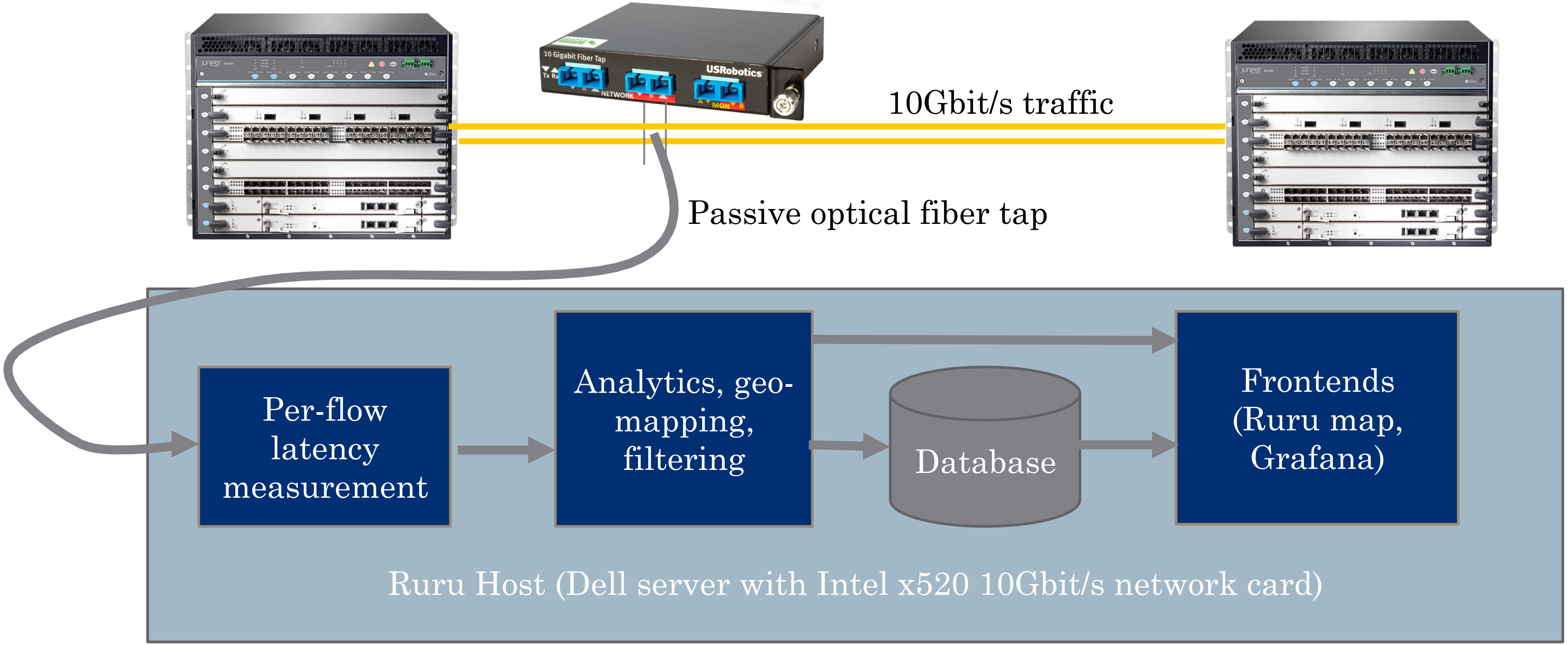
- Ruru is a measurement pipeline that runs on a commodity server
- Ruru measures **actual, accurate** end-to-end (e.g., device-to-server) latency in real-time and maps it to geo-locations
  - What we see is exactly what a user experiences
- Ruru visualizes measurements in **real-time on a world map**
- It is using today's cutting-edge, **open-source** technologies
  - Intel DPDK – high speed packet processing
  - Zero MQ – zero copy socket communication
  - Influx DB – time series data storage
  - WebGL – high-performance 3D graphics library in a web browser

