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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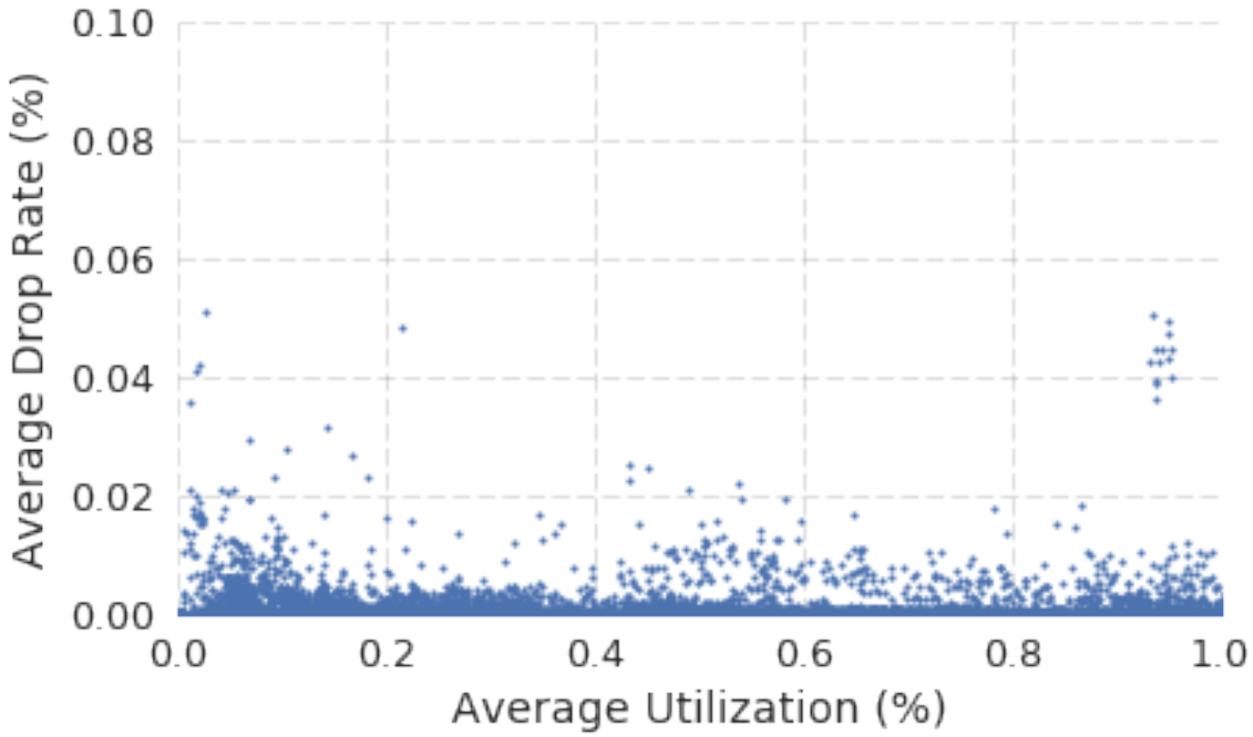
Too coarse-grained !

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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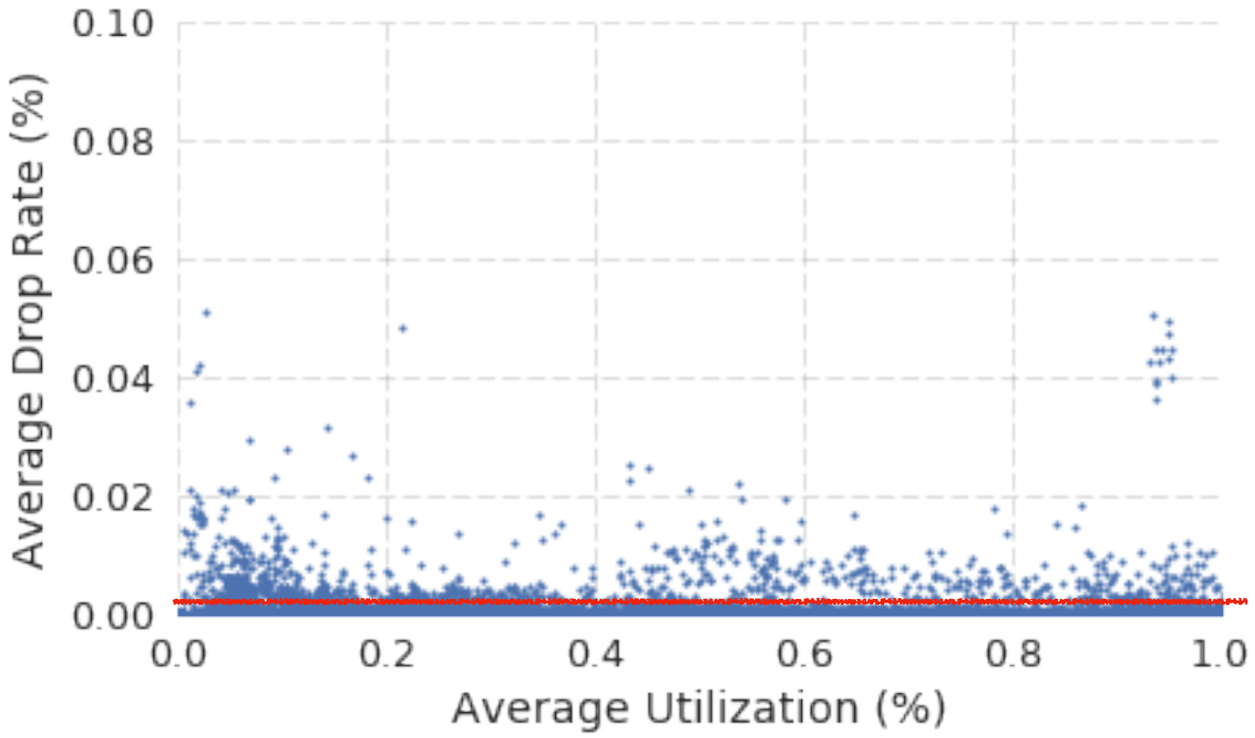

drop rate generally very low

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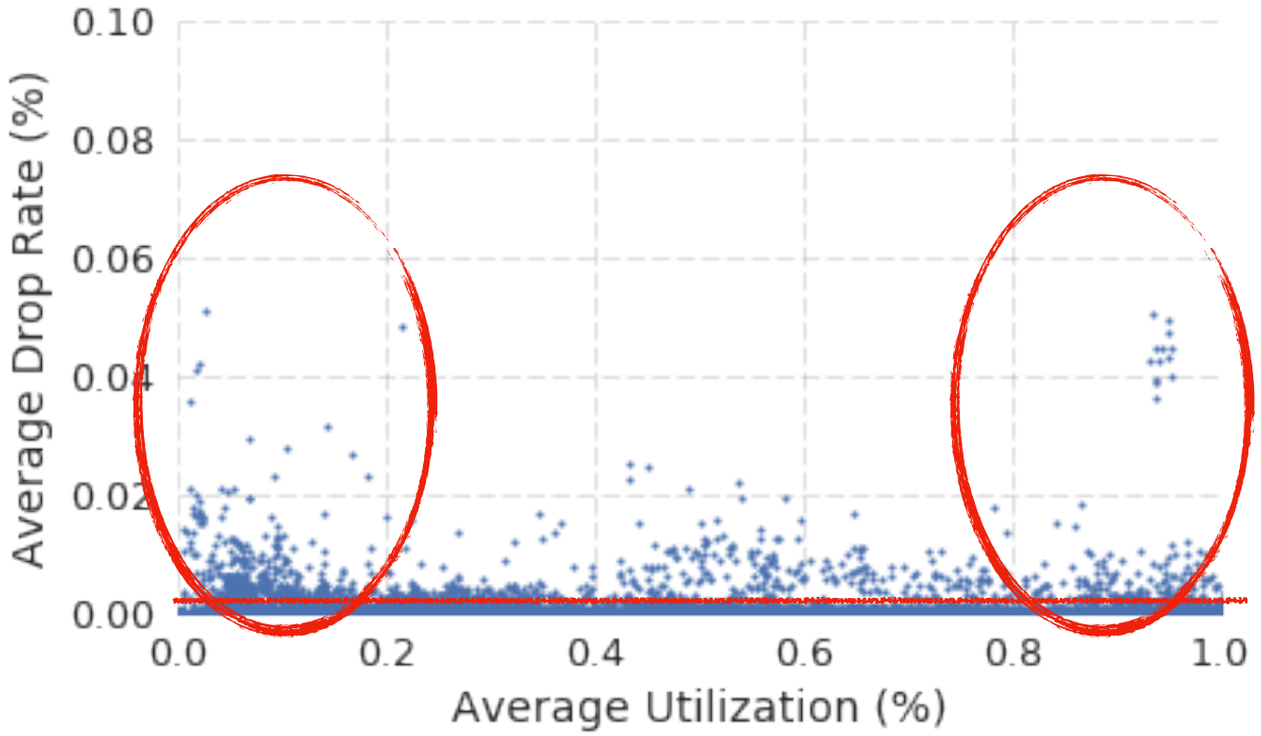
The Case for High Resolution

unusual drop rates at both low and high utilization



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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

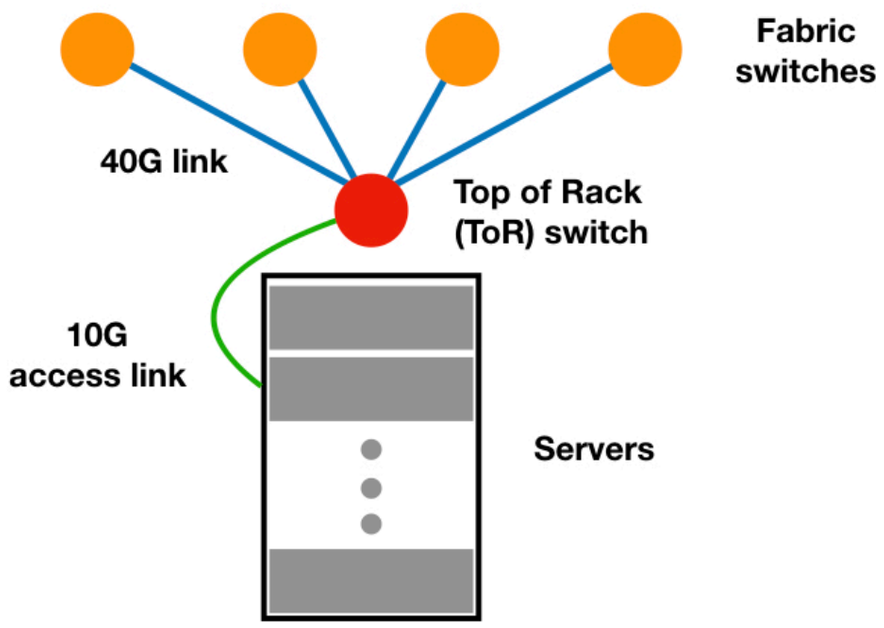
1. **Byte count**: cumulative and used to compute utilization
2. **Packet size**: a histogram of packet sizes
3. **Peak buffer occupancy**: for single port and shared pool

