DeTail

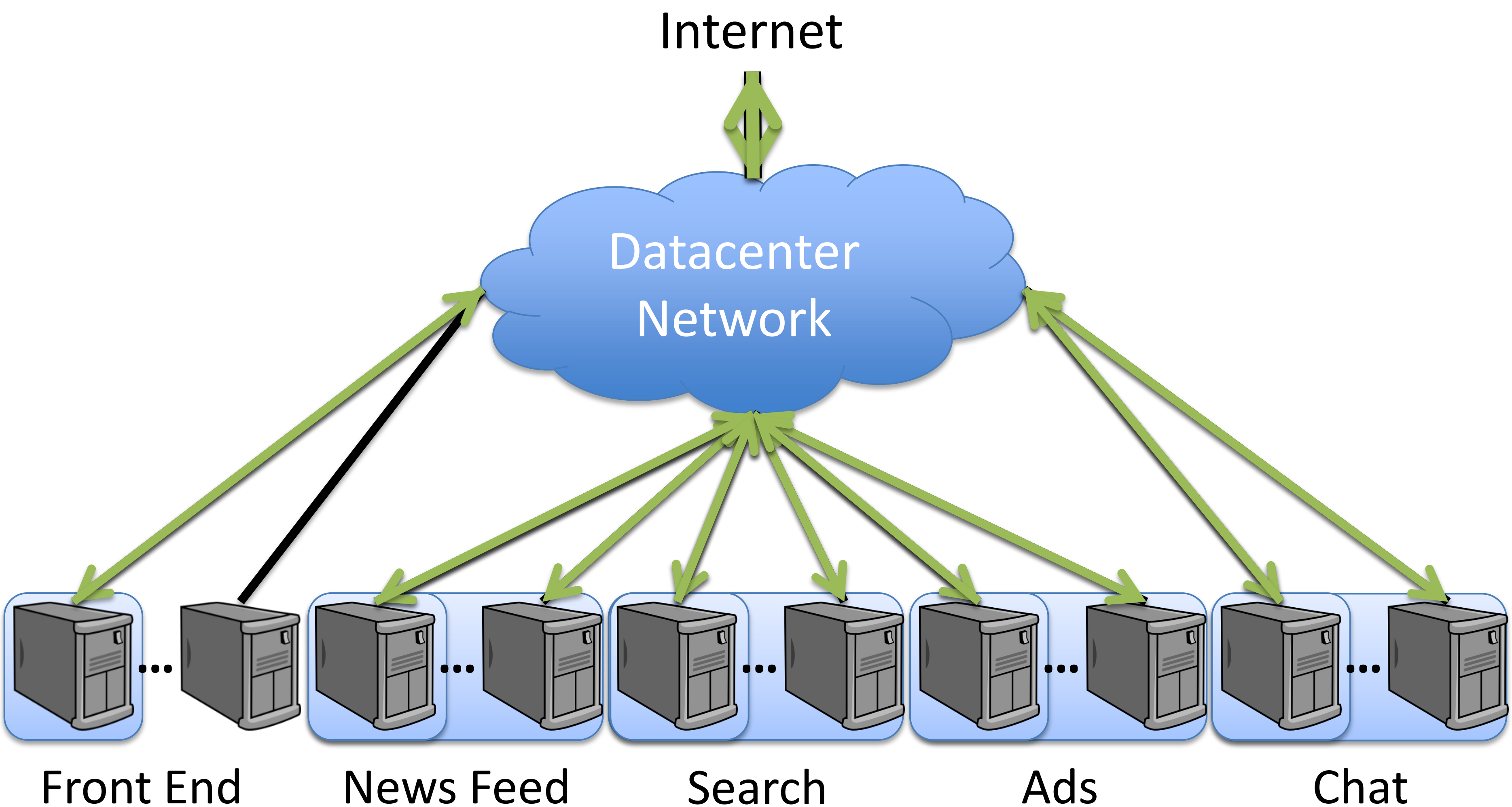
Reducing the Tail of Flow Completion Times in Datacenter Networks

David Zats, Tathagata Das, Prashanth Mohan,
Dhruba Borthakur, Randy Katz

A Typical Facebook Page

Modern pages have many components

Creating a Page



What’s Required?

