High-resolution Measurement of Data Center Microbursts

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Networks are Fast, Measurements are not...

Data center networks are getting faster

- 100Gbps, ~100 ns to process a packet, 10-100 μs RTT

But measurement frameworks are not keeping up

- **SNMP counters** (e.g. bytes sent or drops) typically collected every couple minutes

- **Packet sampling** (sFlow or iptables) typically at low sampling rate, e.g. 1/30k
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Too coarse-grained!
The Case for High Resolution

- Packet drop correlates poorly with utilization at 4 minute granularity
- 4 minute granularity hides short-term traffic spikes
- Need high-resolution to reveal finer-grained behaviors
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![Diagram showing the relationship between average drop rate and average utilization, indicating a generally very low drop rate.](image-url)
The Case for High Resolution

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unusual drop rates at both low and high utilization

drop rate generally very low
Roadmap

Mechanism

- It is possible to do high resolution measurements on today's switches

Results

- Many if not most traffic bursts are very short-lived
High-resolution Counter Collection Framework

We designed a high-resolution counter collection framework

- Switch CPUs poll ASIC registers with microsecond level latency
- Sample fast (~25 μs) while keeping sampling loss below 1%

We focus on three kinds of counters

1. **Byte count**: cumulative and used to compute utilization
2. **Packet size**: a histogram of packet sizes
3. **Peak buffer occupancy**: for single port and shared pool
Deployment

- One of the largest data centers at Facebook with a 3-tier Clos network
- Only collect from ToRs due to deployment constraints
- 10Gbps server links and 4x40Gbps ToR uplinks
Workload and Methodology

- Mostly single-role racks
  - Web: handle user request, lookup with cache
  - Cache: handle k-v lookups, respond to Web servers
  - Hadoop: handle batched processing
- 30 racks in total: 10 racks for each app, over 24 hours
  - Sample a random 2-minute interval per hour, for 1TB+
Microburst Measurements

Microburst:
a period of short-term high utilization (e.g. >50%)

• How long do they last and how often do they occur?
• How much of congestion is caused by microbursts?
• Does network behavior differ significantly inside a burst?
• Are there synchronized behaviors during bursts?
Distribution of Link Utilization
Distribution of Link Utilization

a lot of intervals with almost nothing happening

25 μs

CDF

% Link Utilization

Web
Cache
Hadoop
Distribution of Link Utilization

A lot of intervals with almost nothing happening.

A few intervals have ~100% utilization.

25 μs
Distribution of Link Utilization

- A lot of intervals with almost nothing happening.
- Some intervals have ~100% utilization.
- Insensitive to 50% threshold.
Bursts are Short

- **Burst**: an unbroken sequence of hot samples (> 50% util)
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> many bursts last at most 25 μs
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Many bursts last at most 25 μs.
Bursts are Short

- **Burst**: an unbroken sequence of hot samples (> 50% util)

Many bursts last at most 25 µs

Almost all congestion is short-lived

90pct at 200 µs
Time between Bursts

CDF

Inter-burst Duration (ms)

Web
Cache
Hadoop

25 μs
Time between Bursts

For Web/Hadoop, 50% < 1 RTT

25 μs
Time between Bursts

For Web/Hadoop, 50% < 1 RTT

Even for cache, median is < 10x RTT

25 μs
Time between Bursts

- Some predictability: a burst is likely to be followed by another relatively soon
- Potential for re-balance between bursts

For Web/Hadoop, 50% < 1 RTT

Even for cache, median is < 10x RTT

$25 \mu s$
Packet Size Distribution

Inside Burst

Outside Burst

Bigger packets inside bursts for Web/Cache

100 μs
Packet Size Distribution

Bigger packets inside bursts for Web/Cache

Burst are correlated with app-level behaviors (e.g. sending bigger responses or scatter-gather/incast)
Directionality of Bursts

300 μs
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More bursts towards servers due to high fan-in

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Cache see more bursts on uplinks as responses are typically bigger than requests

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Efficacy of Network Load Balancing

- 4 ToR Uplinks: compute mean absolute deviation (MAD) for each polling interval
- \( \text{MAD} = \text{mean}( |u - \bar{u}| / \bar{u} ) \), so MAD=0 means perfect load balancing
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links well balanced at 1s scale

40 \mu s
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![Graph showing CDF of MAD of Uplink Utilization with links well balanced at 1s scale and highly unbalanced at 40 μs scale.](image)
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Implications for design of network, e.g. for low latency and loss.
Conclusions

• Deployed a microsecond-scale measurement framework in production
  
  • Demonstrated it is possible to do high-resolution measurement on today's switches
  
  • Microbursts are real, short, correlated, and related to application behaviors
  
  • Future work to correlate with end-host measurements to better understand causes for microbursts