Backdraft: a Lossless Virtual Switch that Prevents the Slow Receiver Problem

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Brent E. Stephens

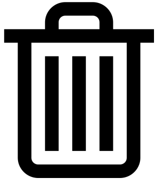
The University of Utah

Packet loss is a problem

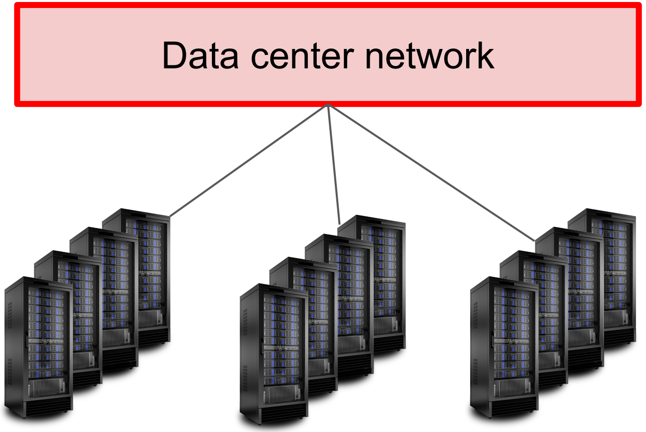
Packet loss impacts tail latency!

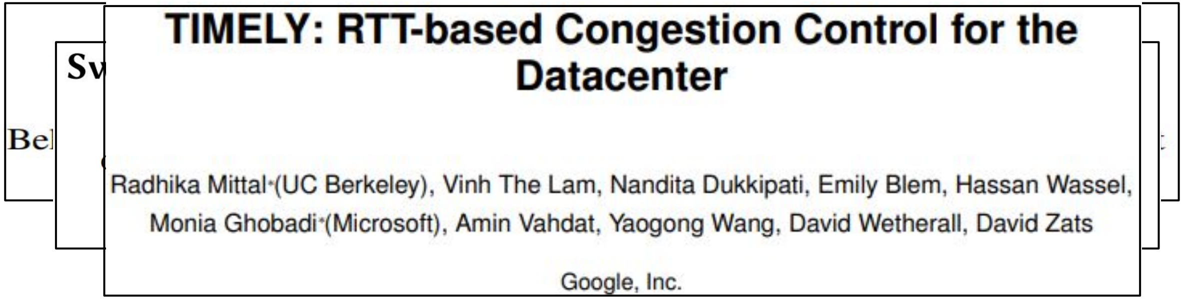
Packet loss degrades throughput!

Packet loss wastes compute!



Packet loss can occur in the network

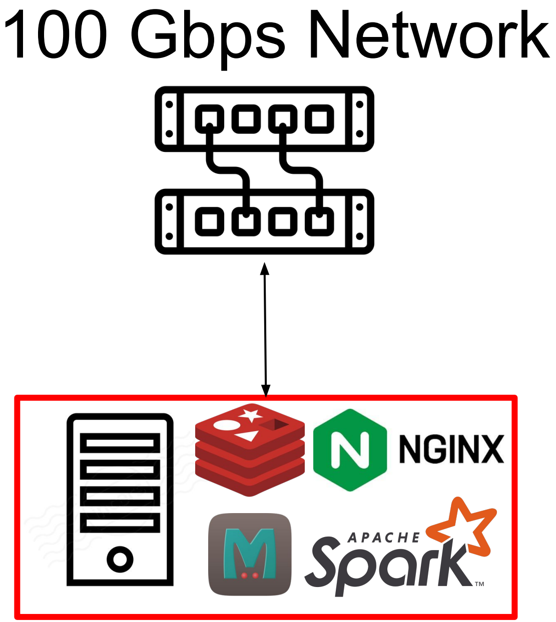



TIMELY: RTT-based Congestion Control for the Datacenter

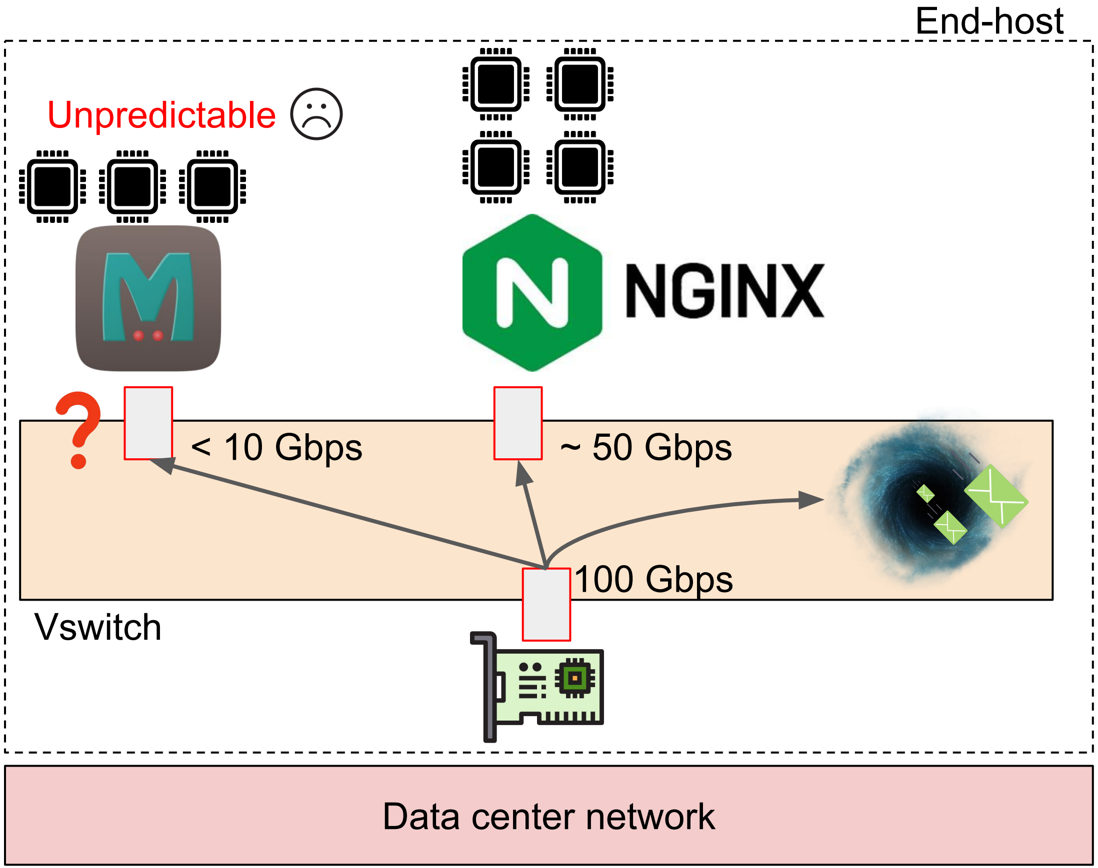
Radhika Mittal*(UC Berkeley), Vinh The Lam, Nandita Dukkipati, Emily Blem, Hassan Wassel,
Monia Ghobadi*(Microsoft), Amin Vahdat, Yaogong Wang, David Wetherall, David Zats

Google, Inc.