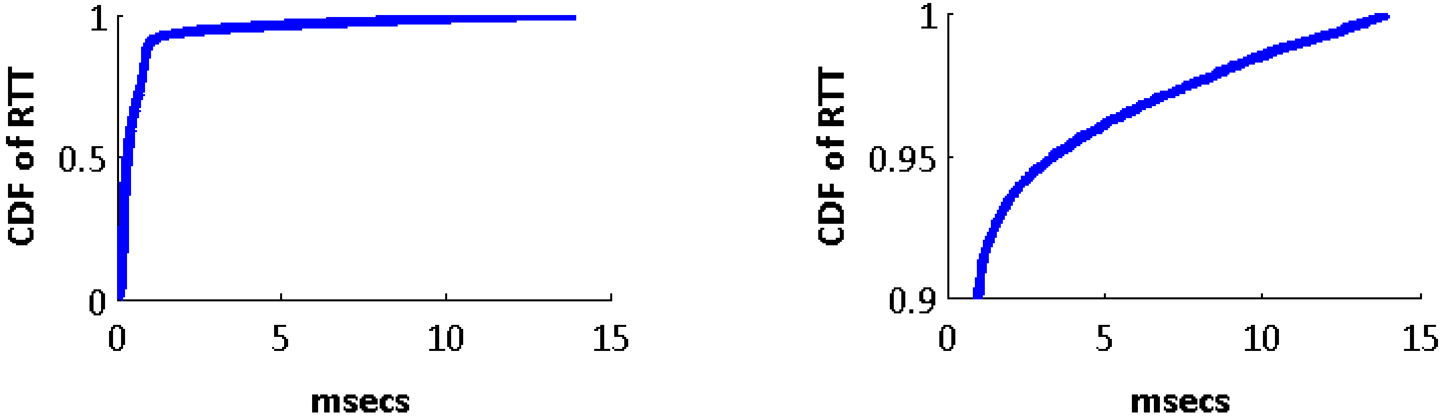
- Servers must perform 100’s of data retrievals*
  - Many of which must be performed serially
- While meeting a deadline of 200-300ms**
  - SLA measured at the 99.9^{th} percentile**
- Only have 2-3ms per data retrieval
  - Including communication and computation

*The Case for RAMClouds [SIGOPS’09]

**Better Never than Late [SIGCOMM’11]

What is the Network's Role?

- Analyzed distribution of RTT measurements:



- Median RTT takes 334μs, but 6% take over 2ms
- Can be as high as 14ms

Network delays alone can consume the data retrieval's time budget

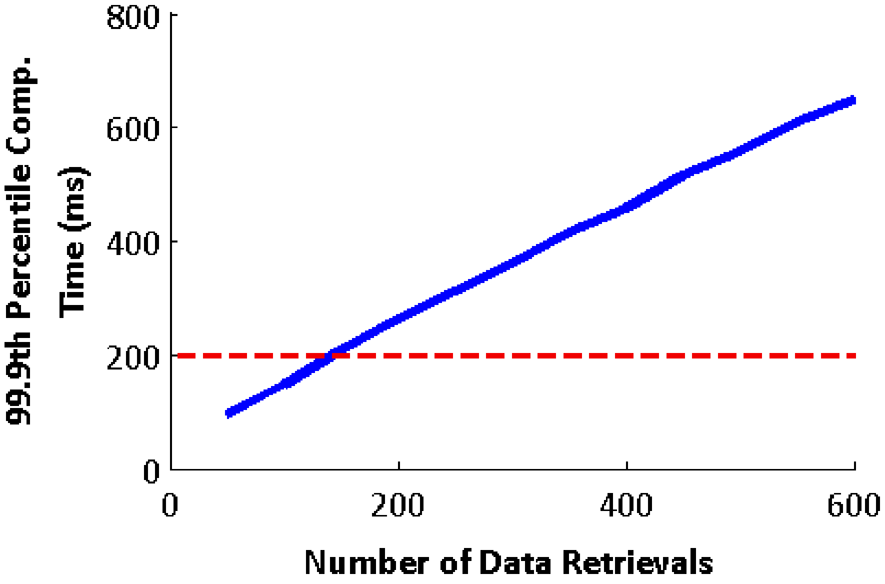
Why the Tail Matters

- Recall: 100's of data retrievals per page creation

- The unlikely event of a data retrieval taking too long is likely to happen on *every* page creation
  - Data retrieval dependencies can magnify impact