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+

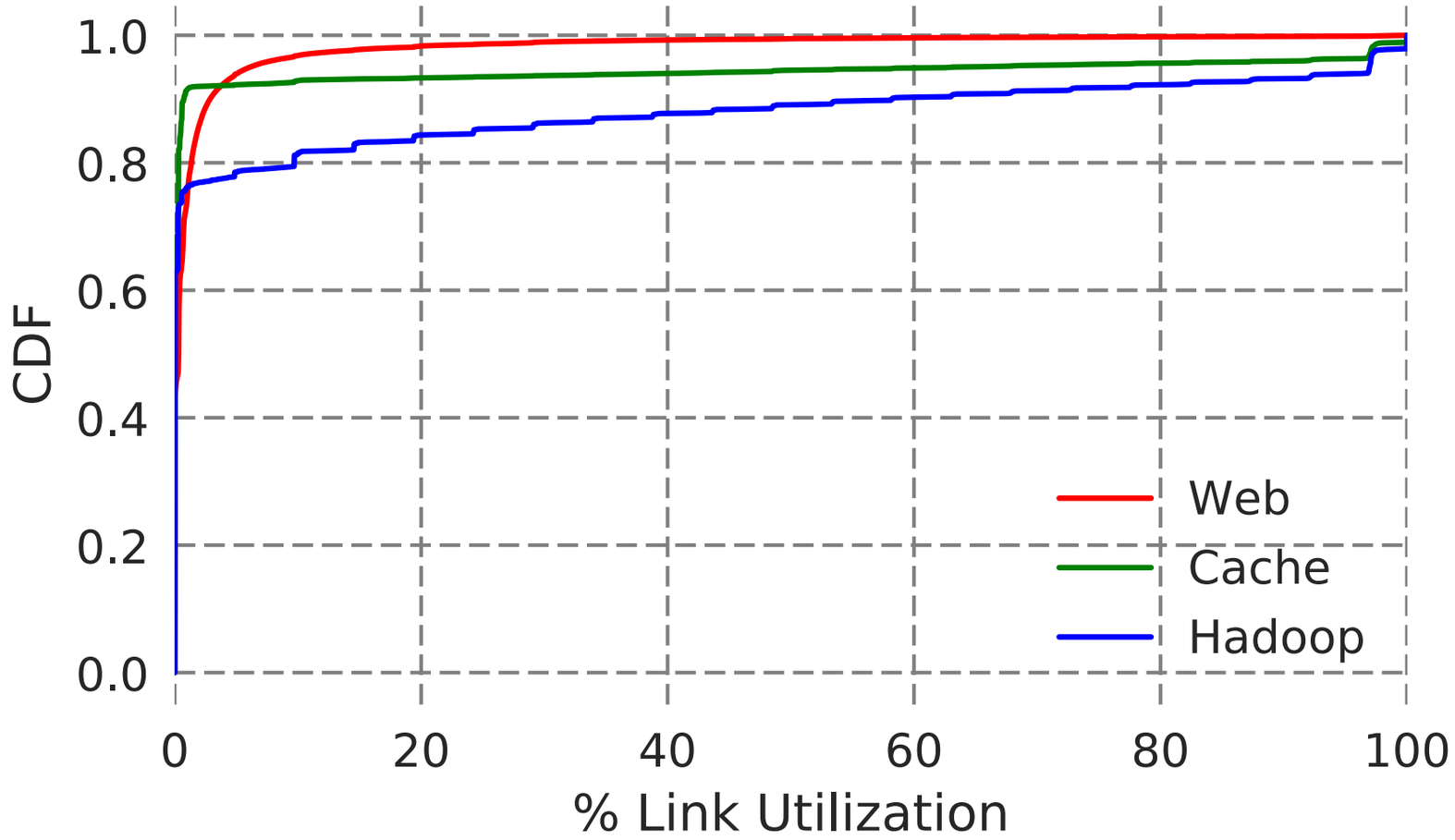
Microburst Measurements

Microburst:

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

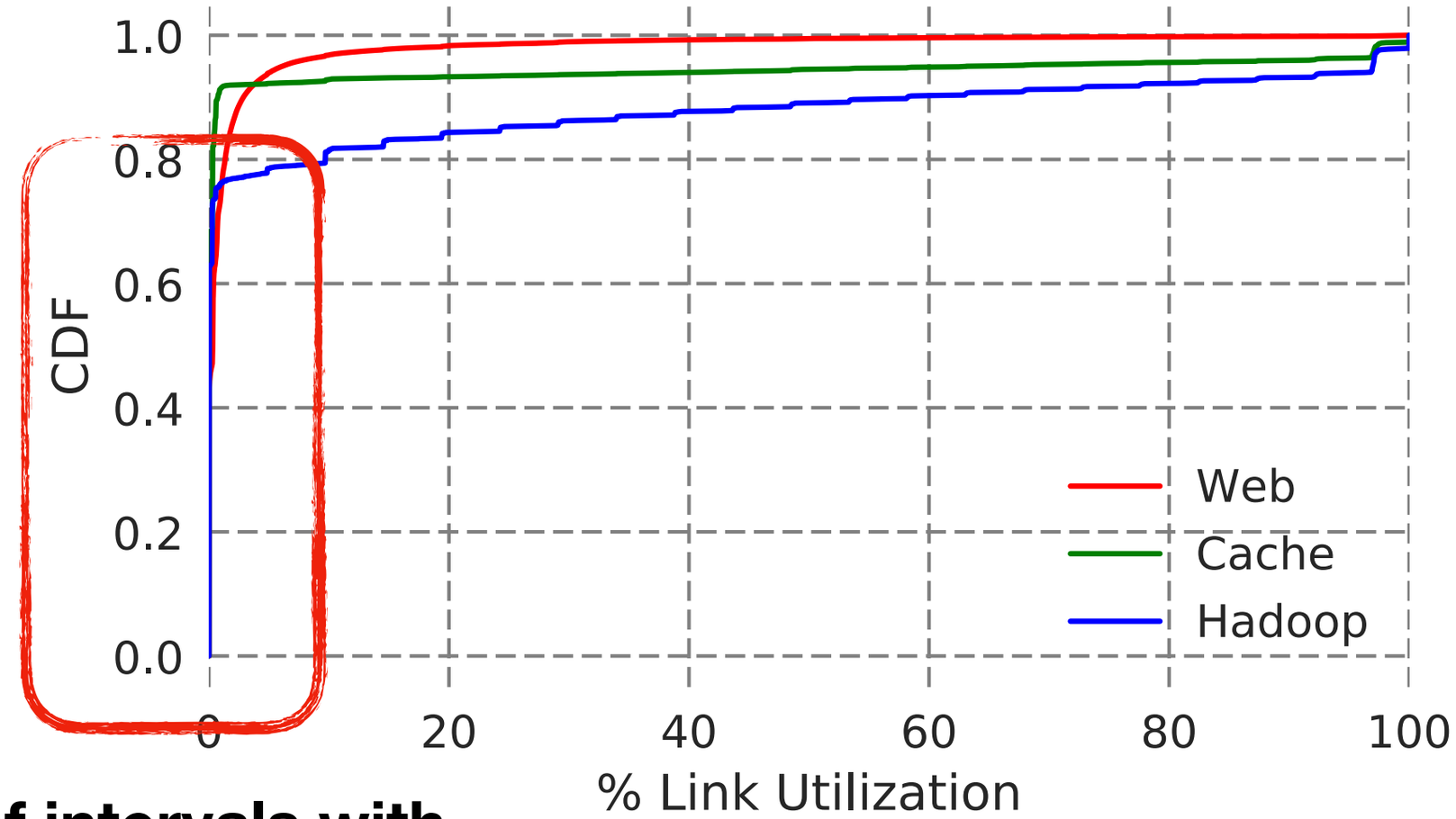
- How long do they last and how often do they occur?
- How much of congestion is caused by microbursts?
- Does network behavior differ significantly inside a burst?
- Are there synchronized behaviors during bursts?

Distribution of Link Utilization



25 µs

Distribution of Link Utilization



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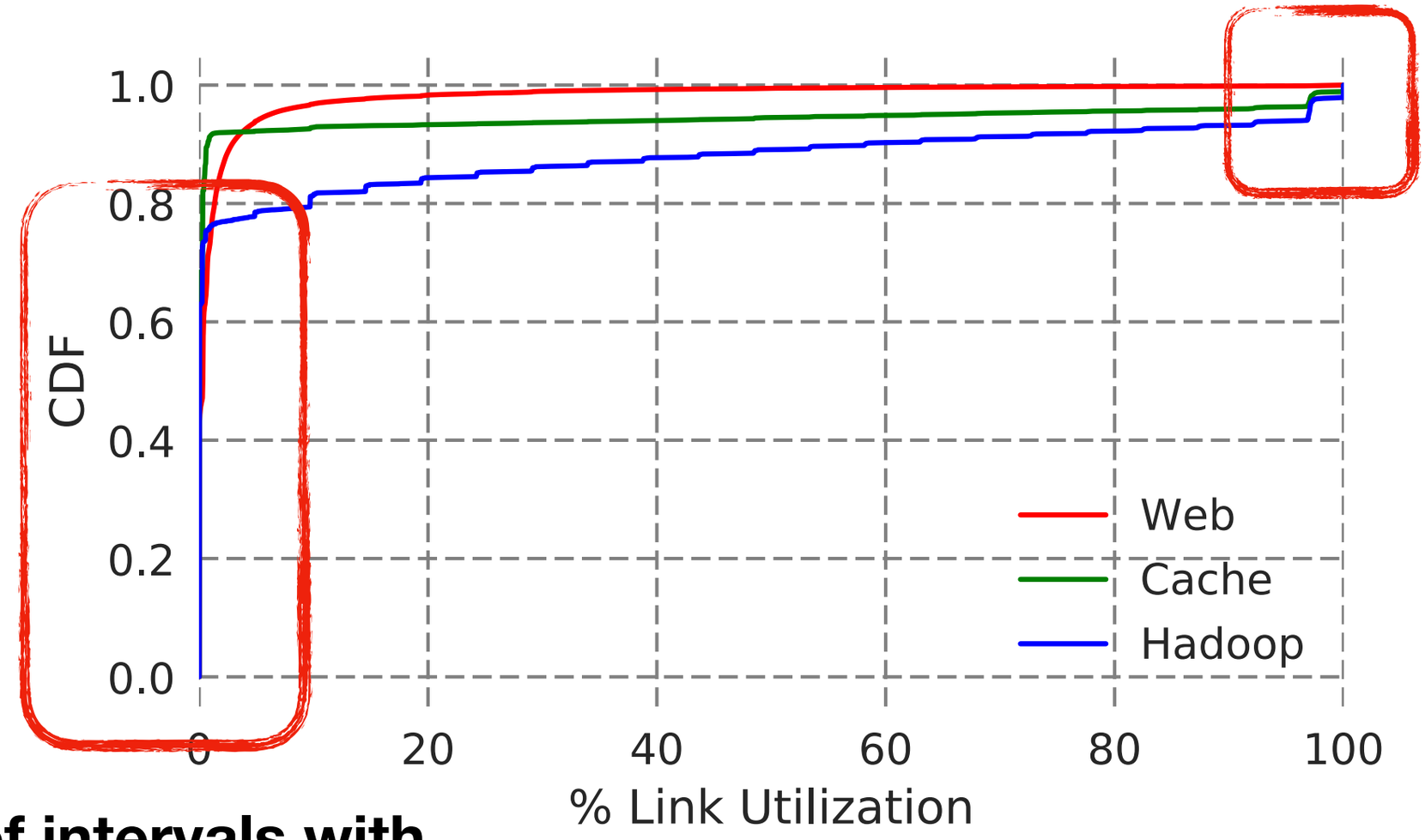

a few intervals have ~100% utilization

a lot of intervals with almost nothing happening

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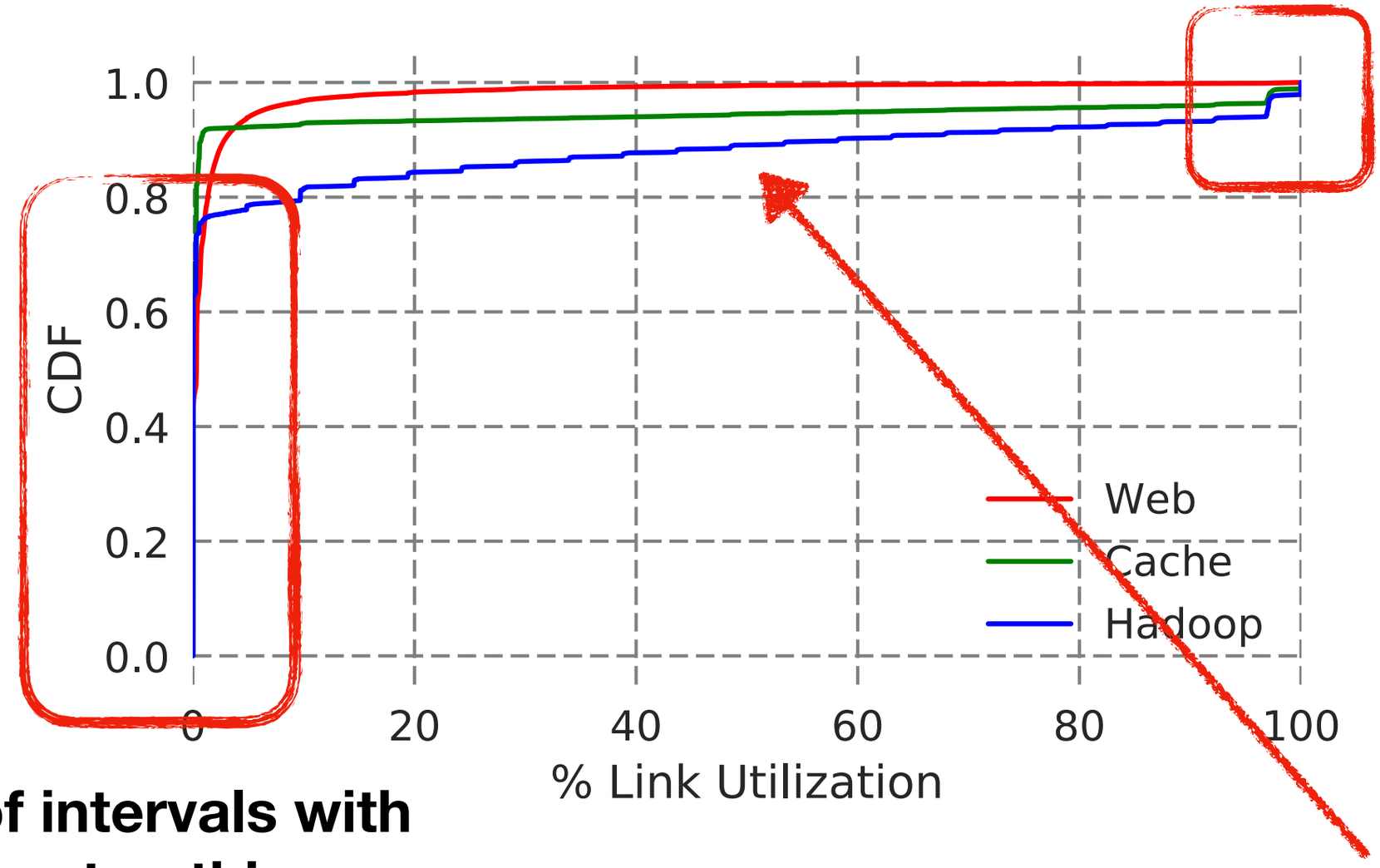