Packet loss can ALSO occur at the end-hosts



Vagaries of CPU performance



The slow receiver problem

Slow receivers are applications unable to keep up with the offered load

RDMA over Commodity Ethernet at Scale

Understanding Host Network Stack Overheads

Qizhe Cai
Cornell University

Shubham Chaudhary
Cornell University

Midhul Vuppalapati
Cornell University

Jaehyun Hwang
Cornell University

Rachit Agarwal
Cornell University

Sw … in the Datacenter

Gautam Kumar, Nandita Dukkipati, Keon Jang (MPI-SWS)*, Hassan M. G. Wassel, Xian Wu, Behnam Montazeri,
Yaogong Wang, Kevin Springborn, Christopher Alfeld, Michael Ryan, David Wetherall, and Amin Vahdat
Google LLC

Backdraft is a lossless virtual switch that solves the slow receiver problem

Lossless virtual switching is challenging

Head-of-line Blocking

Congestion Spreading

Wasted Compute

Backdraft: A 10,000 Ft. View

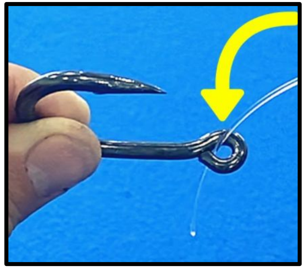
Backdraft provides per flow queuing in the virtual switches

Backdraft implements **Backpressure** all the way to the application

Backdraft allows for **higher throughput** and **lower tail latency**

Outline

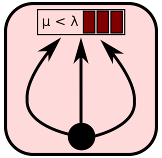
Motivation



Backdraft design

Backdraft evaluation

Insights of Backdraft



Slow receivers are pervasive!

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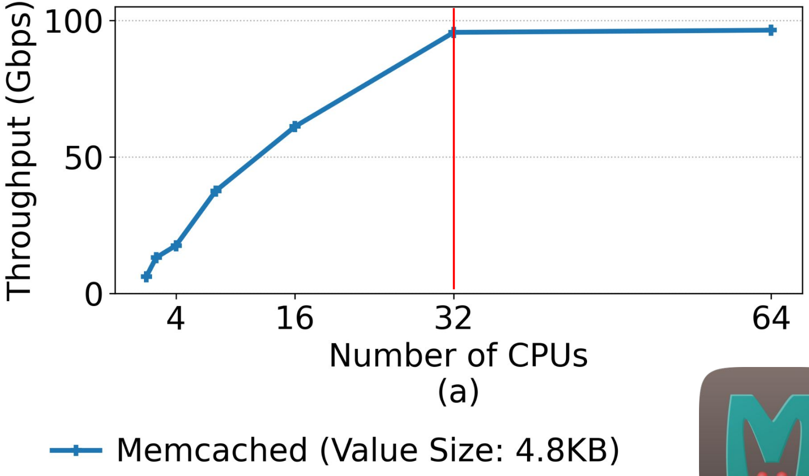
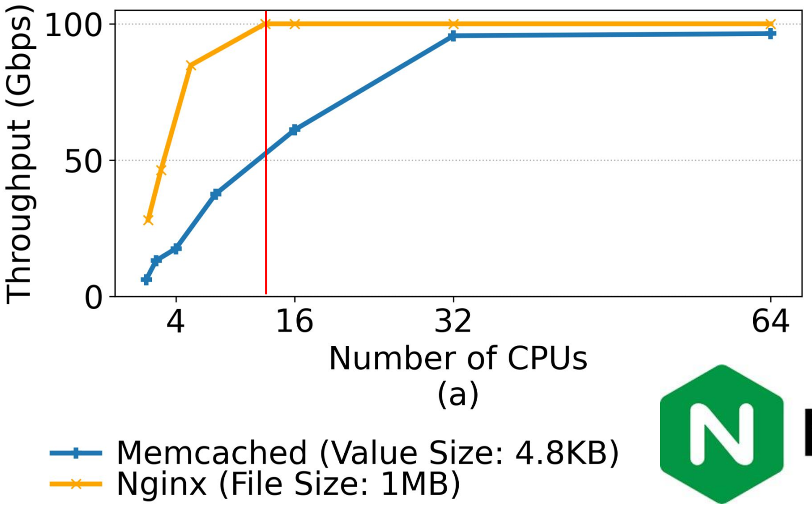


Memcached needs 32 cores to achieve 100 Gbps with large values

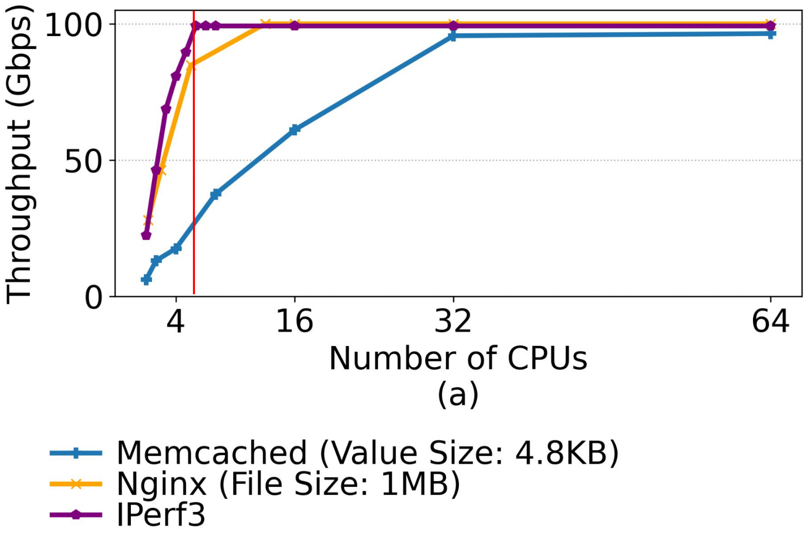
Slow receivers are pervasive



NGINX

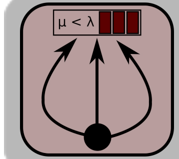
Nginx needs 14 cores to achieve 100 Gbps