Measuring end-to-end latency

- Round-trip time (RTT)
  - In telecommunications, the round-trip delay time (RTD) or round-trip time (RTT) is the length of time it takes for a signal to be sent plus the length of time it takes for an acknowledgment of that signal to be received.
- TCP only
  - Web browsing, e-mail, chat, etc.
  - But usually not media
- IPv4 only for now
  - Geolocation is only available for IPv4
- RTT guidelines
  - NZ to South Africa: 500ms
  - NZ to US: 130ms



Architecture (high level)



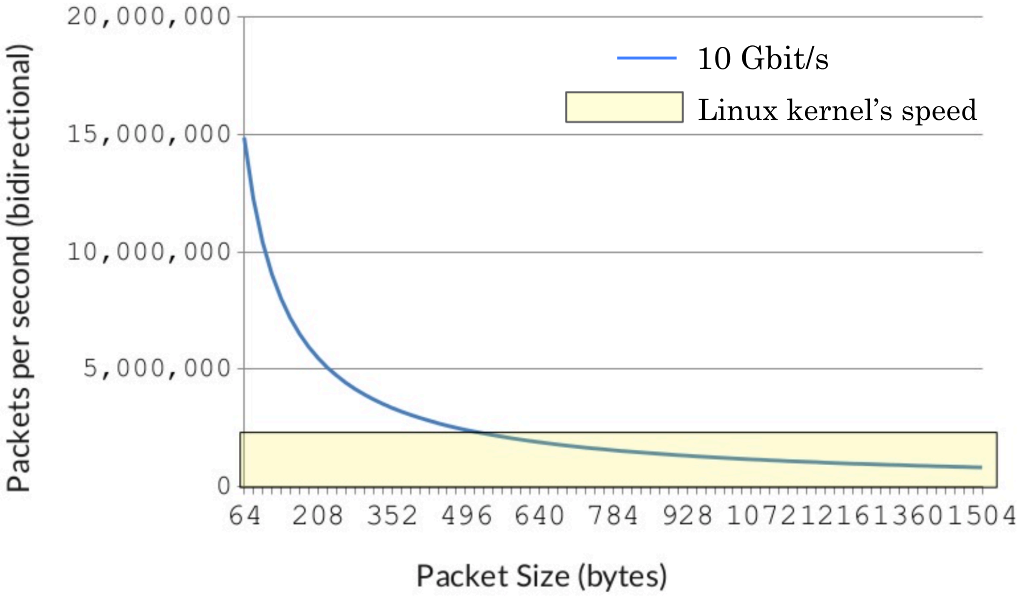
Challenge 1/3

How do we **process** **10Gbit/s** international backbone traffic per flow **in real-time**?

Linux kernel performance

Goal: to process 10Gbit/s traffic in real time

Can't we use just libraries such as Scapy or tcpdump?



Source: Intel DPDK overview

Some calculations

- Why do we need to bypass the kernel?
  - Minimum Ethernet packet: 64 bytes + 20 preamble
  - Maximum number of pps at 10Gbit/s: 14 880 952 (10^10/84 bytes*8)
  - Time to process a single packet: 67.2 ns
  - CPU cycles required on a 3Ghz CPU: 201 cycles (1 Ghz -> 1 cycle/ns)

Packet size	1024 bytes
Packets / sec	1.2 million
Arrival rate	835 ns
2 GHz	1620 cycles
3 GHz	2505 cycles

Packet size	64 bytes
Packets / sec	14.8 million
Arrival rate	67.2 ns
2 GHz	135 cycles
3 GHz	**201** cycles

Some calculations…

- Why do we need to bypass the kernel?
  - L3 cache hit: 40 cycles
  - L3 cache miss: 200 cycles (no budget for this with 64 byte packets)

Packet size	1024 bytes
Packets / sec	1.2 million
Arrival rate	835 ns
2 GHz	1620 cycles
3 GHz	2505 cycles