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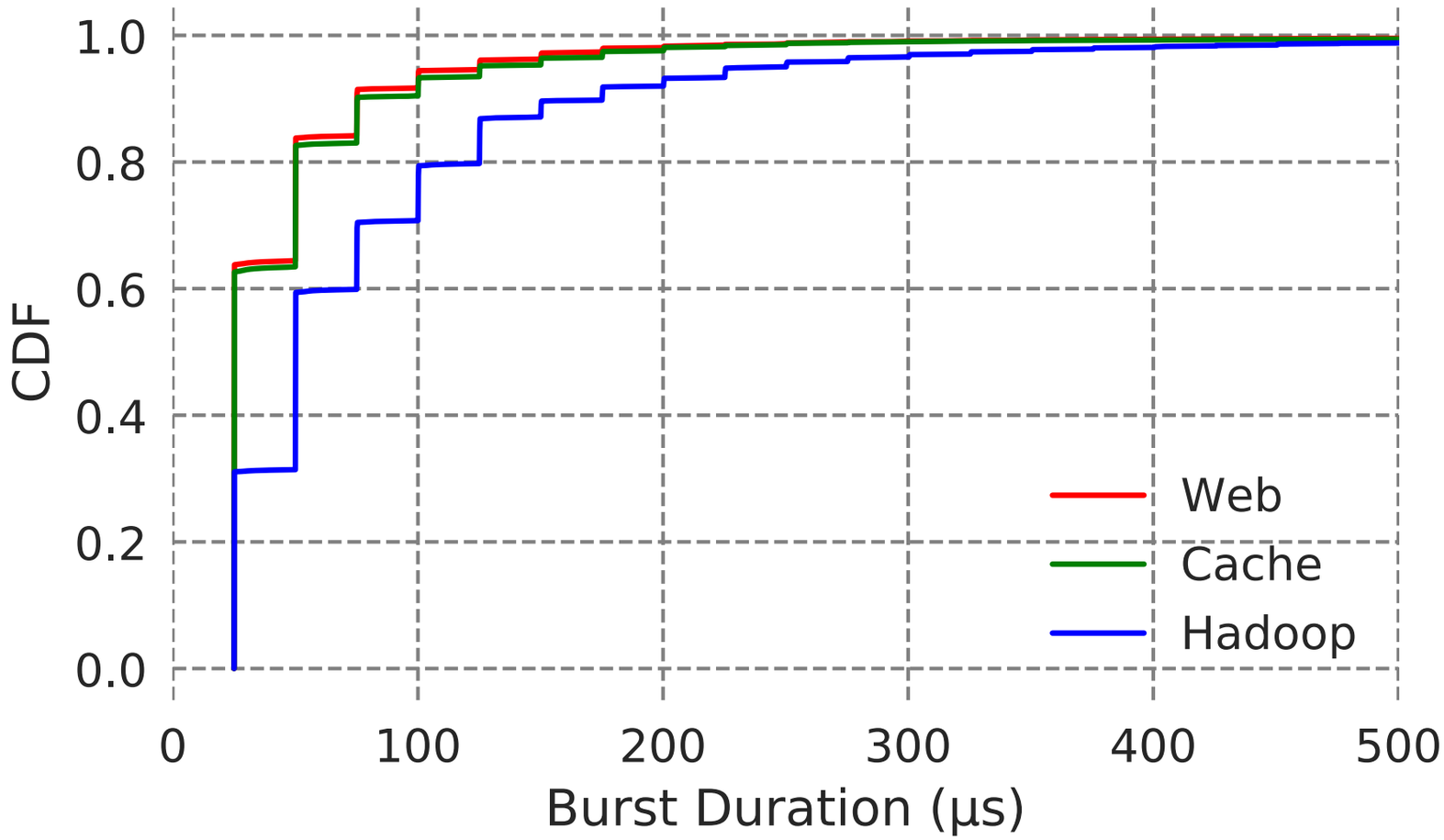
a lot of intervals with almost nothing happening

insensitive to 50% threshold

25 µs

Bursts are Short

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



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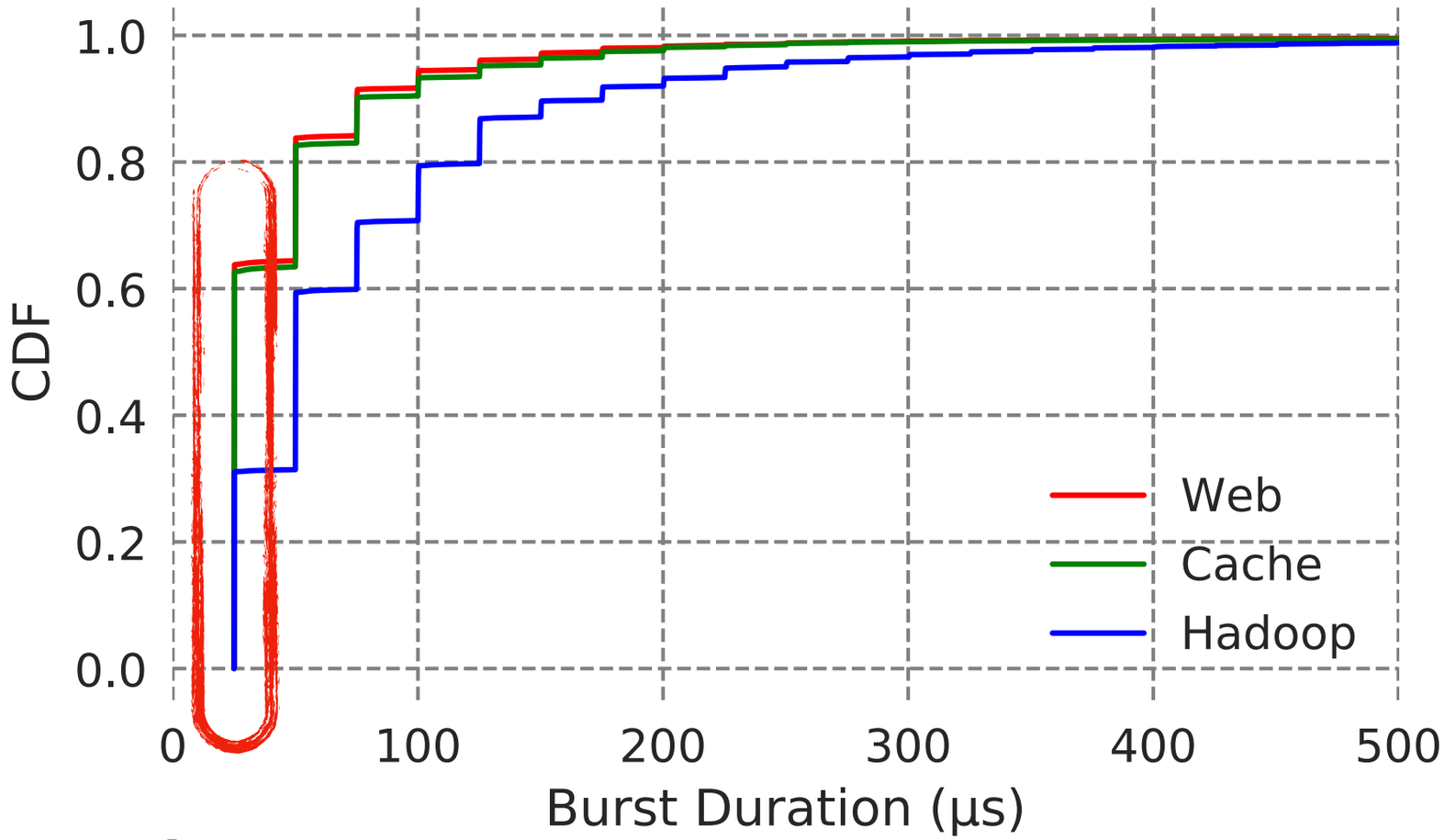

many bursts
last at most 25 µs

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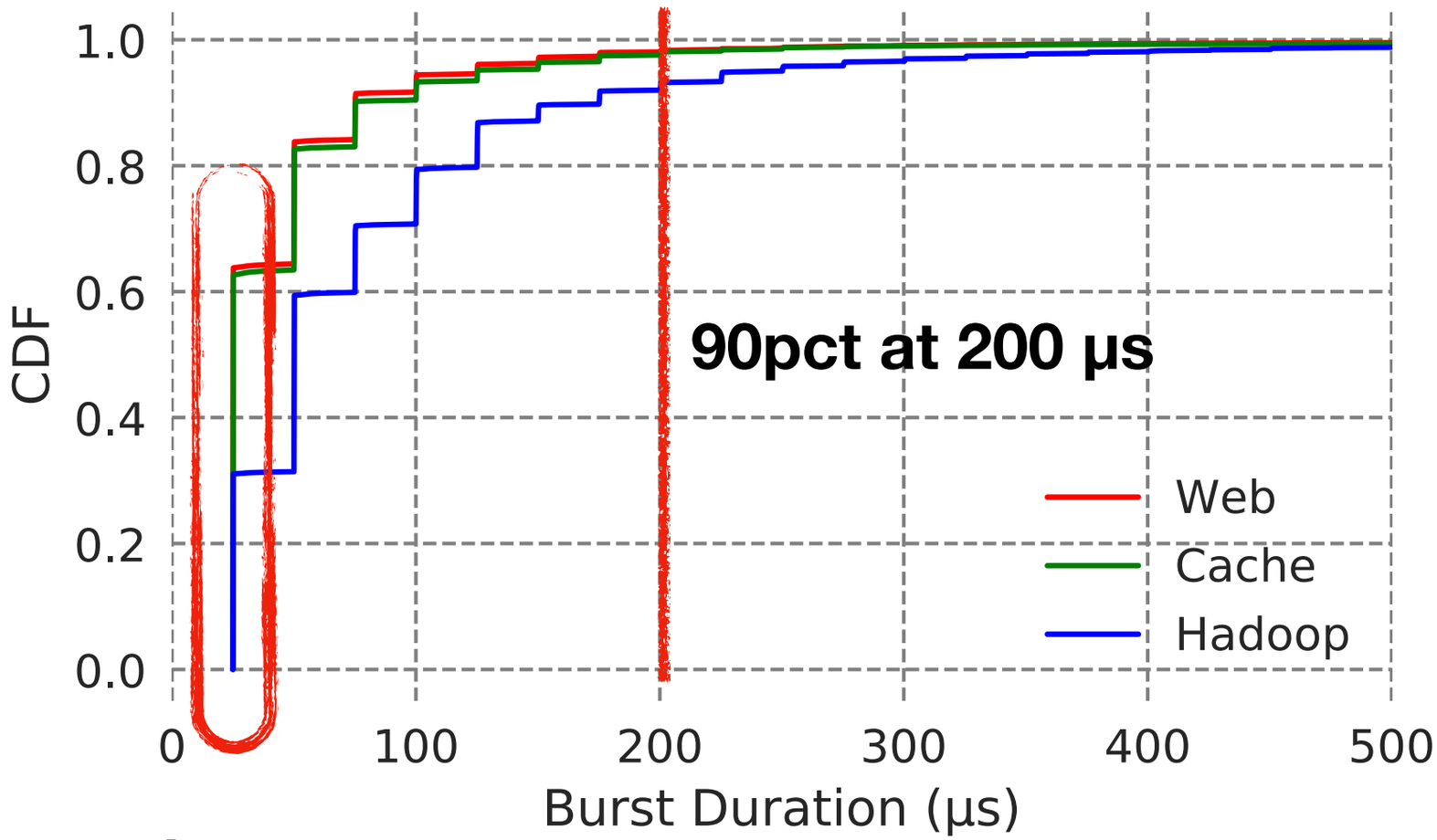