Slow receivers are pervasive



IPerf3 only does networking functionality yet needs at least 6 cores to achieve 100 Gbps

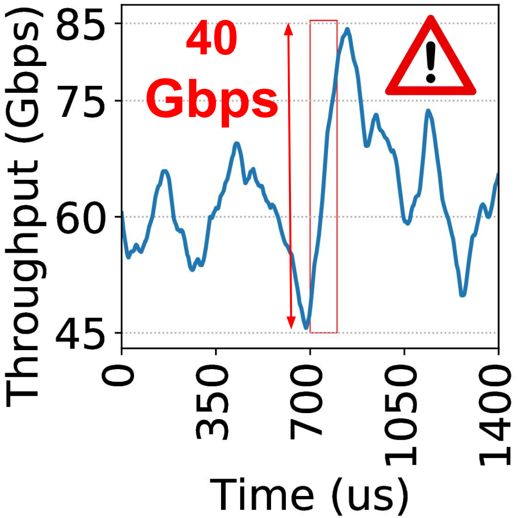
Insights of Backdraft



Slow receivers are pervasive!

The slow receiver problem manifests at μs-scale.

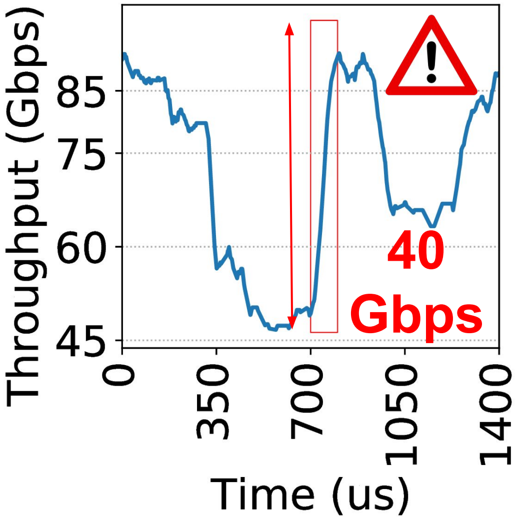
Slow receivers manifest at µs-scale



40 Gbps throughput variation in 100us!

Slow receivers manifest at µs-scale

NGINX



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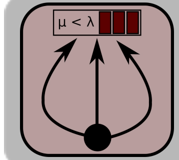
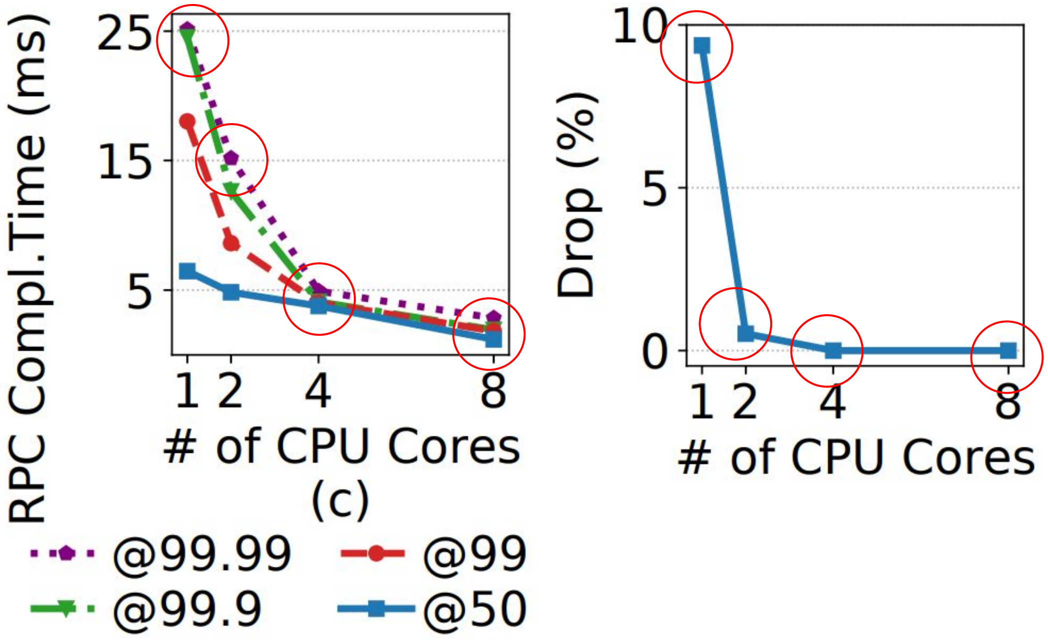


Slow receivers are pervasive!

The slow receiver problem manifests at μs-scale

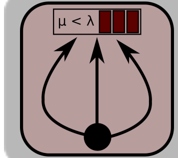
Packet loss occurs in presence of Homa

Homa – RPC completion time & Drop



Homa experiences high RPC completion time *due to the slow receiver problem*

Insights of Backdraft



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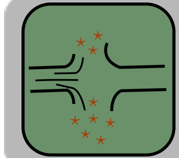


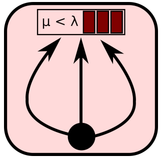
Packet loss occurs in presence of Homa

Standard lossless techniques cannot be used in a virtual context

Standard lossless techniques are not practical in virtual switching realm

Rate limiting	Unknown line rate on CPU	☹	
Backpressure	HOL blocking Congestion Spreading	☹	
Credit-based	Extra RTT	☹	
PicNIC	Wasted CPU	☹	

Insights of Backdraft



Slow receivers are pervasive!

The slow receiver problem manifests at short time scales.

Packet loss occurs in presence of the state-of-the art congestion controls – Homa

Standard lossless techniques cannot be used in a virtual context

Outline

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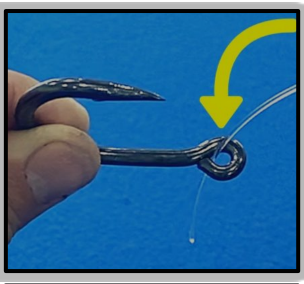
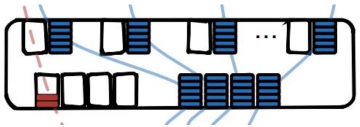