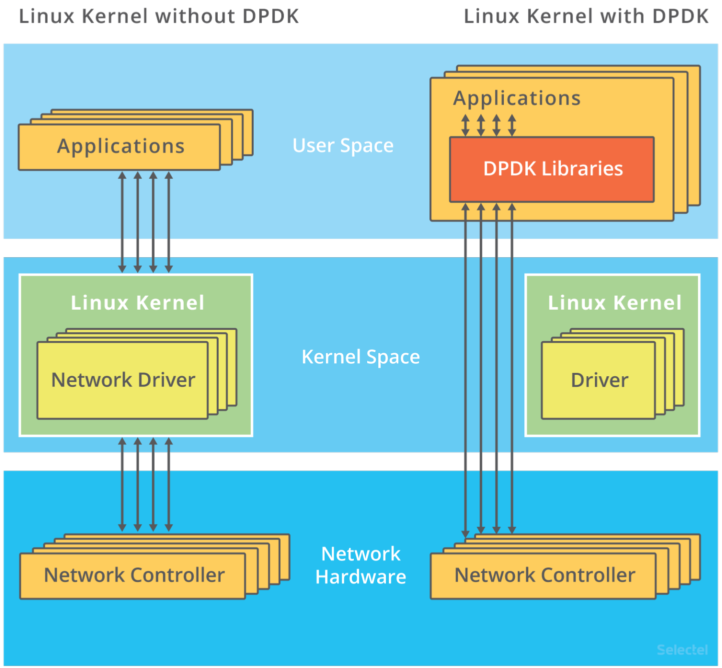
Packet size	64 bytes
Packets / sec	14.8 million
Arrival rate	67.2 ns
2 GHz	135 cycles
3 GHz	**201** cycles

DPDK overview

- Set of libraries and drivers for fast packet processing
- Runs on any processors, mostly in Linux userland
- Main libraries:
  - multicore framework
  - huge page memory
  - ring buffers
  - poll-mode drivers for networking , crypto and eventdev
- These libraries can be used to:
  - receive and send packets within the minimum number of CPU cycles (usually less than 80 cycles)
  - develop fast packet capture algorithms (tcpdump-like)
  - run third-party fast path stacks

Why did I choose DPDK?

- Direct access to the hardware through userspace
- Open Source API (BSD license)
- Many NICs support it (not just Intel)
- Isolation / security (won't cause segfault on the machine)
- Proven high performance (20M 64 bytes pps with native DPDK)



Challenge 2/3

How do we **geographically map**
10Gbit/s international backbone traffic
per flow **in real-time**?

Ruru Analytics

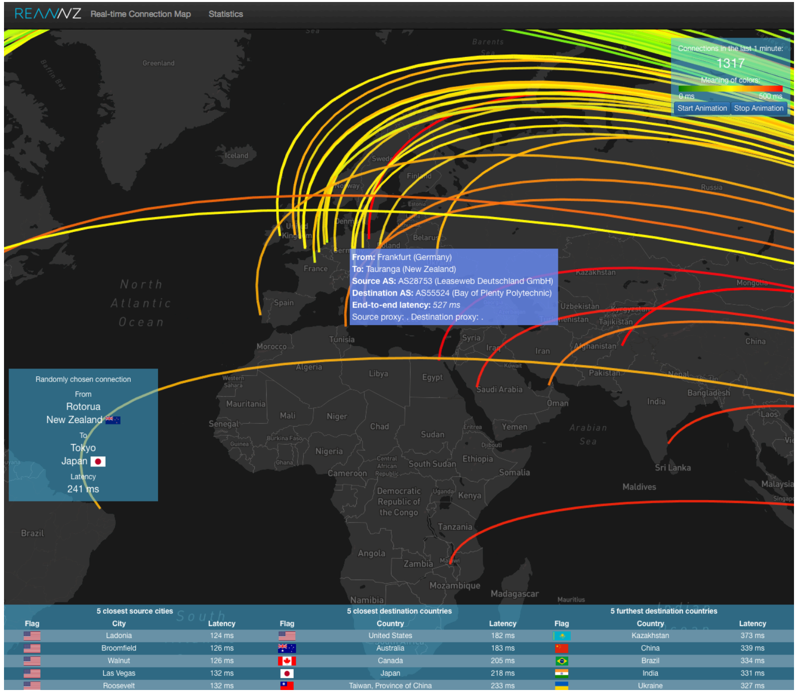
- We need high-performance way of:
  - Mapping to geo-locations
    - Most high-level libraries (e.g., GeoIP) will suffer as they make a REST (very slow) calls for every lookup
  - Filtering results from pipeline
- Solution: multi-threaded C program with offline geo-database and cache
  - I used IP2location databases (99.5% accuracy)
  - I do ASN and geo lookups for each source and destination IP
  - A small 5000 size cache for the lookups helps a lot