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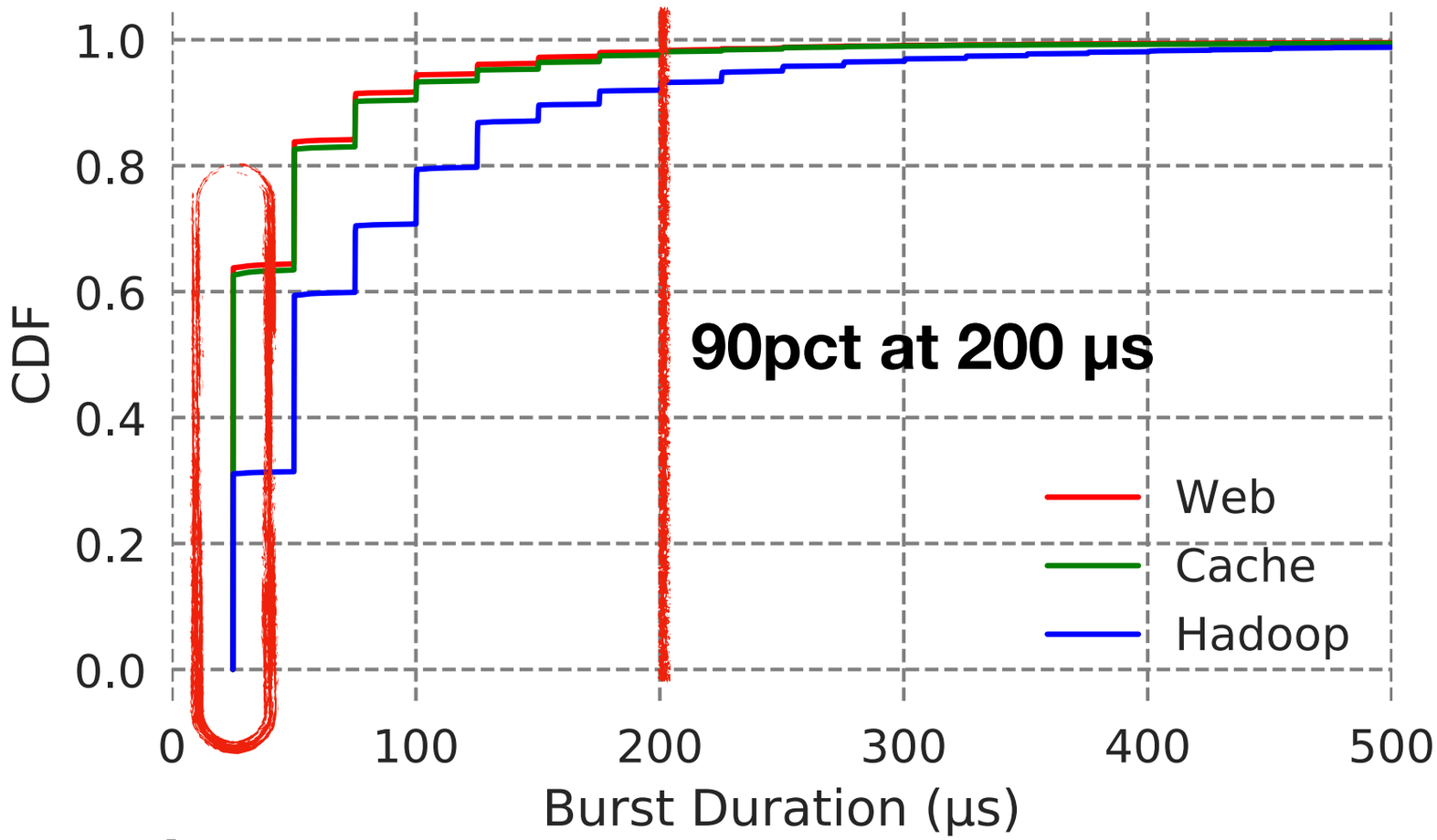
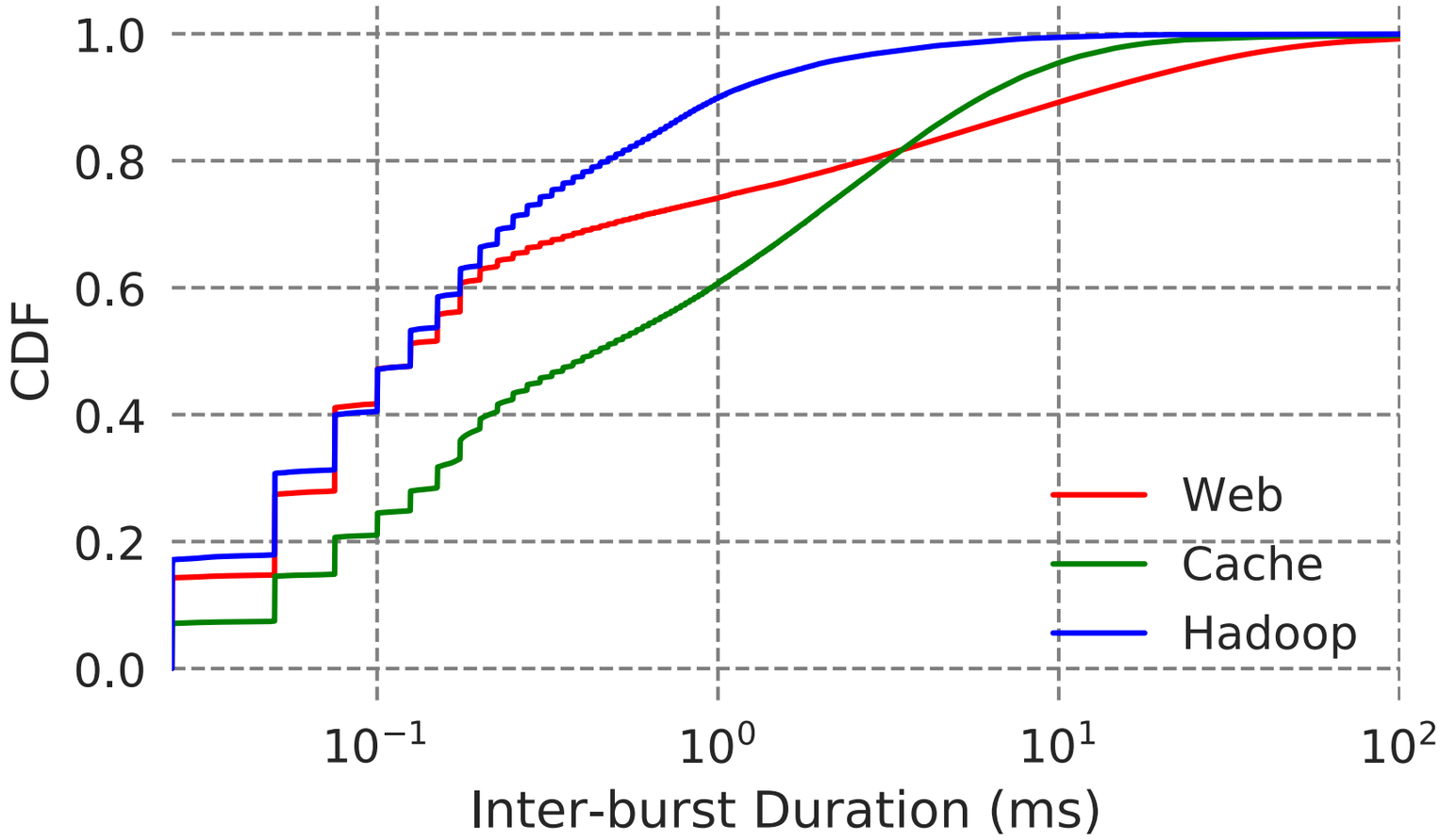


many bursts
last at most 25 µs

Almost all congestion is short-lived

25 µs

Time between Bursts



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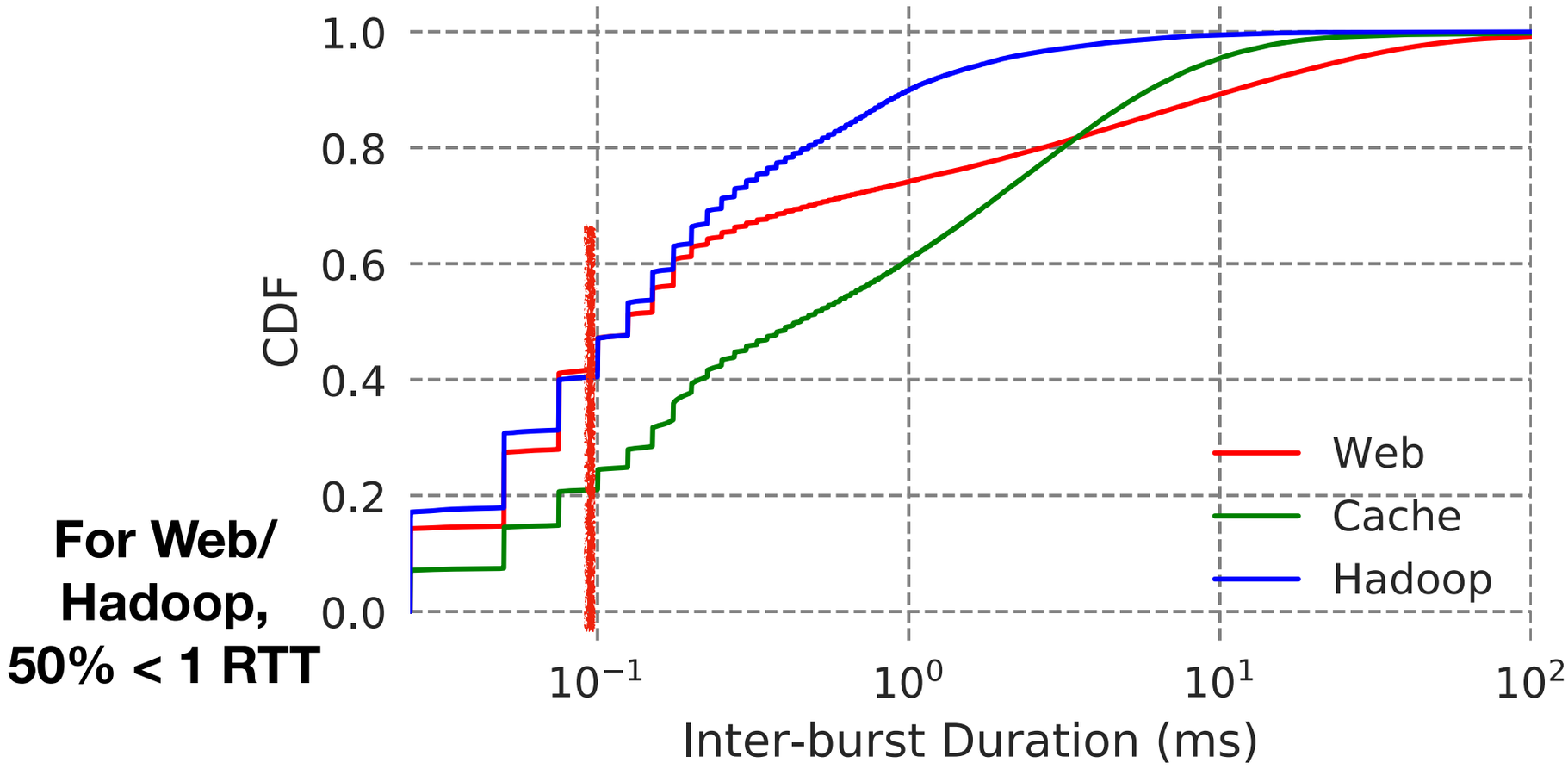