Backdraft design

Backdraft evaluation

Three components of Backdraft

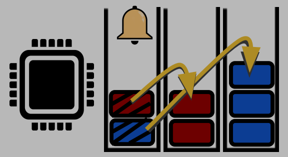
1) Dynamic per flow queueing



Avoids HOL blocking

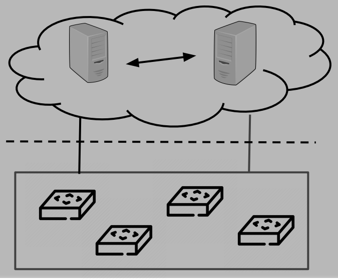
On-demand memory use

2) Doorbell queues



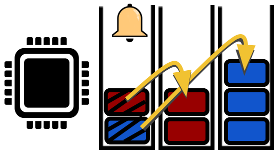
Avoids wasted CPU

3) Backdraft overlay network



Avoids packet loss

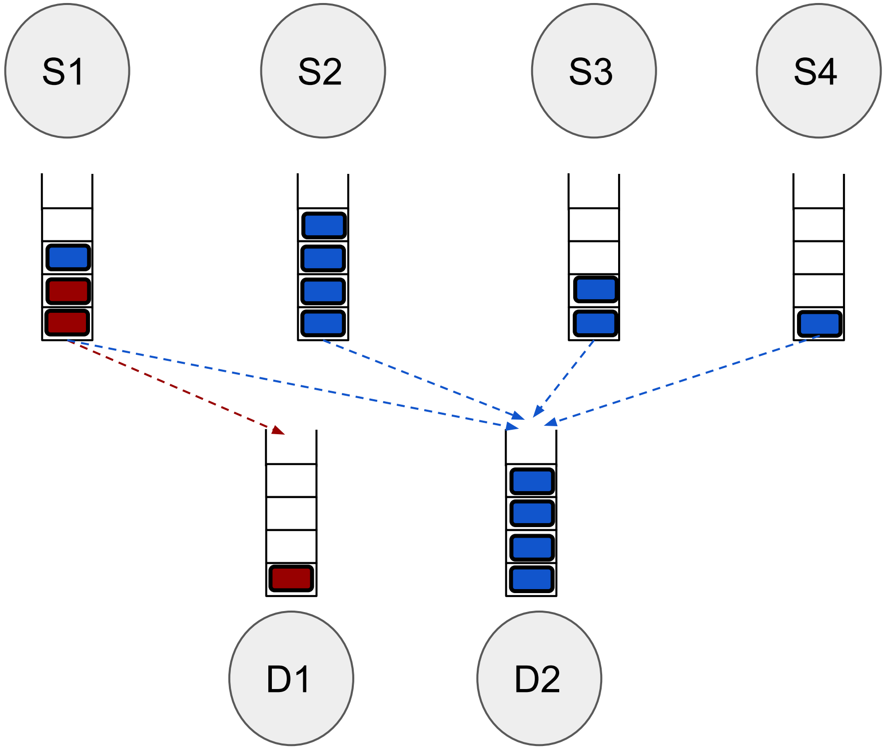
Prevents congestion spreading



Key idea behind the per flow queuing

If each flow has its own separate queue, then each flow can be paused and resumed individually without the HOL blocking problem!

Why do we lose packets?



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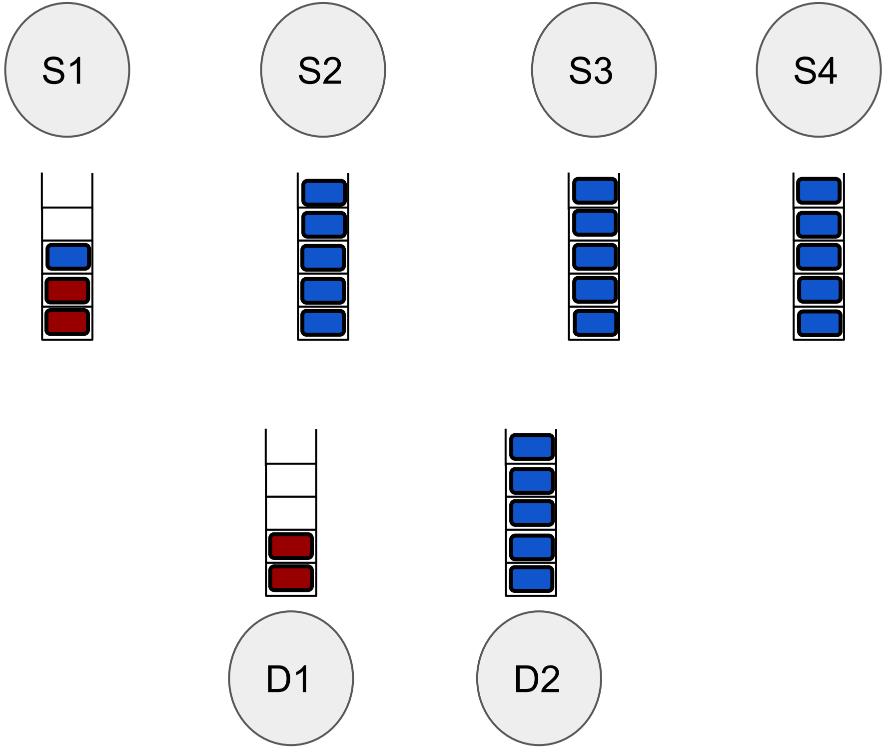