Impact on Page Creation

- Under the RTT distribution, 150 data retrievals take 200ms (ignoring computation time)



As Facebook already at 130 data retrievals per page, need to address network delays

App-Level Mitigation

- Use timeouts & retries for critical data retrievals
  - Inefficient because of high network variance
  - Choose from conservative timeouts and long delays or tight timeouts and increased server load
- Hide the problem from the user
  - By caching and serving stale data
  - Rendering pages incrementally
  - User often notices, becomes annoyed / frustrated

Need to focus on the root cause

Outline

- Causes of long data retrieval times
- Cutting the tail with DeTail
- Evaluation

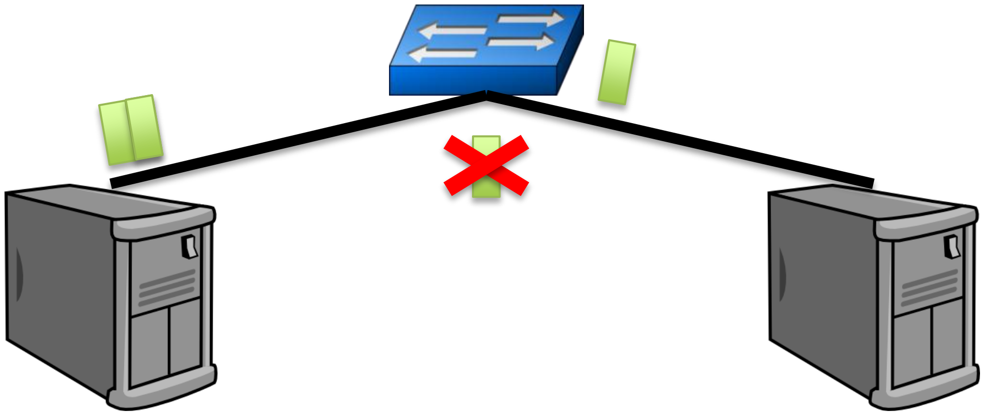
Causes of Long Data Retrieval Times

- Data retrievals are short, highly variable flows
  - Typically under 20KB in size, with many under 2KB*

- Short flows provide insufficient information for transport to agilely respond to packet drops
- Variable flow sizes decrease efficacy of network-layer load balancers

*Data Center TCP (DCTCP) [SIGCOMM'10]

Transport Layer Response



Timeout

Transport does not have sufficient information to respond agilely

Network Layer Load Balancers

- Expected to support single-path assumption
- Common approach: hash flows to paths
  - Does not consider flow size or sending rate
- Results in uneven load spreading
  - Leads hotspots and increased queuing delays

The single-path assumption restricts the ability to agilely balance load

Recent Proposals

- Reduce packet drops
  - By cross-flow learning [DCTCP] or explicit flow scheduling [D^3]
  - Maintain the single-path assumption
- Adaptively move traffic
  - By creating subflows [MPTCP] or periodically remapping flows [Hedera]
  - Not sufficiently agile to support short flows