For Web/ Hadoop, 50% < 1 RTT

25 µs

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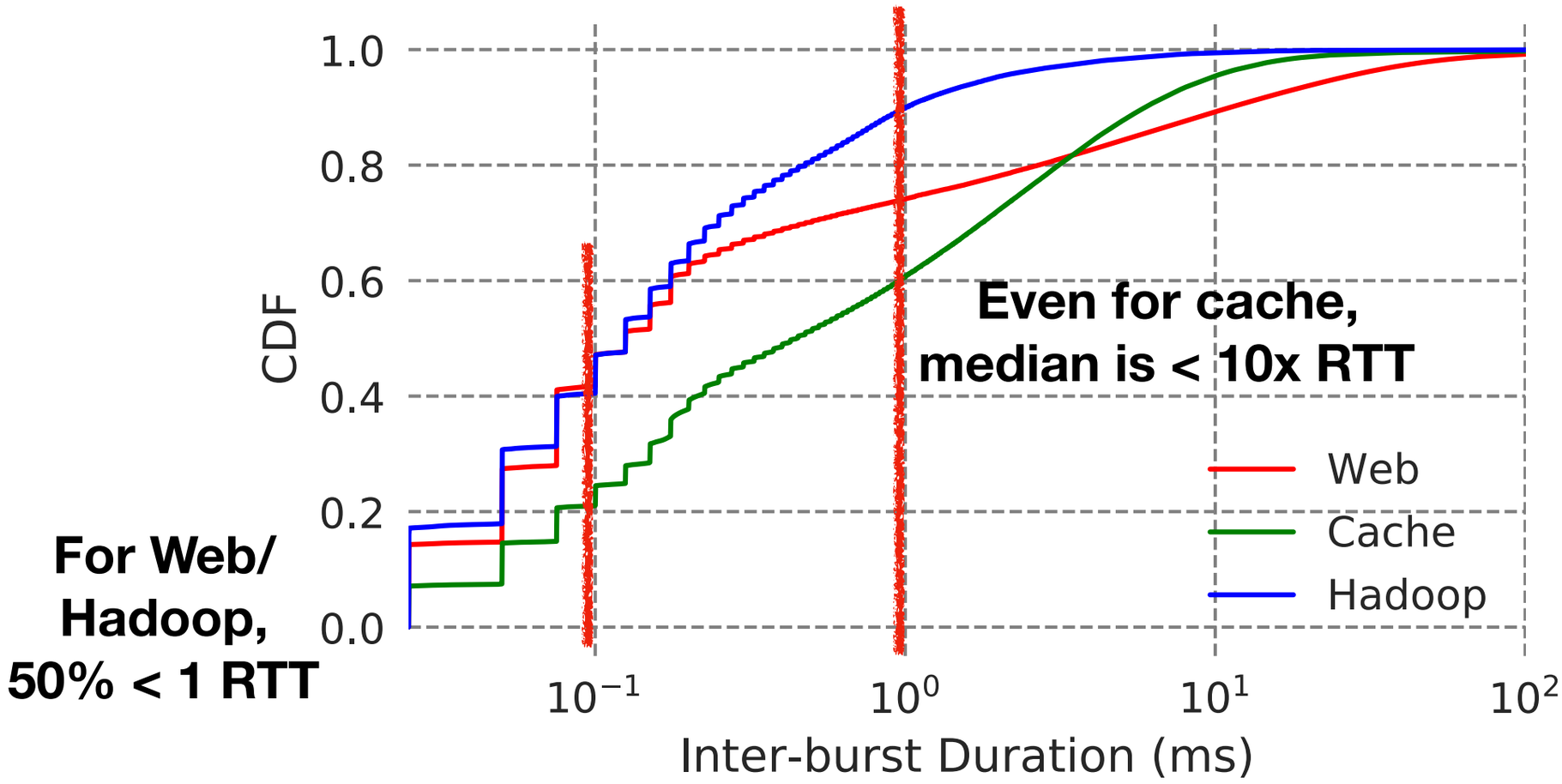

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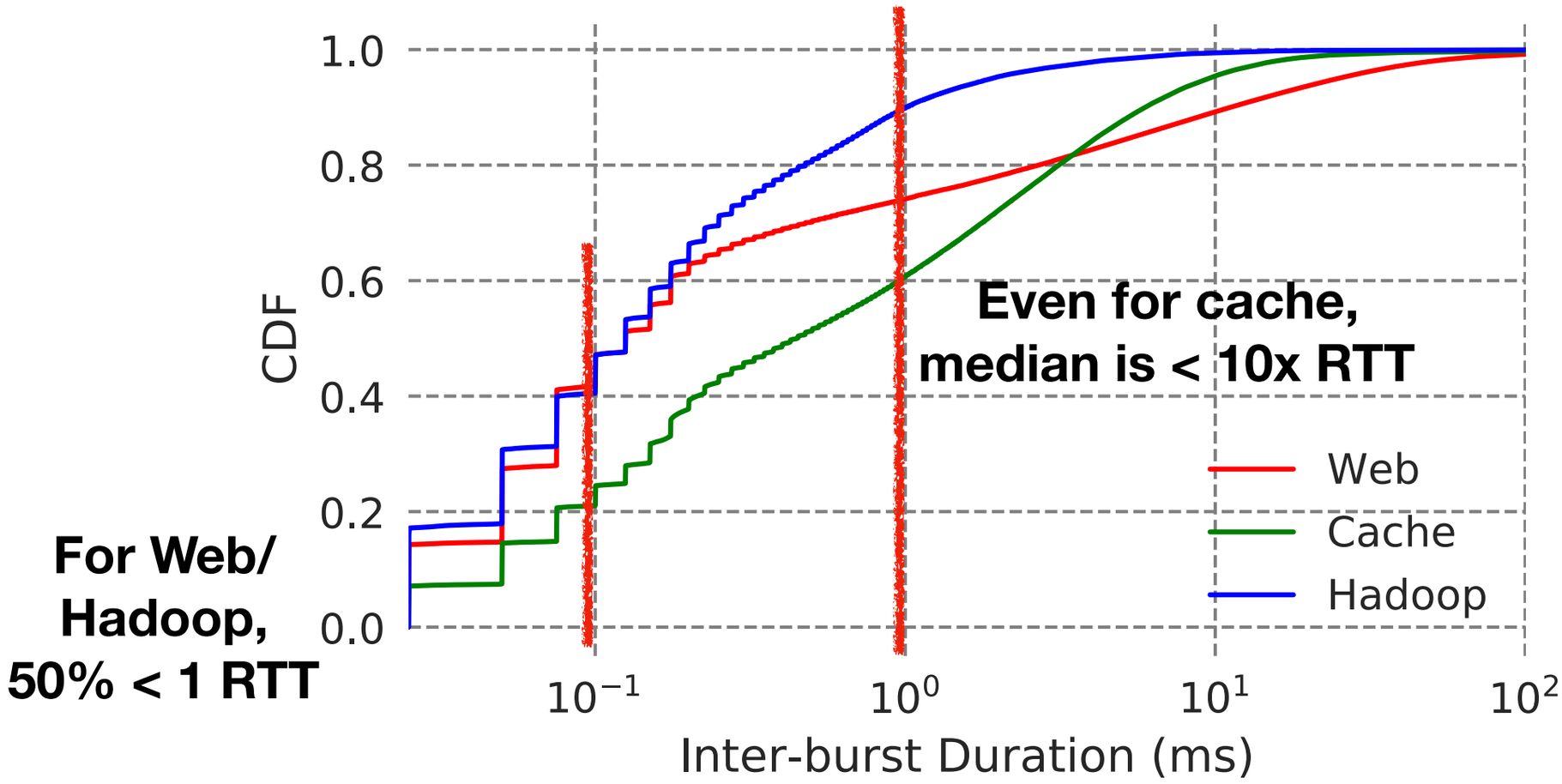
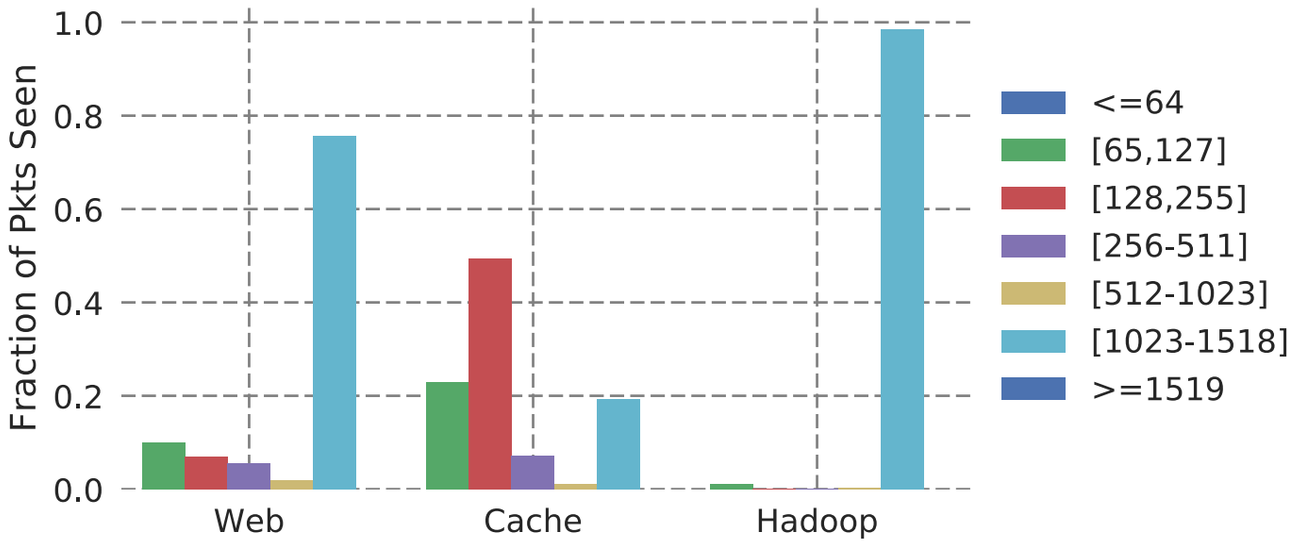


- **Some predictability: a burst is likely to be followed by another relatively soon**

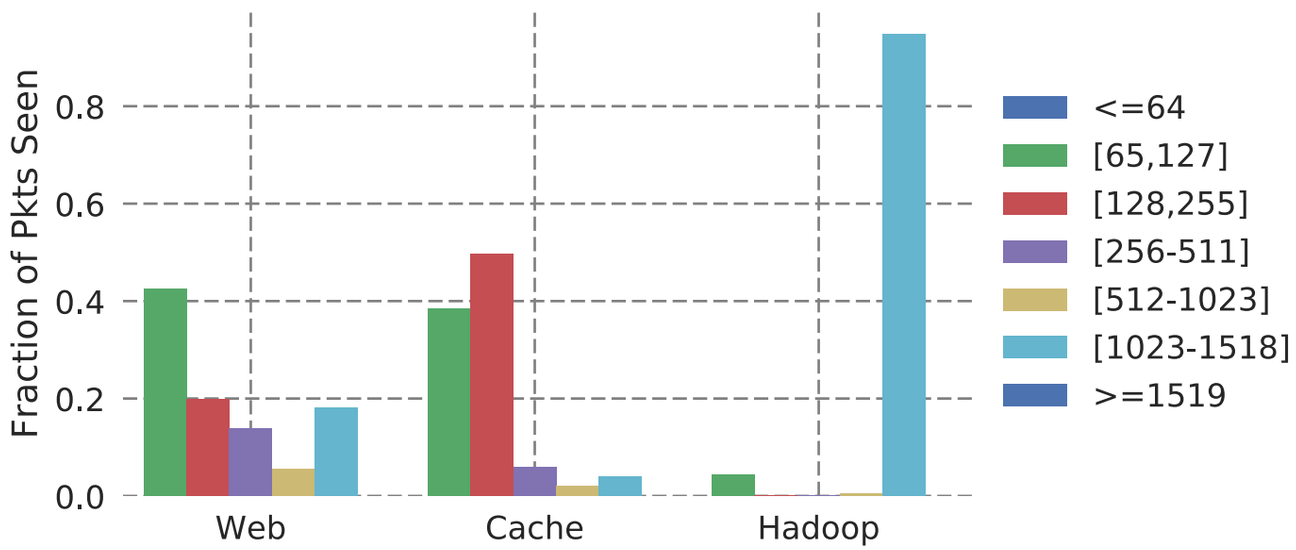
- **Potential for re-balance between bursts**