Challenge 3/3

How do we visualize **10Gbit/s**
international backbone traffic
per flow **in real-time**?

Map frontend

- Goal: to visualize multiple thousand connections per second
  - High-level libraries can not visualize in this rate (e.g., d3)
- Solution: to use WebGL-powered 3D visualization
- I am using libraries, such as:
  - Deck-gl: rendering stacks of visual overlays over map
  - Luma-gl: WebGL library
  - React-map-gl: Mapbox for the actual map (separate API key is required)
- As a result, we can run the visualization with the speed of 21 fps (using Safari on a 2016 Macbook)

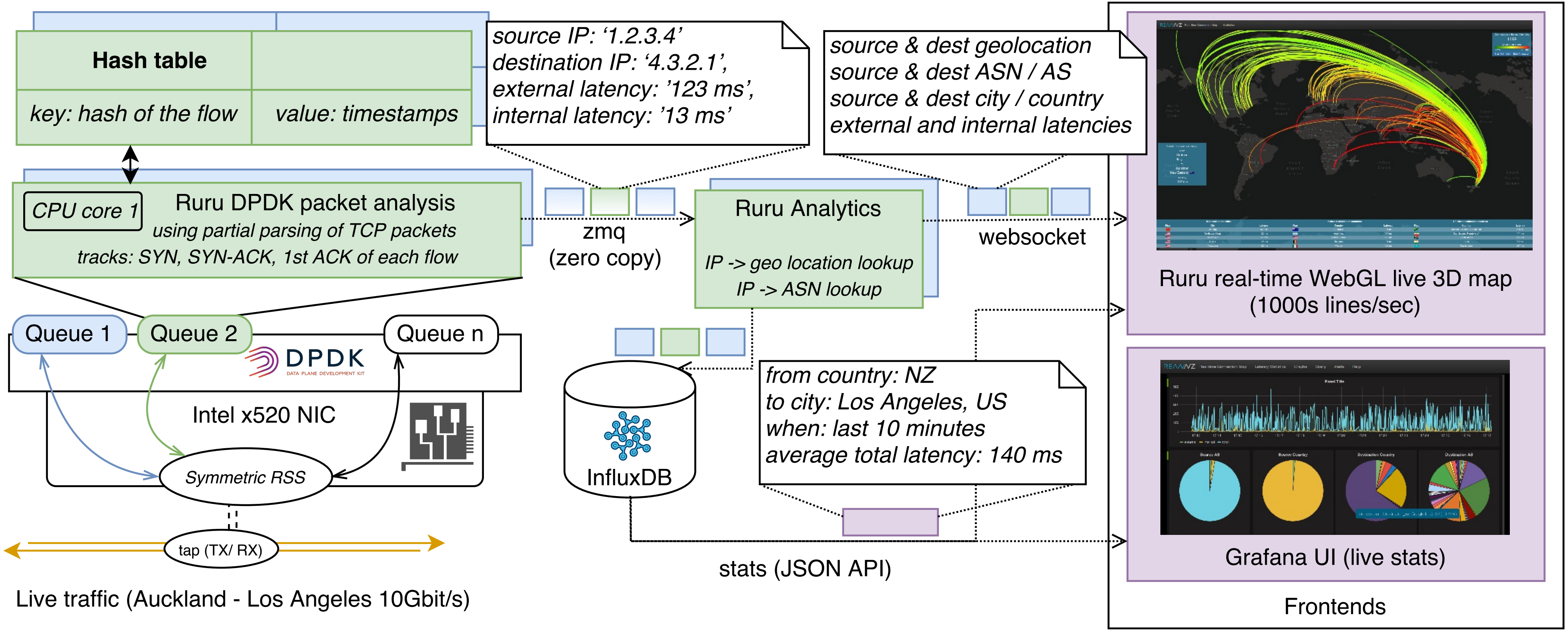


Challenges solved

1. Measuring end-to-end latency
2. Geo-mapping measurements
3. Visualizing traffic

$\xrightarrow{\text{... in 10Gbit/s ...}}$ Ruru

Architecture (all pieces together)