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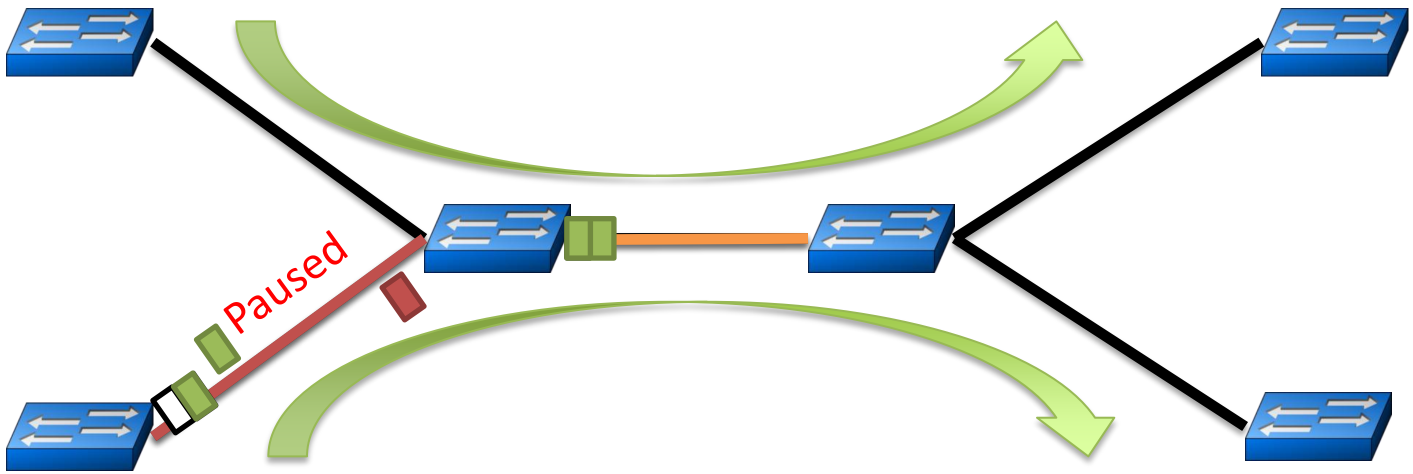
DeTail Stack

- Use in-network mechanisms to maximize agility
- Remove restrictions that hinder performance

- Well-suited for datacenters
  - Single administrative domain
  - Reduced backward compatibility requirements

Hop-by-hop Push-back

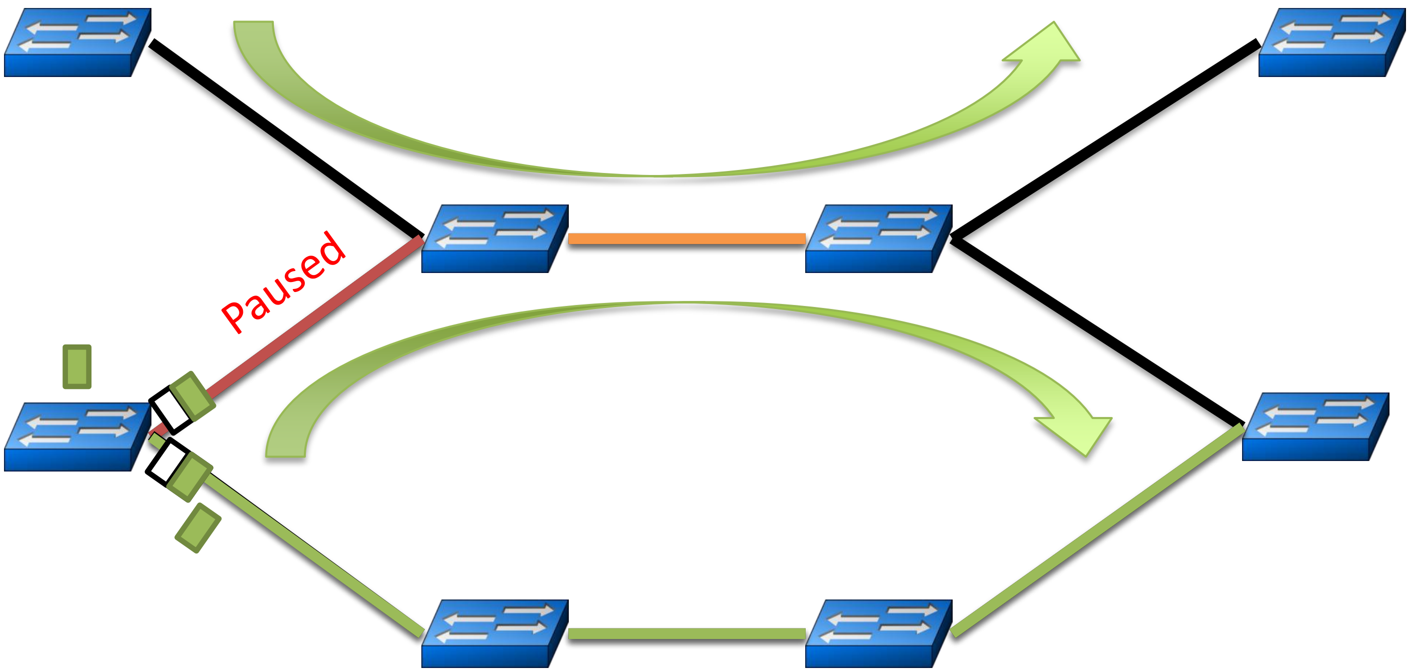
- Agile link-layer response to prevent packet drops