25 µs

Packet Size Distribution



Inside Burst



Outside Burst

100 µs

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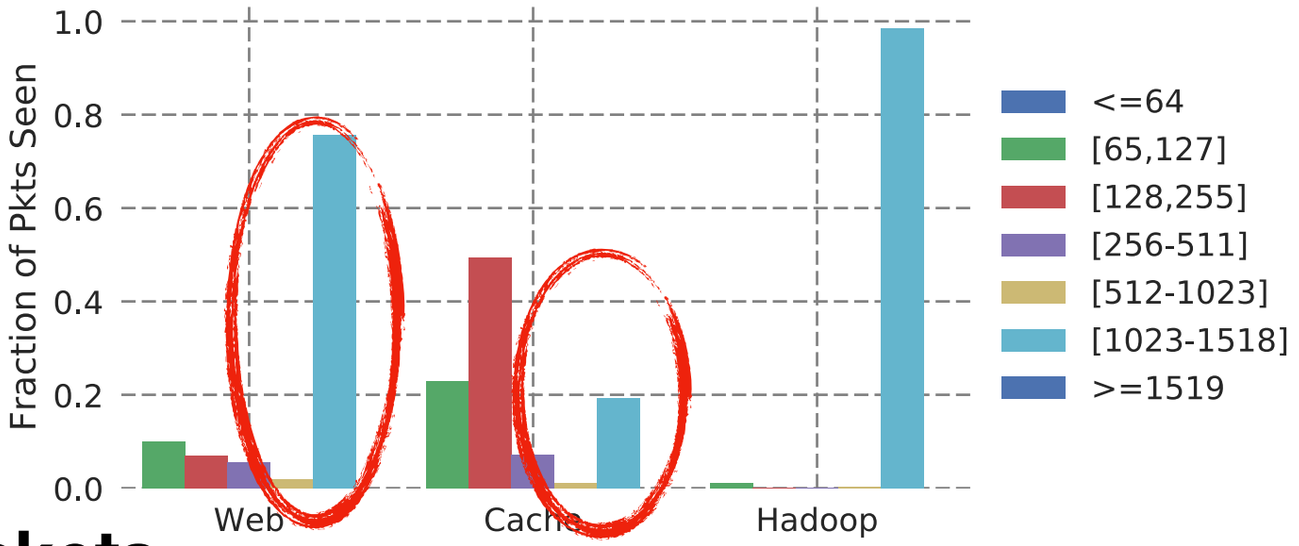
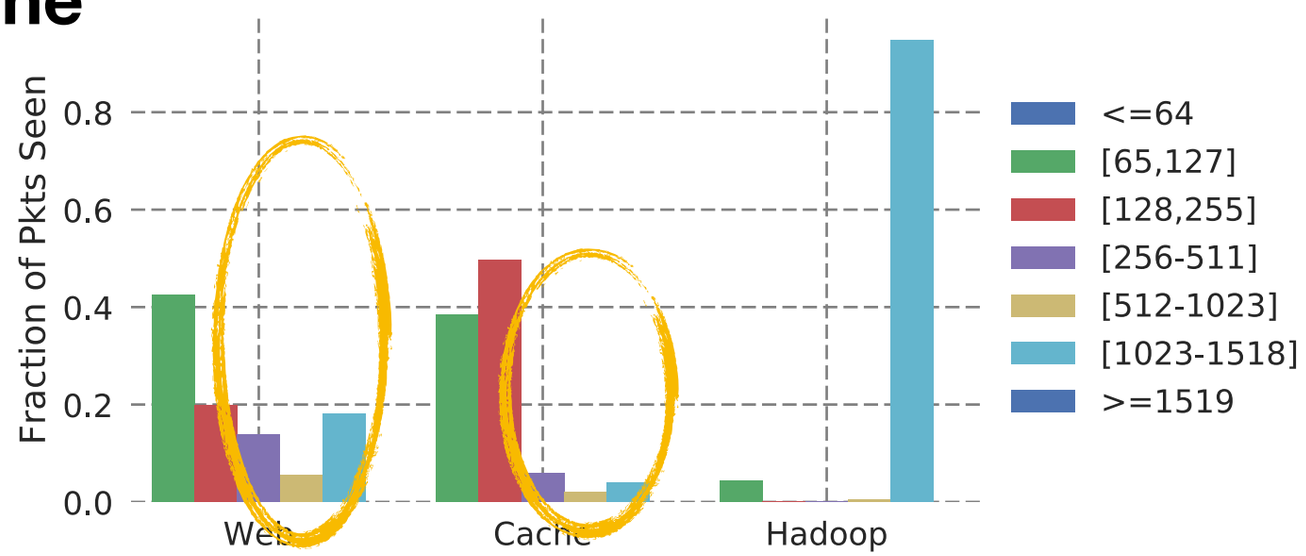


Inside Burst

Bigger packets inside bursts for Web/Cache



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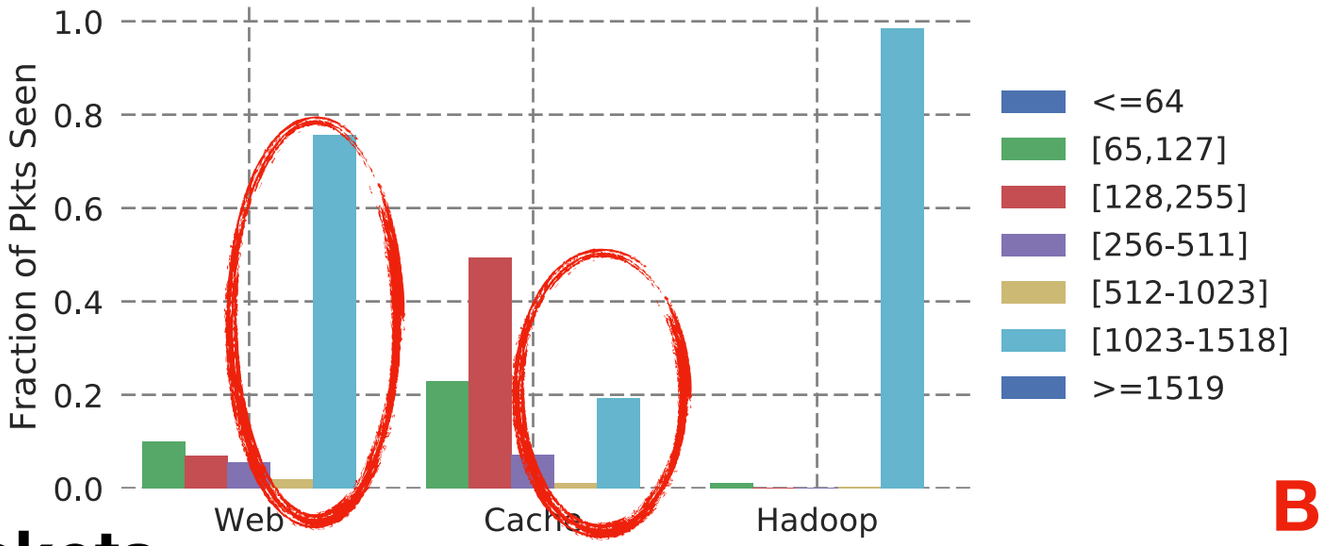

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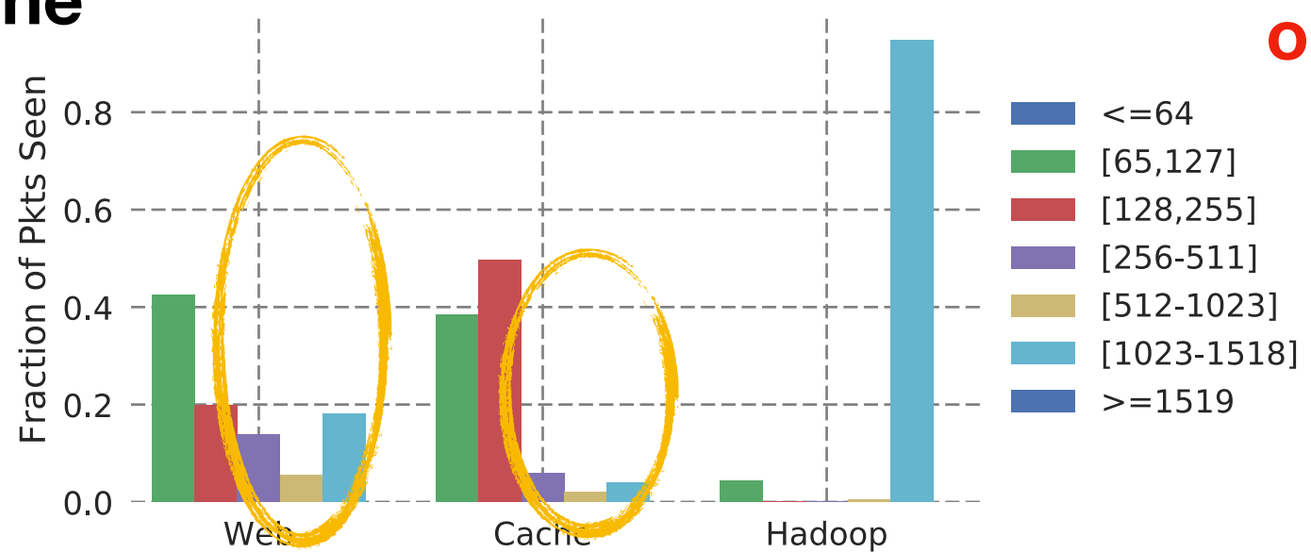
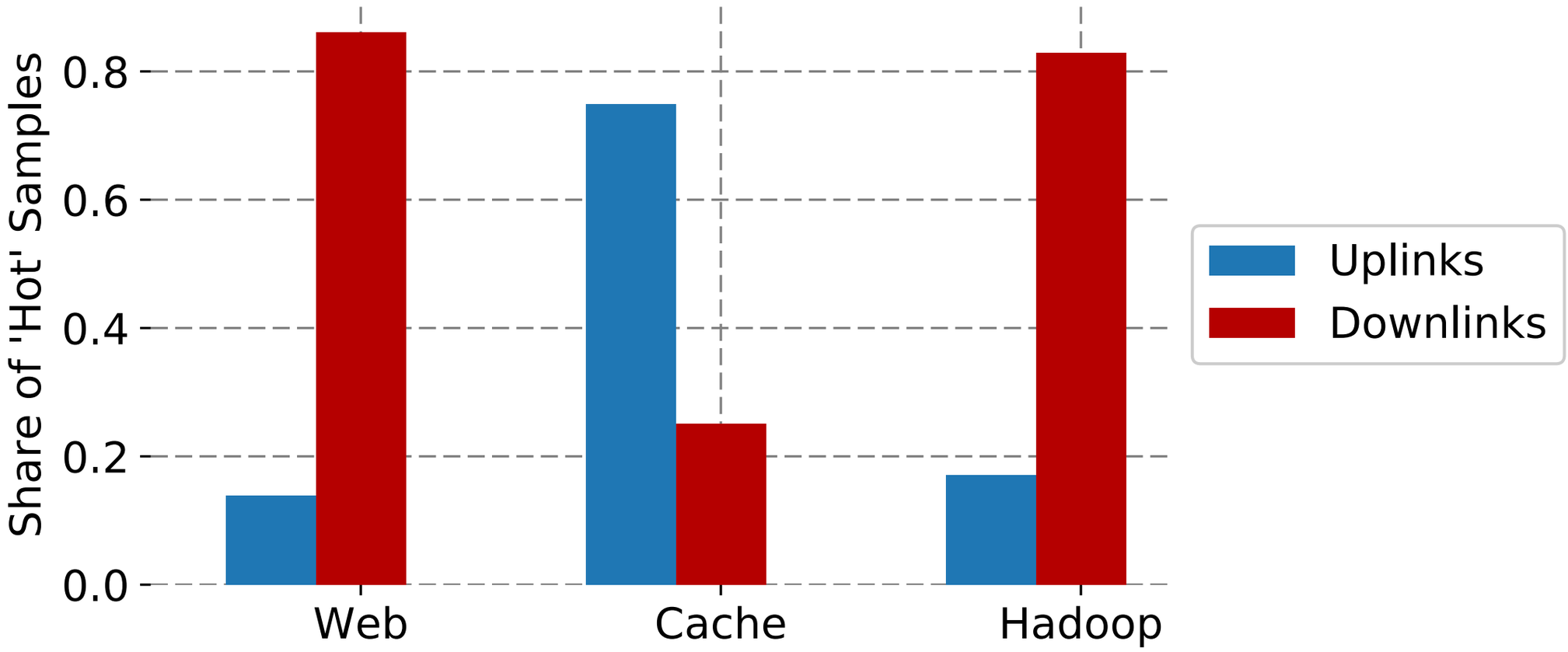
Burst are correlated with app-level behaviors (e.g. sending bigger responses or scatter-gather/incast)