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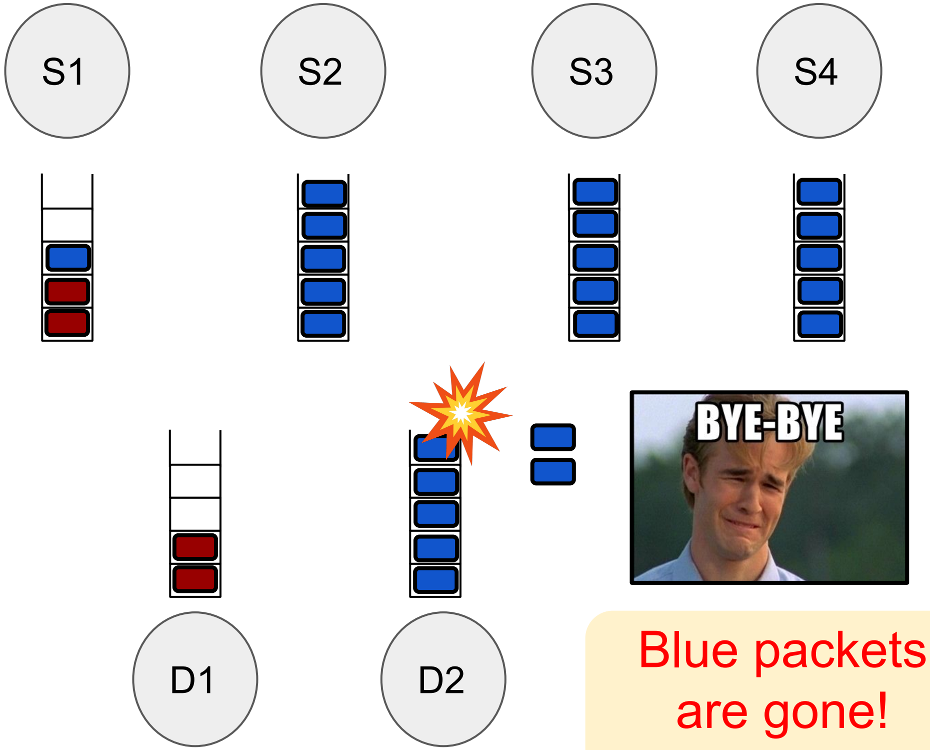
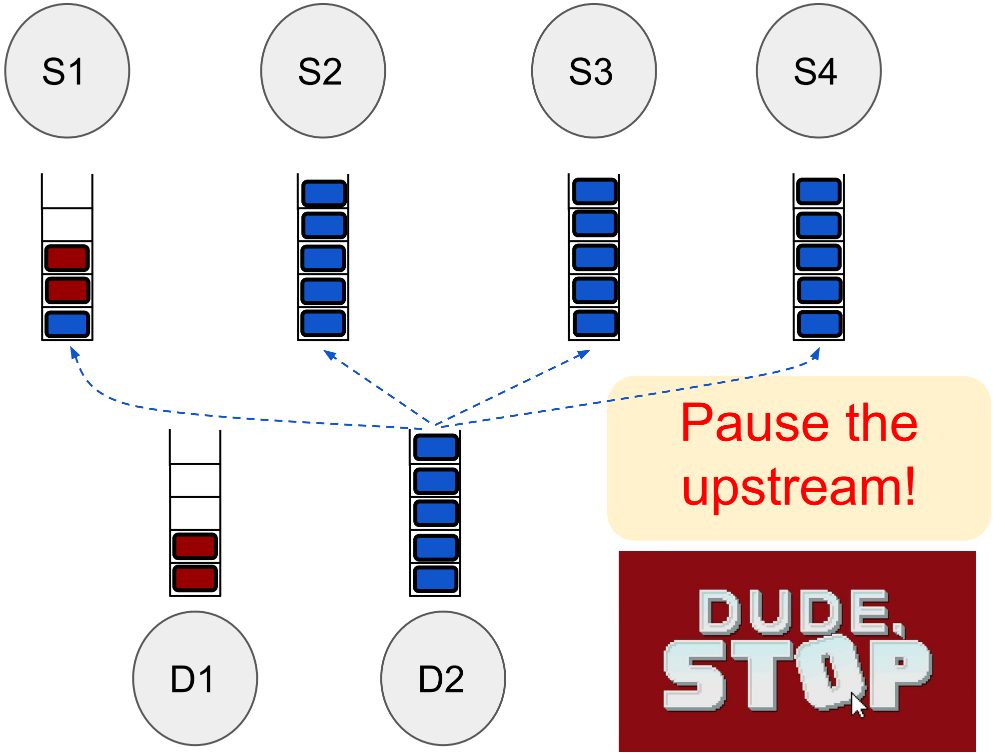
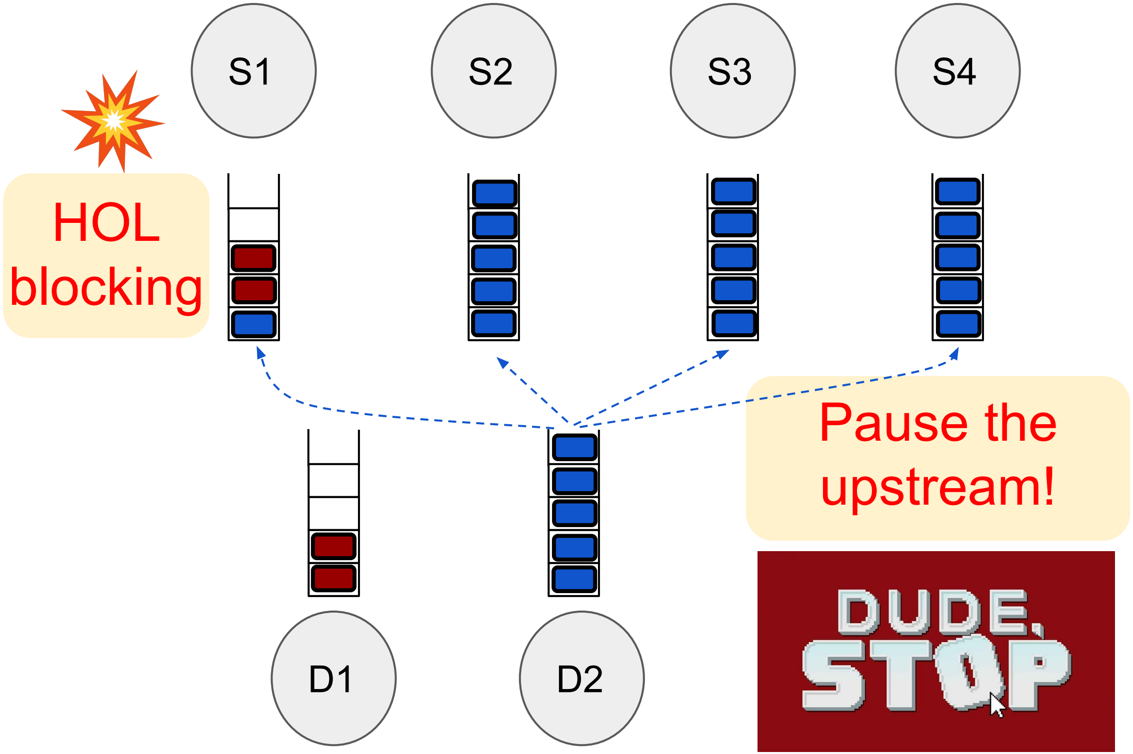


Blue packets are gone!