What about head-of-line blocking?

Adaptive Load Balancing

- Agile network-layer approach for balancing load



Synergistic relationship: local output queues indicate downstream congestion because of push-back

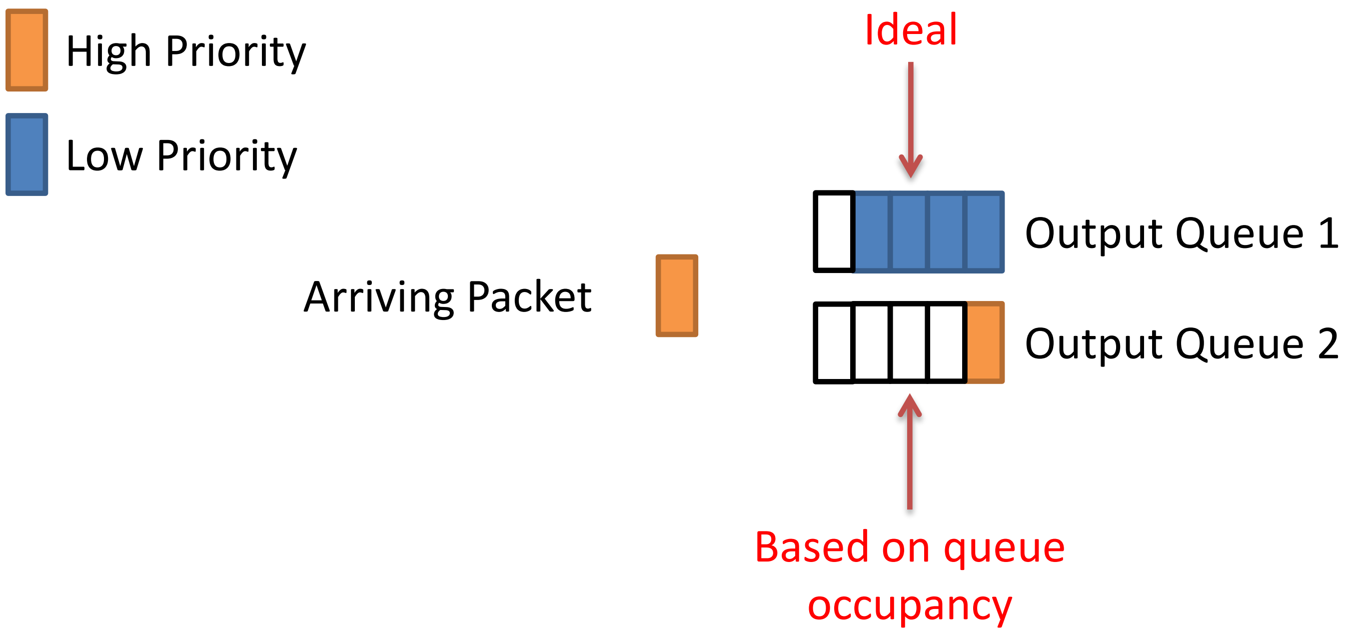
Load Balancing Efficiently

- DC flows have varying timeliness requirements*
  - How to efficiently consider packet priority?