Outside Burst

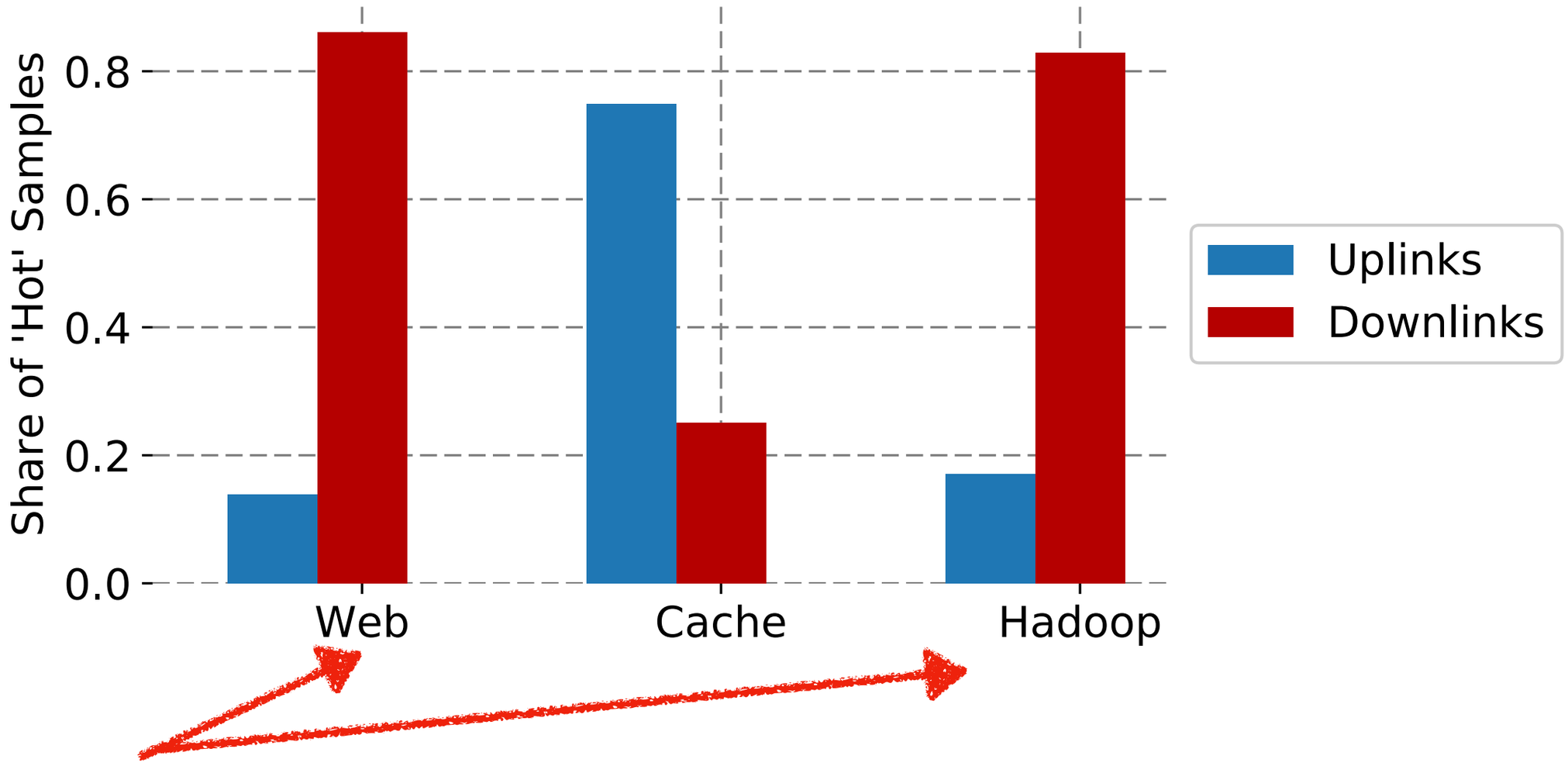
100 µs

Directionality of Bursts



300 µs

Directionality of Bursts



More bursts towards servers due to high fan-in

300 µs

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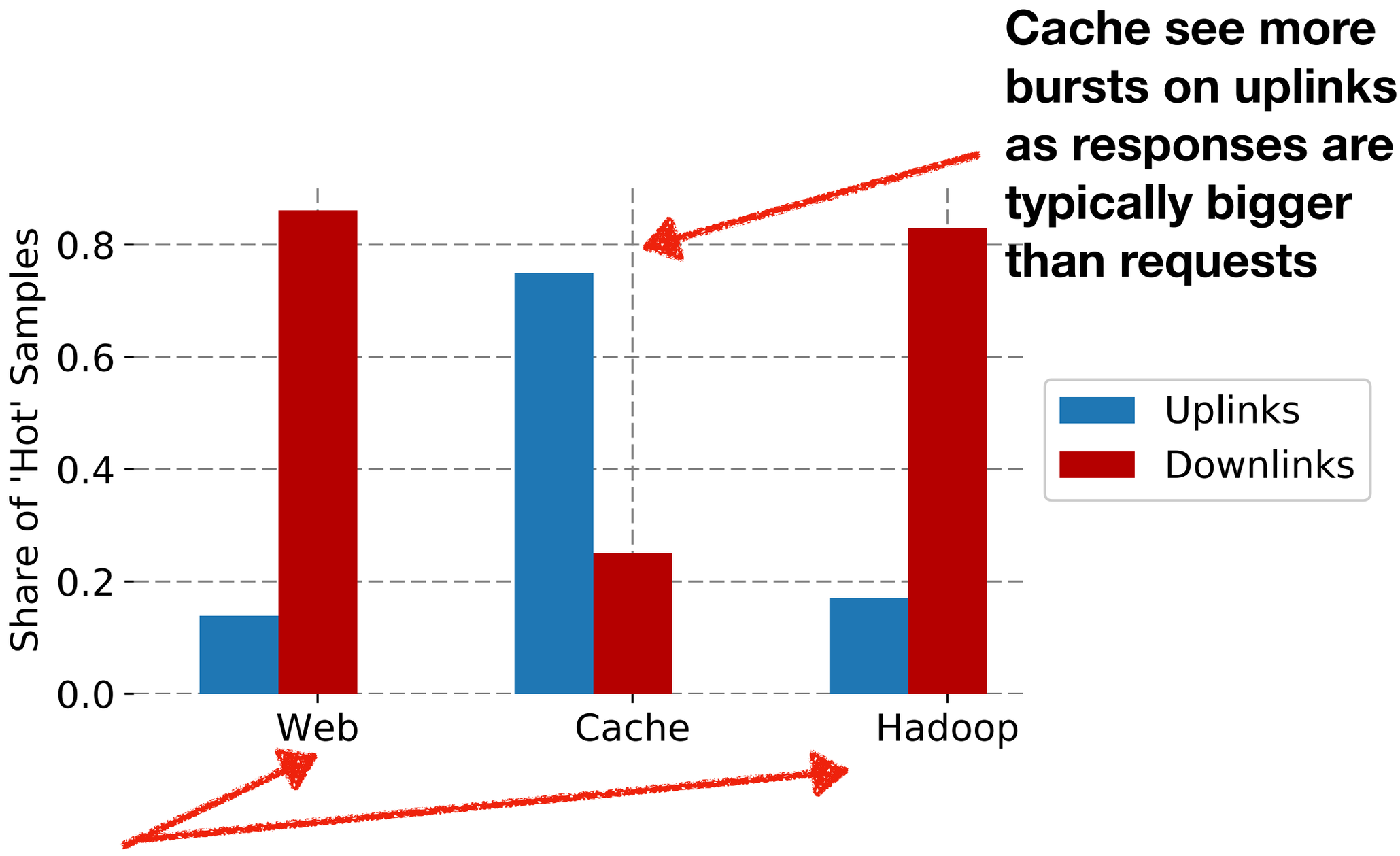

Cache see more bursts on uplinks as responses are typically bigger than requests

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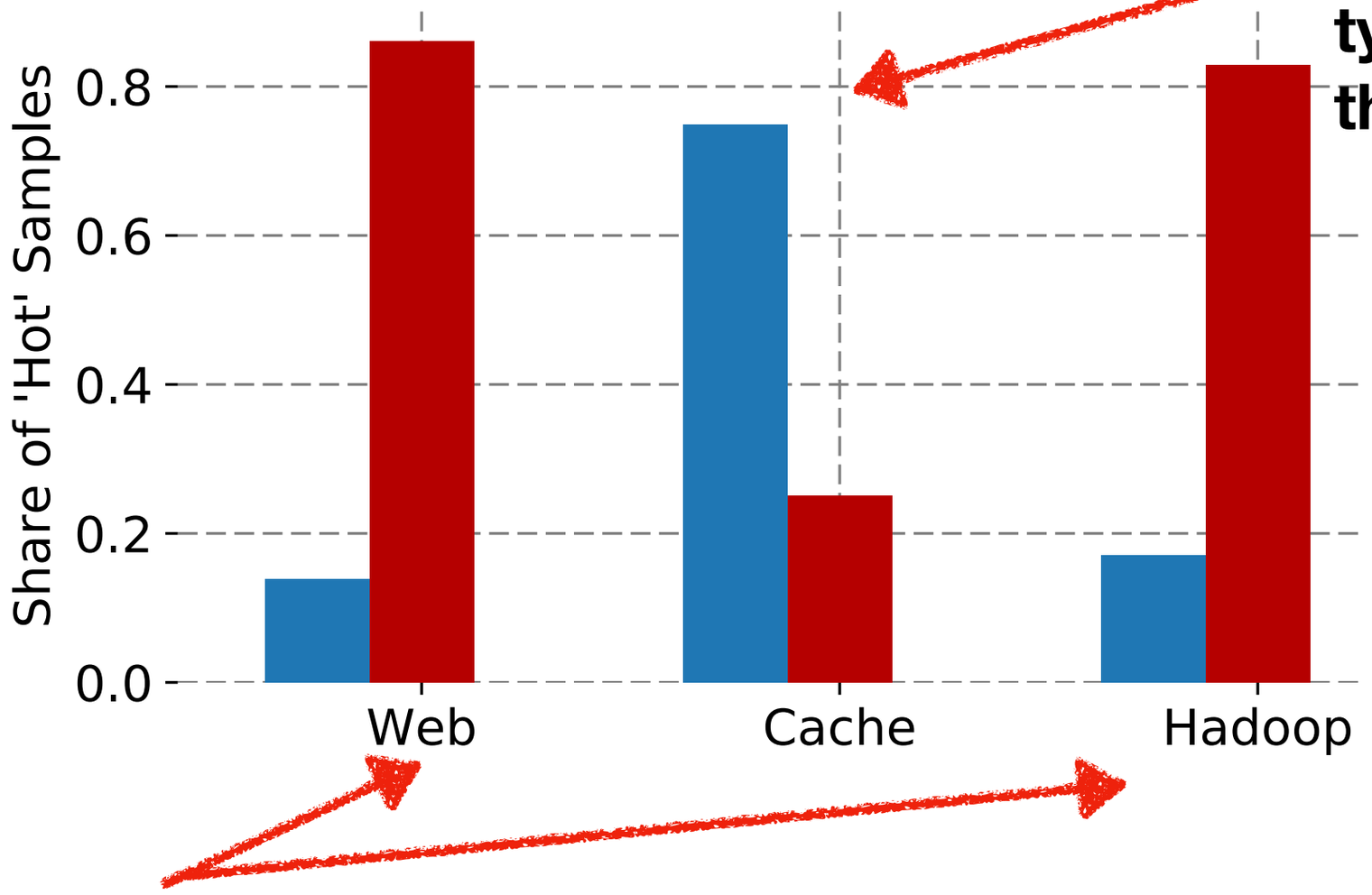

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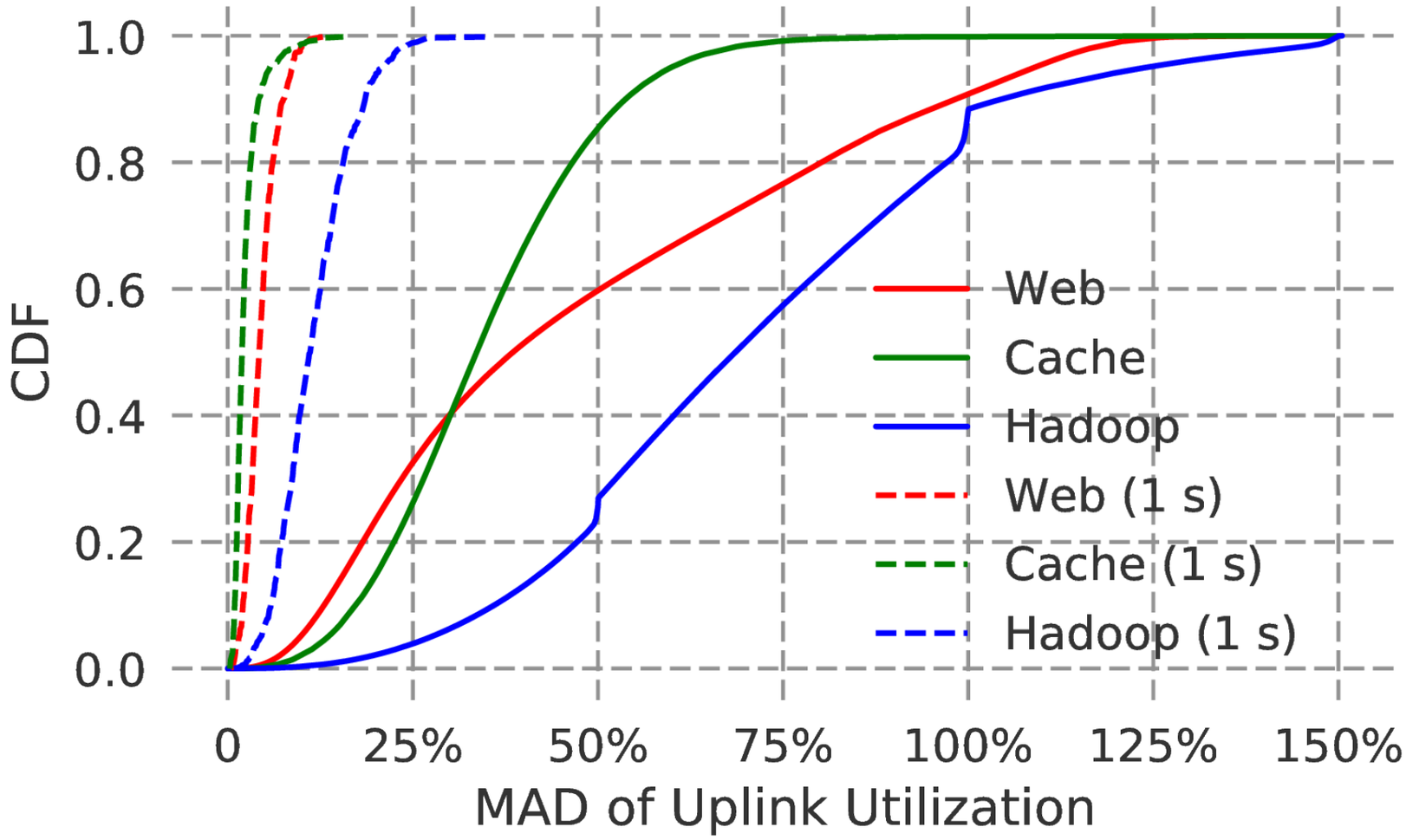
Bursts are correlated with app behaviors