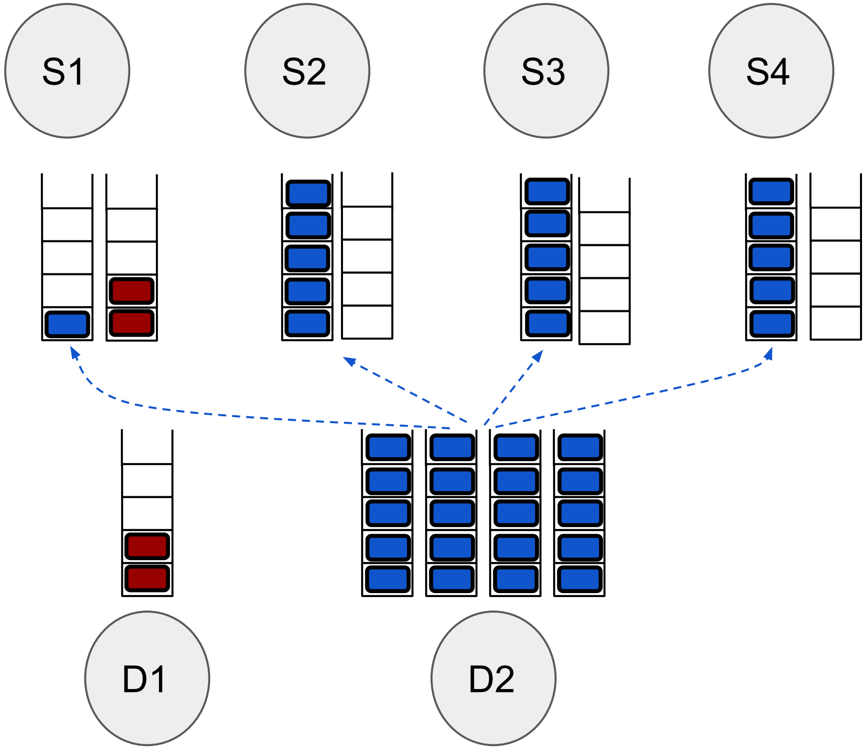
Would pausing the upstream work?



HOL blocking



Per flow queuing to the rescue!



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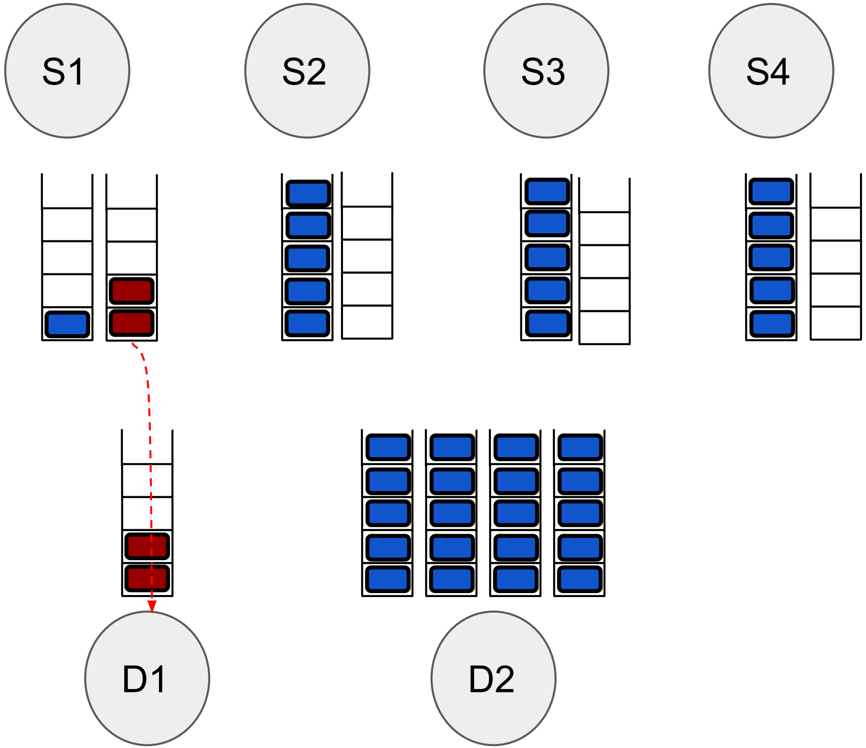

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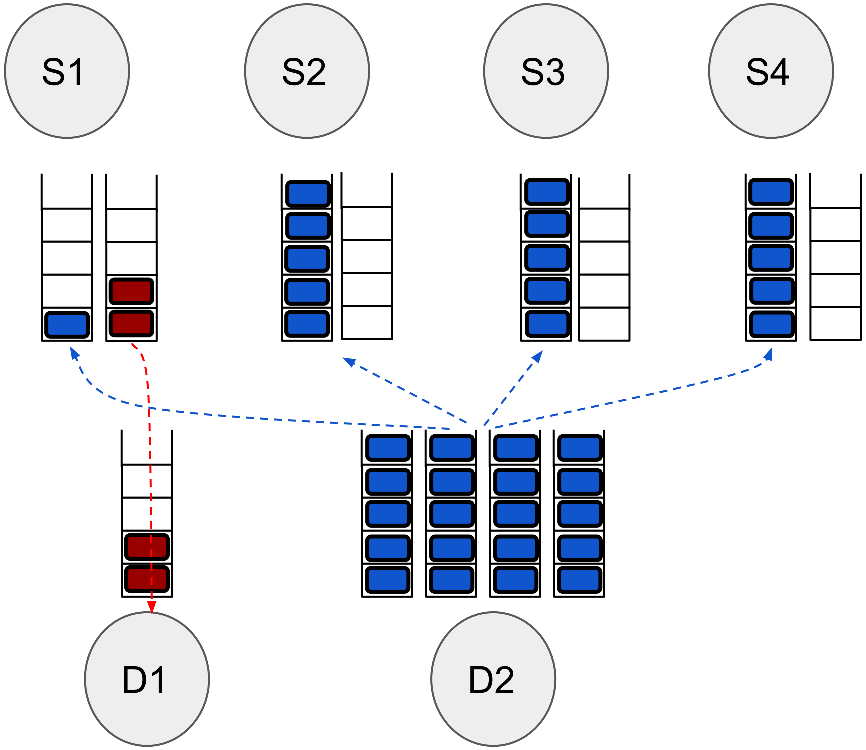


Design space of the Per Flow Queuing

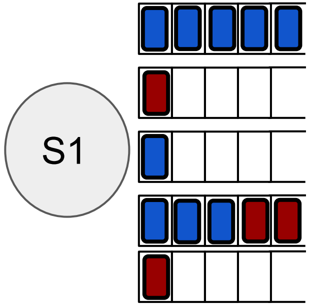
A **large** number **short** queues

Memory is limited

A **small** number **long** queues

High flow isolation

Low burst absorbance



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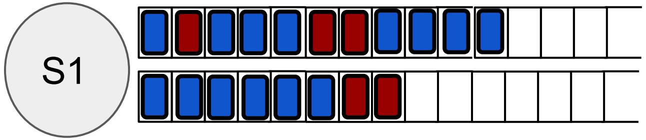