- Compare queue occupancies for every decision
  - How to efficiently compare many of them?

*Data Center TCP (DCTCP) [SIGCOMM'10]

Priority in Load Balancing



How to enqueue packet so it is sent soonest?

Priority in Load Balancing

- Approach: track how many bytes to be sent before new packet
- Use per-priority counters
  - Update on each packet enqueue/dequeue
  - Compare counters to find least occupied port

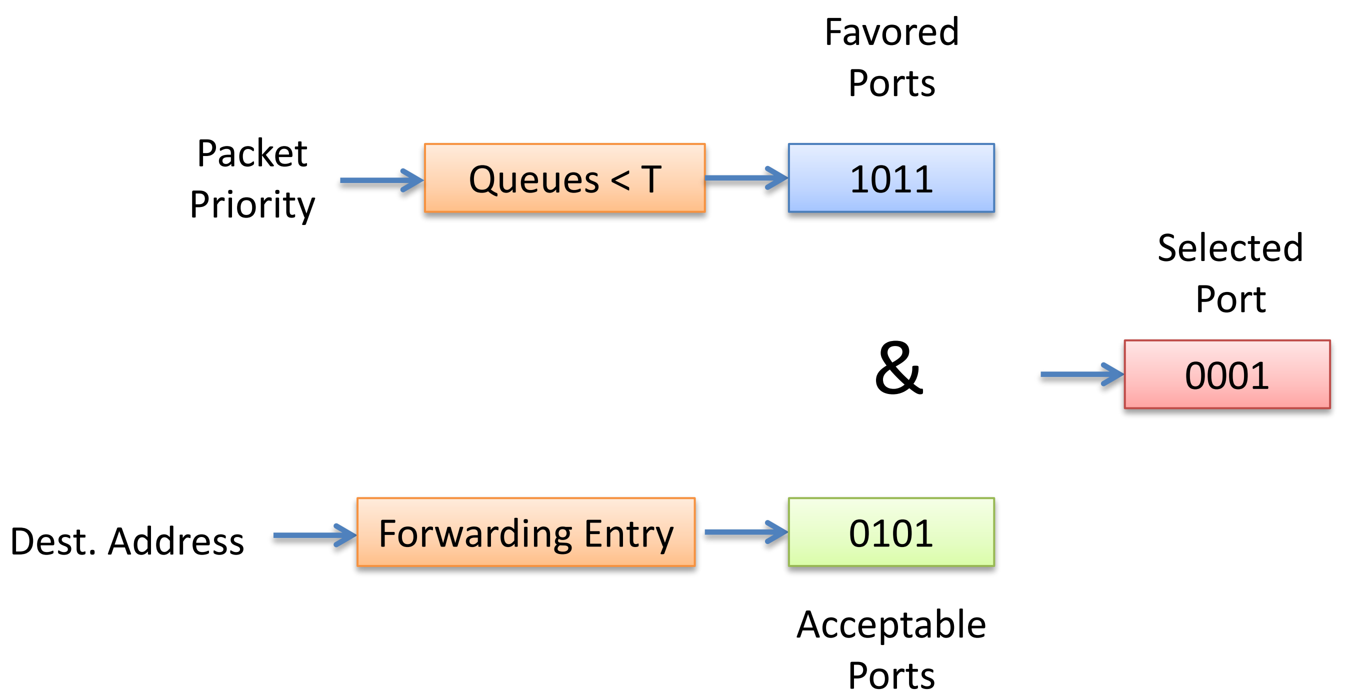
Comparing Queue Occupancies

- Many counter comparisons required for every forwarding decision

- Want to efficiently pick the least occupied port
  - Pre-computation is hard as solution is destination, time dependent

Use Per-Counter Thresholding

- Pick a good port, instead of the best one



Reorder-Resistant Transport

- Handle packet reordering due to load balancing
  - Disable TCP's fast recovery and fast retransmission
- Respond to congestion (no more packet drops)
  - Monitor output queues and use ECN to throttle flows