300 µs

Efficacy of Network Load Balancing

- 4 ToR Uplinks: compute mean absolute deviation (MAD) for each polling interval
- MAD = mean(|u - ū| / ū), so MAD=0 means perfect load balancing



40 µs

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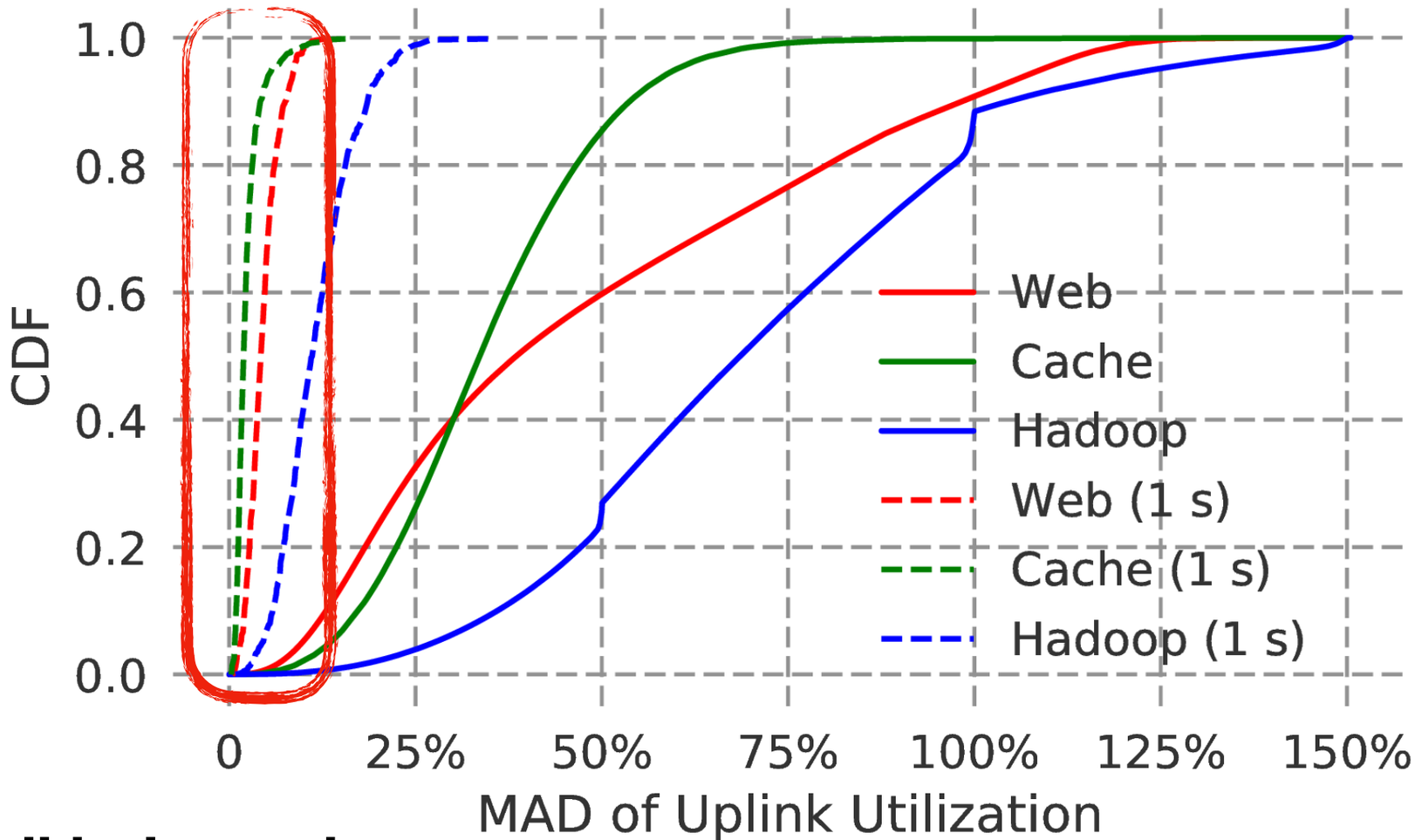

links well balanced at 1s scale

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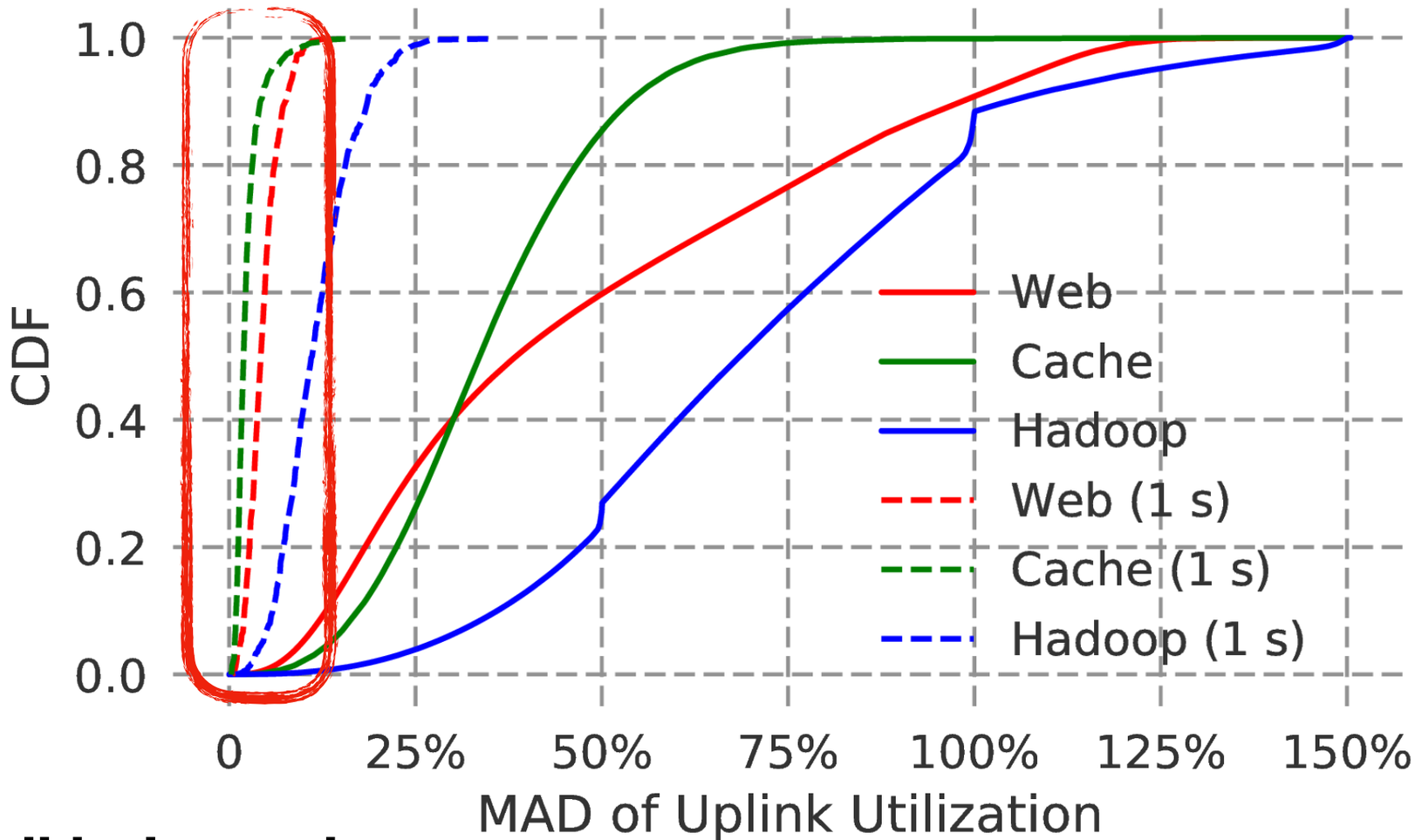

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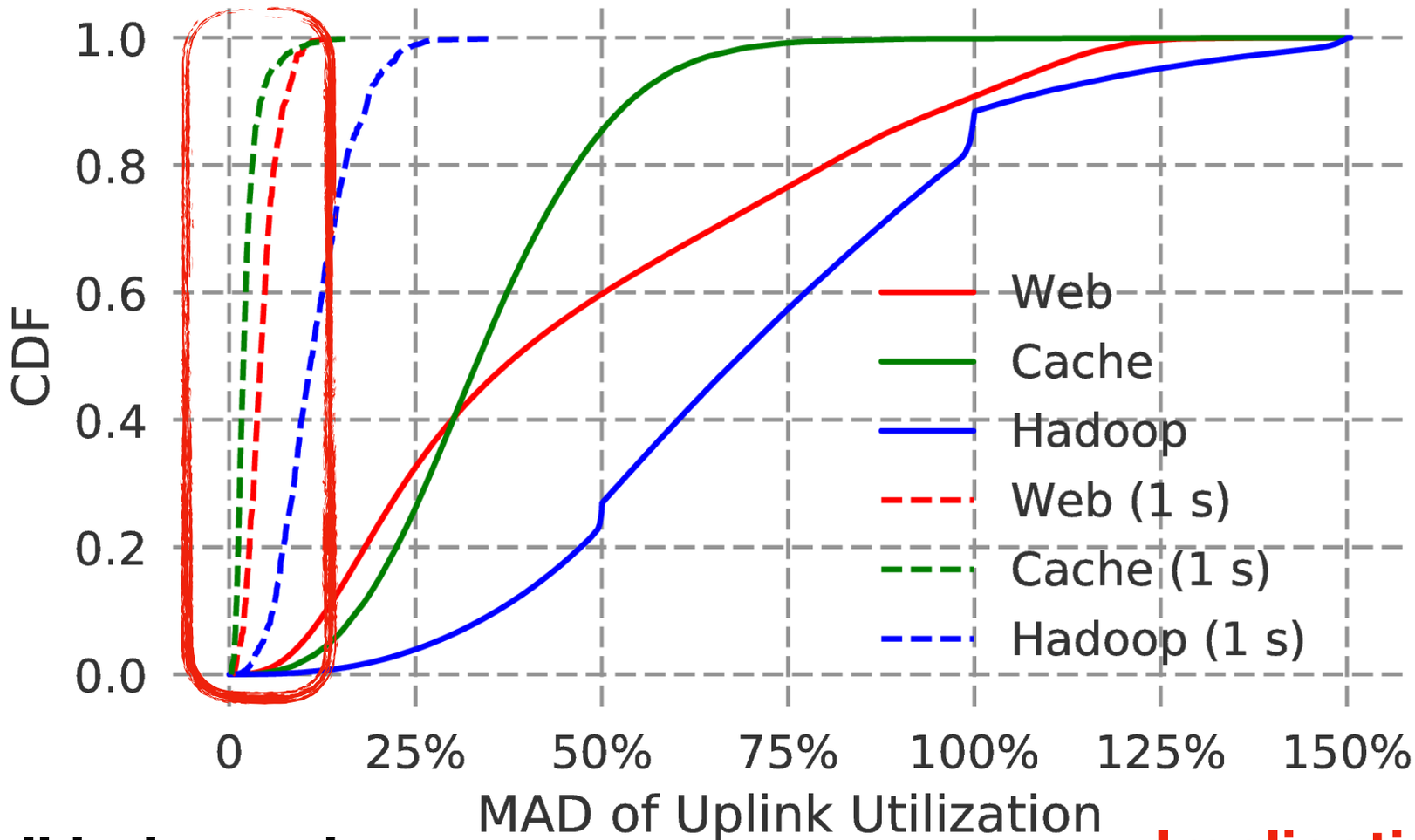

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Implications for design of network, e.g. for low latency and loss

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