Packet-Level Telemetry in Large Datacenter Networks

Yibo Zhu, Nanxi Kang, Jiaxin Cao, Albert Greenberg, Guohan Lu, Ratul Mahajan, Dave Maltz, Lihua Yuan, Ming Zhang, Ben Zhao, Haitao Zheng
Datacenter networks (DCN)

- Datacenter networks are large and complex
  - O(10K) switches, O(100K) links, O(100K) servers
  - Low-cost devices and complex software stack

- Network faults are unavoidable
  - Packet drop, latency spike, low throughput, load imbalance

- Debugging is a daunting task
  - Why application A performs poorly?
Example #1: silent packet drops

Too many switches/links: hard to localize using ping/traceroute

Alerts: high TCP retransmissions

Discard counter > 0
Example #2: latency spikes
Example #2: latency spikes

Interface counters: too coarse-grained
Ping/traceroute: cannot measure per link latency
Solution: packet tracing

- Tracing packet $p$ at every hop
  - Locate drop from $p$’s last appearance
  - Identify bottleneck from per-hop latency
Packet-level network telemetry
Data-plane match & mirror

- Rule-based match & mirror for scalability
- Huge capacity with zero control plane overhead
Match & mirror rules

• Rules based on existing chip
  – IPID-based random sampling
  – One bit in DSCP field: selective packet tracing
  – TCP SYN/FIN/RST: every TCP flow
  – Protocol traffic: BGP, PFC, RDMA

• Support needed from P4 programmable chip
  – Match on (hash value of) certain packet fields
  – Truncate mirrored packet
Challenges with packet drops

Where is $p$ dropped?

Why is $p$ dropped?

Trace collector
Debugging packet drops

- Current solution:
  - Inject guided probe into suspect switches
- P4 programmable chip/NIC:
  - Export metadata: incoming/outgoing port, matched rule
  - Mirroring triggered by metadata: packet drop reason
Challenges with link latency

• Switch does not provide timestamp

\[ t_2 - t_1 \neq \text{latency of } S_1 \rightarrow S_2 \]
Measuring link latency

- **Current solution**
  - Inject guided probe to bounce between $S_1$ and $S_2$
- **P4 programmable chip**
  - Attach switch timestamp to mirrored packet
Conclusion

• Packet-level telemetry is both *crucial* and *practical* in large-scale DCNs
  – Packet drop, latency spike, load imbalance…

• P4 programmable chip/NIC will greatly enhance the utility of EverFlow
  – Export packet metadata in mirrored packet
  – Mirroring triggered by packet metadata