DeTail Stack

Layer	Component	Function
Application		
Transport	Reorder-Resistant Transport	Support lower layers
Network	Adaptive Load Balancing	Evenly balance load
Link	Hop-by-hop Push-back	Prevent packet drops
Physical		

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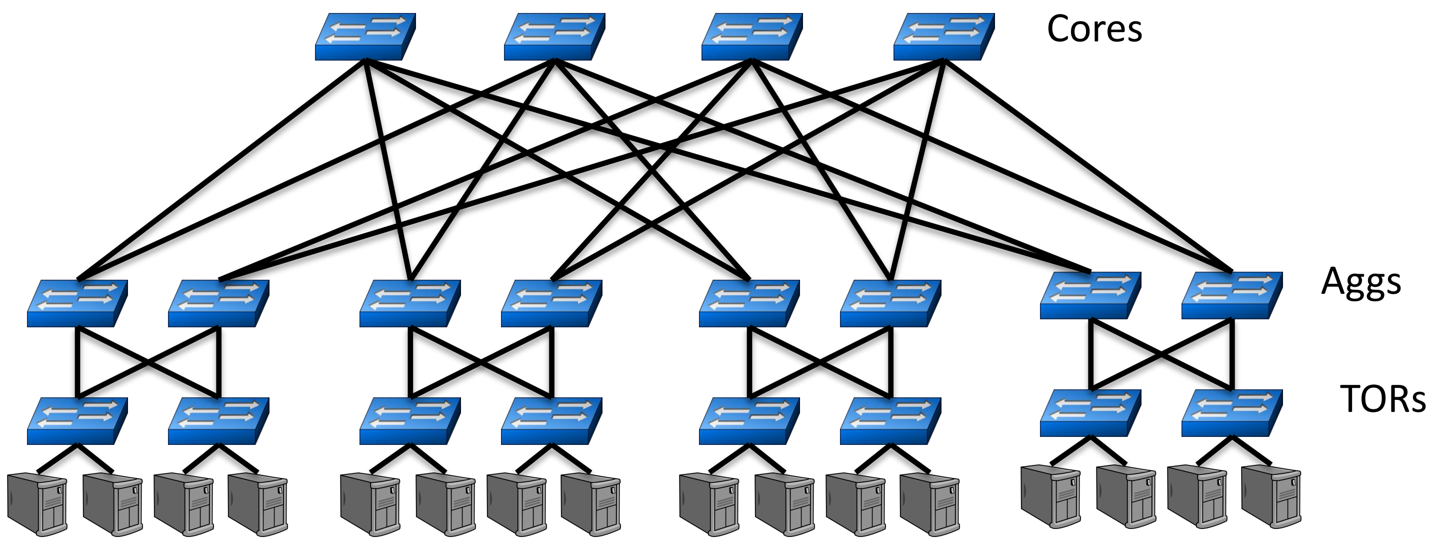
Simulation and Implementation

- NS-3 simulation

- Click implementation
  - Drivers and NICs buffer hundreds of packets
  - Must rate-limit Click to underflow buffers