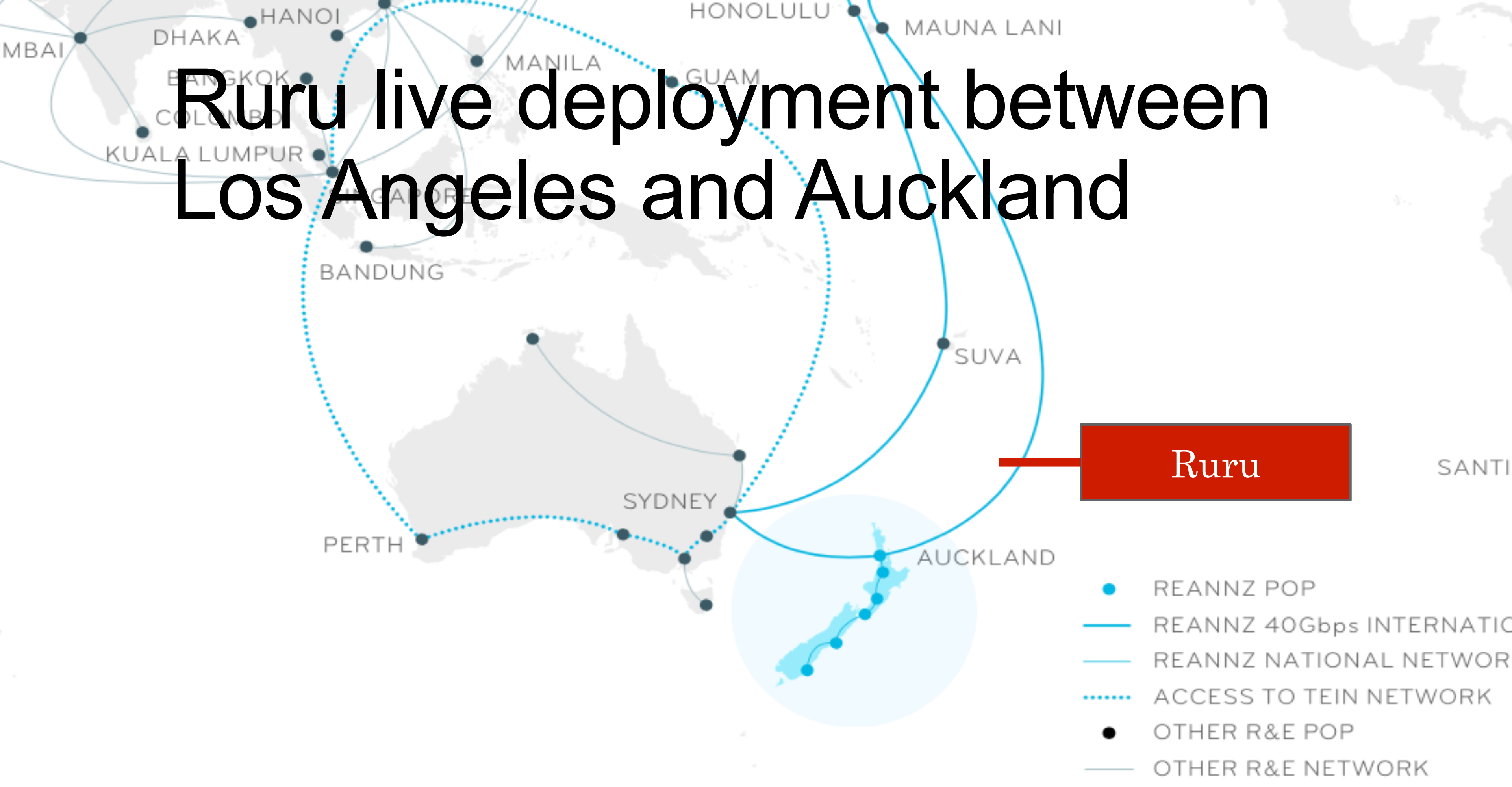


From: Cziva, Richard (University of Glasgow), Lorier, Chris (REANNZ) and Pezaros, D. Pezaros (University of Glasgow) *Ruru: High-speed, Flow-level Latency Measurement and Visualization of Live Internet Traffic.* (2017)
In: ACM SIGCOMM 2017, Los Angeles, CA, USA, 21-25 Aug 2017

Applications of Ruru

- Fault localization for wide area networks
  - “Immediate notice if latency has started to increase to Facebook’s AS”
  - “Some of our users are getting higher latency compared to others”
- Fault localization in your internal network
  - “A set of our users are getting higher internal latency than others”
    - Could be router / switch issue for those clients
    - Ruru shows that e.g., wireless clients usually get higher latency
- Network planning / auditing
  - Ruru shows where user’s connections are going the most and what latency they are experiencing

Ruru live deployment between Los Angeles and Auckland



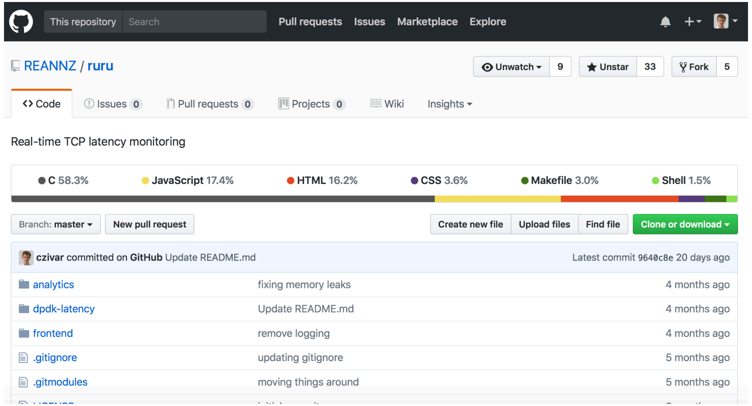
Ruru in production

- Using Ruru we found latency related issues, such as:
  1. The “00:48 bug”
     - Increased latency to 4 sec at 00:48 every night for just a few connections
     - Turned out there was a firewall update that time
  2. Software switch issue has also been noticed
     - Only wireless clients were affected
- Offline analysis has also been conducted