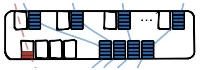

Dynamic Per Flow Queuing

On-demand queue **allocation**

On-demand queue **resizing**

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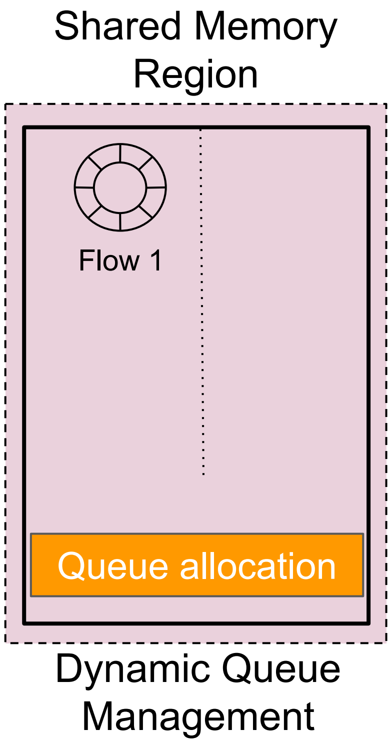

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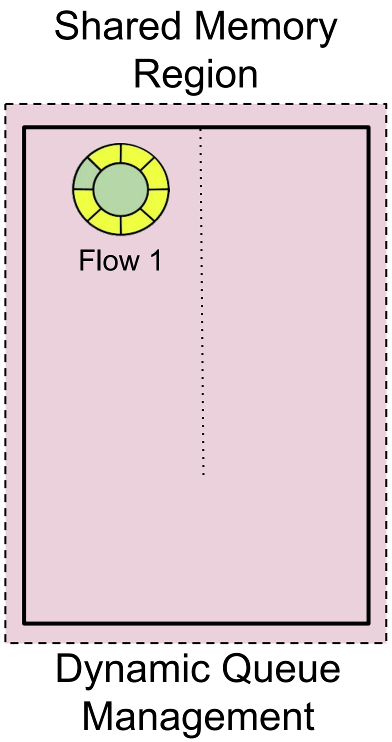

Dynamic Per Flow Queuing

On-demand queue **allocation**

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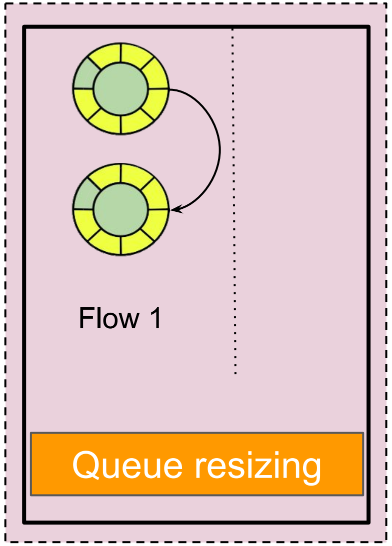
Shared Memory Region

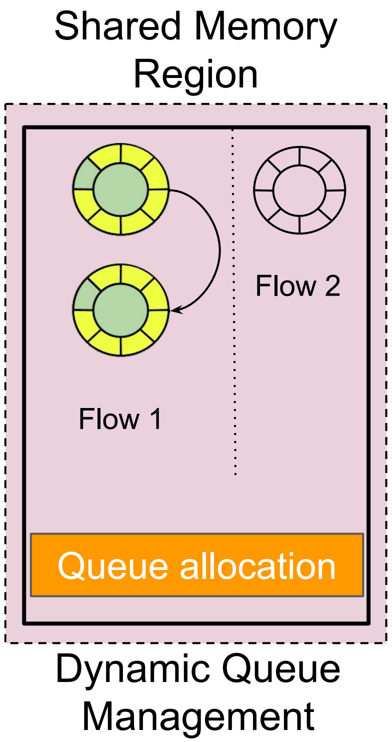


Dynamic Queue Management

Dynamic Per Flow Queuing

On-demand queue **allocation**

On-demand queue **resizing**



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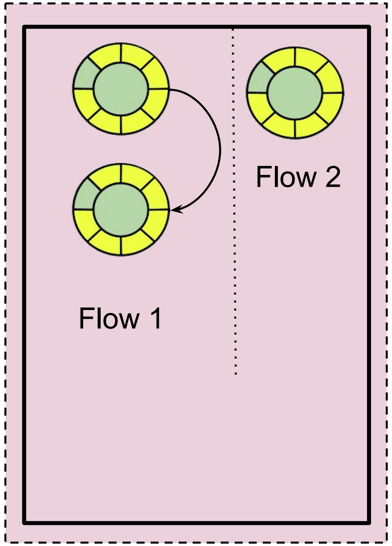

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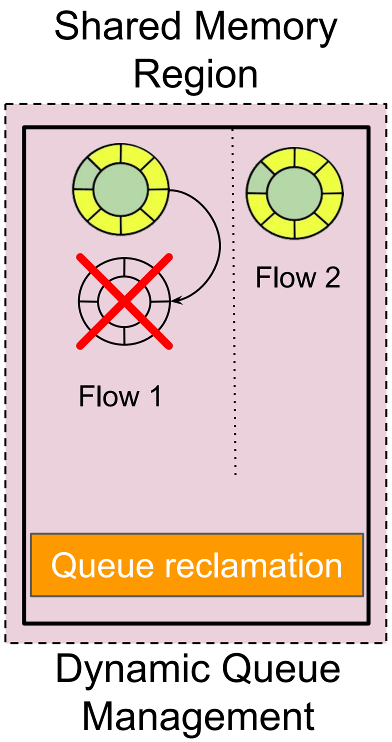
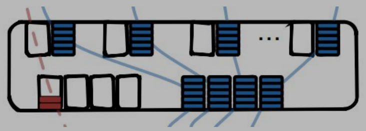