Topology

- FatTree: 128-server (NS-3) / 16-server (Click)
- Oversubscription factor of 4x



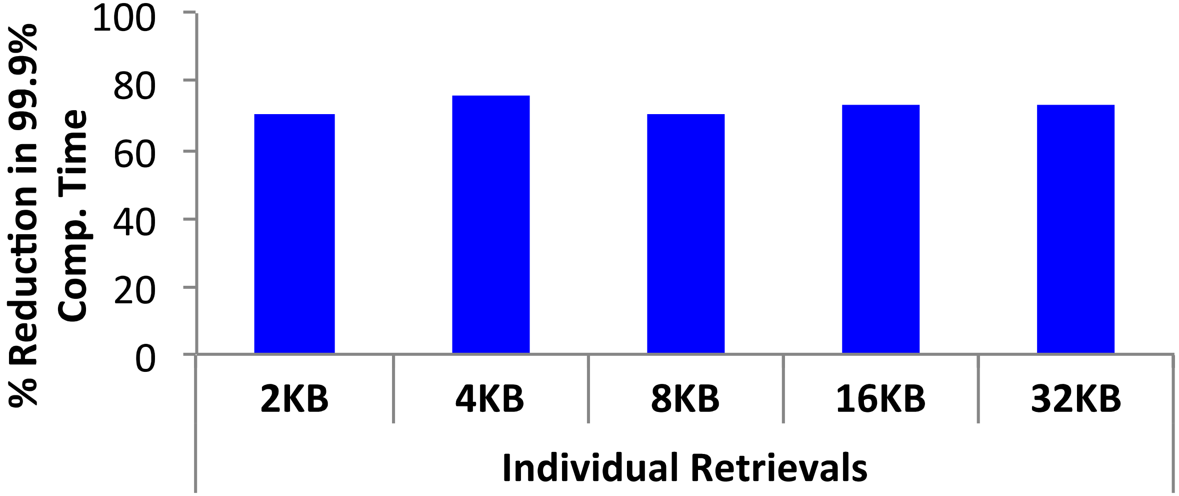
Reproduced From: A Scalable Commodity Datacenter Network Architecture [SIGCOMM'08]

Setup

- Baseline
  - TCP NewReno
  - Flow hashing based on IP headers
  - Prioritization of data retrievals vs. background
- Metric
  - Reduction in 99.9th percentile completion time

Page Creation Workload

- Retrieval size: 2, 4, 8, 16, 32 KB*
- Background traffic: 1MB flows



DeTail reduces 99.9th percentile page creation time by over 50%

*Covers range of query traffic sizes reported by DCTCP

Is the Whole Stack Necessary?

- Evaluated push-back w/o adaptive load balancing
  - Performs worse than baseline

DeTail's mechanisms work together, overcoming their individual limitations

What About Link Failures?

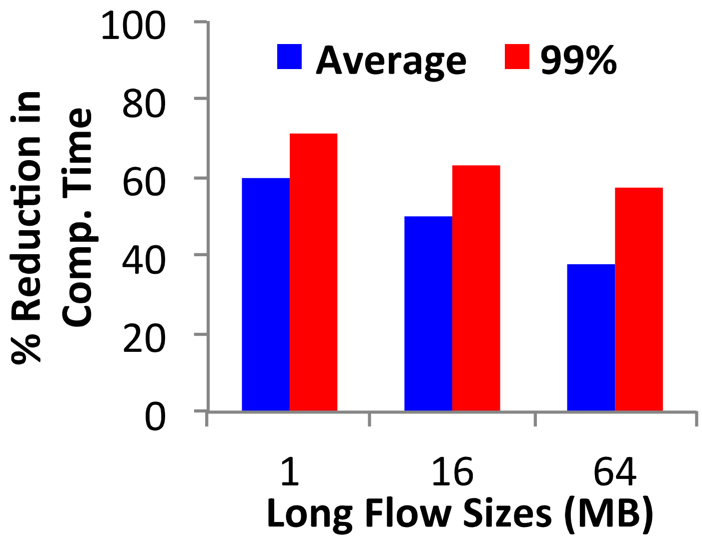
- 10s of link failures occur per day*
  - Creates permanent network imbalance
- Example
  - Core-AGG link degrades from 1Gbps to 100Mbps
  - DeTail achieves 91% reduction in the 99.9th percentile

DeTail effectively moves traffic away from failures, appropriately balancing load

*Understanding Network Failures in Data Centers [SIGCOMM'11]

What About Long Background Flows?

- Background Traffic: 1, 16, 64MB flows*
- Light data retrieval traffic



DeTail's adaptive load balancing also helps long flows

*Covers range of update flow sizes reported by DCTCP

Conclusion

- Long tail harms page creation
  - The extreme case becomes the common case
  - Limits number of data retrievals per page

- The DeTail stack improves long tail performance
  - Can reduce the 99.9^{th} percentile by more than 50%