  - We can identify CDNs easily (providing very low latency)
  - Clients usually start 5-6 flows to the same destination at once
  - Seasonality is clearly visible (latency increases during the day when the network is utilized)
  - ... (more to come)

Live demo

More on Ruru

- Paper: Cziva, Richard (University of Glasgow), Lorier, Chris (REANNZ) and Pezaros, D. Pezaros (University of Glasgow)
  Ruru: High-speed, Flow-level Latency Measurement and Visualization of Live Internet Traffic. (2017)
  In: ACM SIGCOMM 2017, Los Angeles, CA, USA, 21-25 Aug 2017
  - Winner of the ACM SRC competition



- Github: https://github.com/REANNZ/ruru

Project page: https://netlab.dcs.gla.ac.uk/projects/ruru-latency-visualisation

Conclusions

- I believe user-perceived end-to-end latency is an important metric
- To do measurements and visualization on this scale, the go-to tools (e.g., Scapy, GeoIp, d3.js) are insufficient
  - Careful engineering, parallel processing and low level tools are required
- I have created Ruru, an open-source pipeline that can is able to **measure**, **analyze** and **visualize** user perceived TCP latency on 10Gbit/s live traffic

Interested in deploying Ruru? – let's talk!

Image from: http://www.doc.govt.nz

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Thank you for your attention!
Questions?