Three components of Backdraft

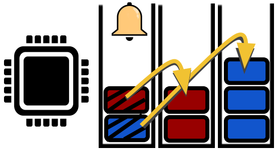
1) Dynamic per flow queueing



Avoids HOL blocking

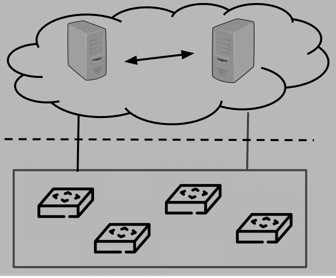
On-demand memory use

2) Doorbell queues



Avoids wasted CPU

3) Backdraft overlay network

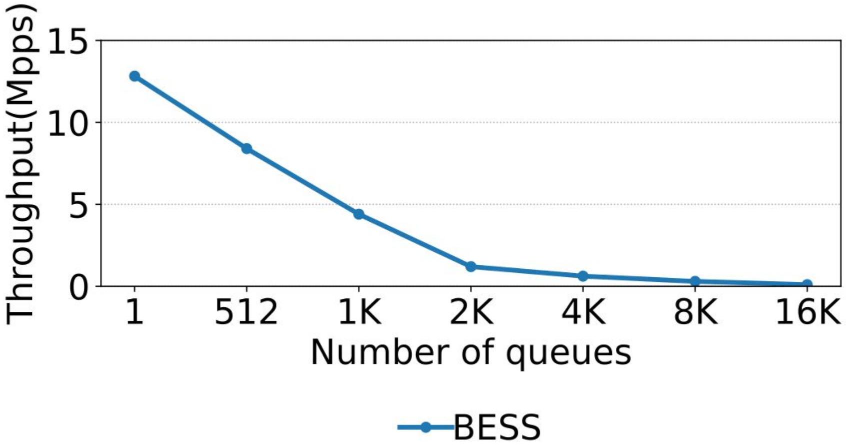


Avoids packet loss

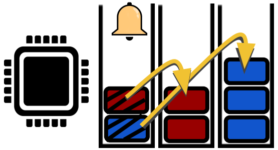
Prevents congestion spreading

Doorbell Queues

Per flow queuing is **NOT scalable** and **wastes CPU cycles**

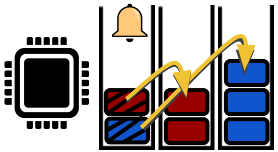


[Berkeley Extensible Software Switch (BESS): Han, et. al. NSDI '14]

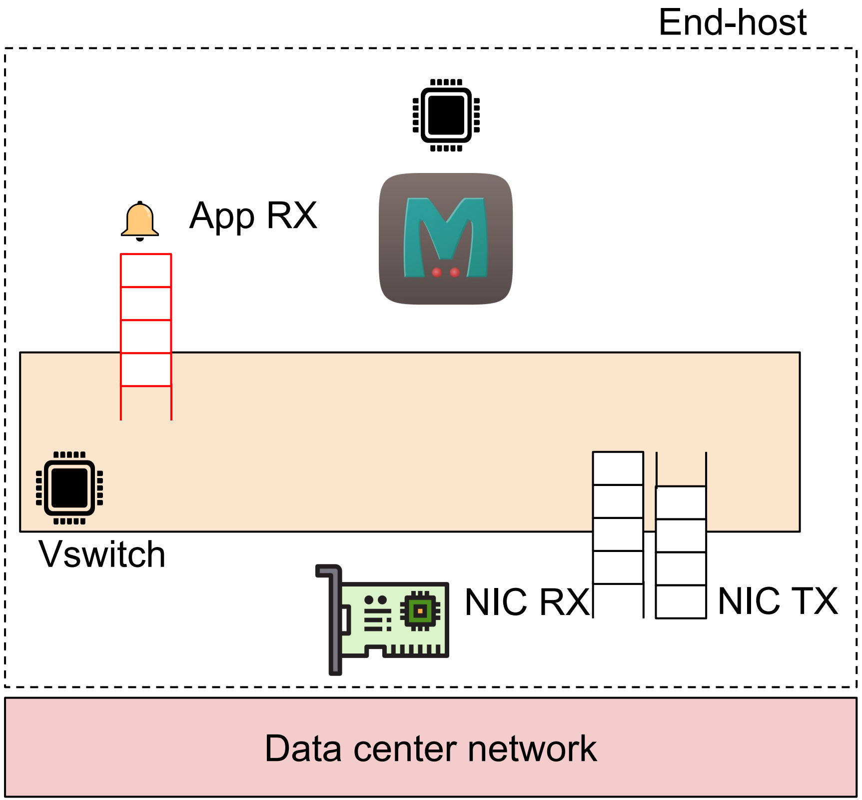


Key idea behind doorbell queues

Backdraft only busy polls one queue per CPU core regardless of the number of created queues!



How does doorbell queues work?



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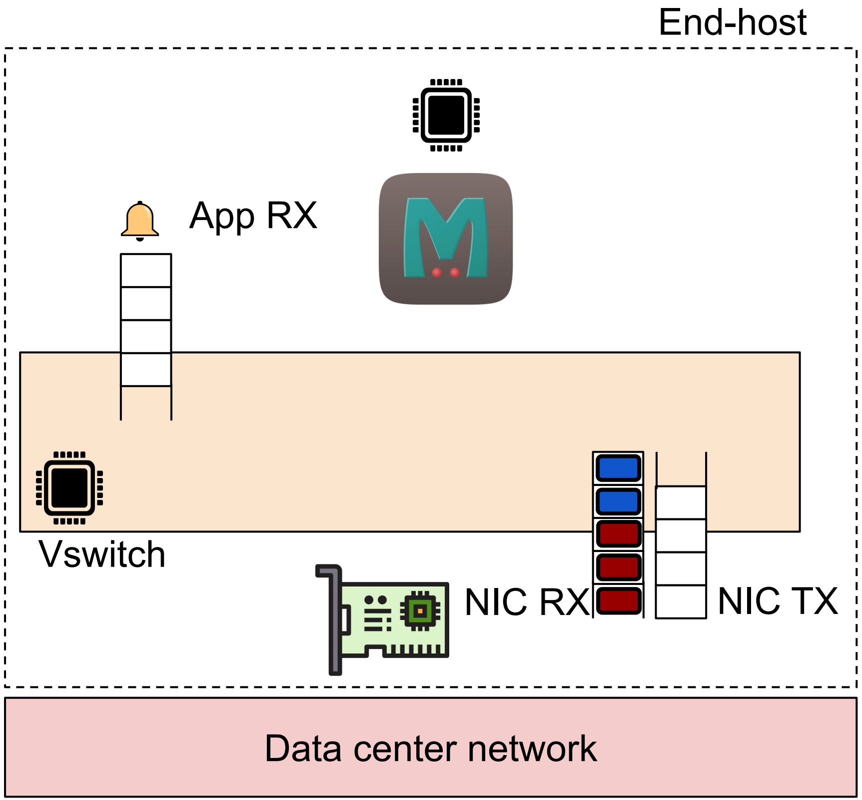

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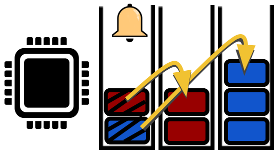

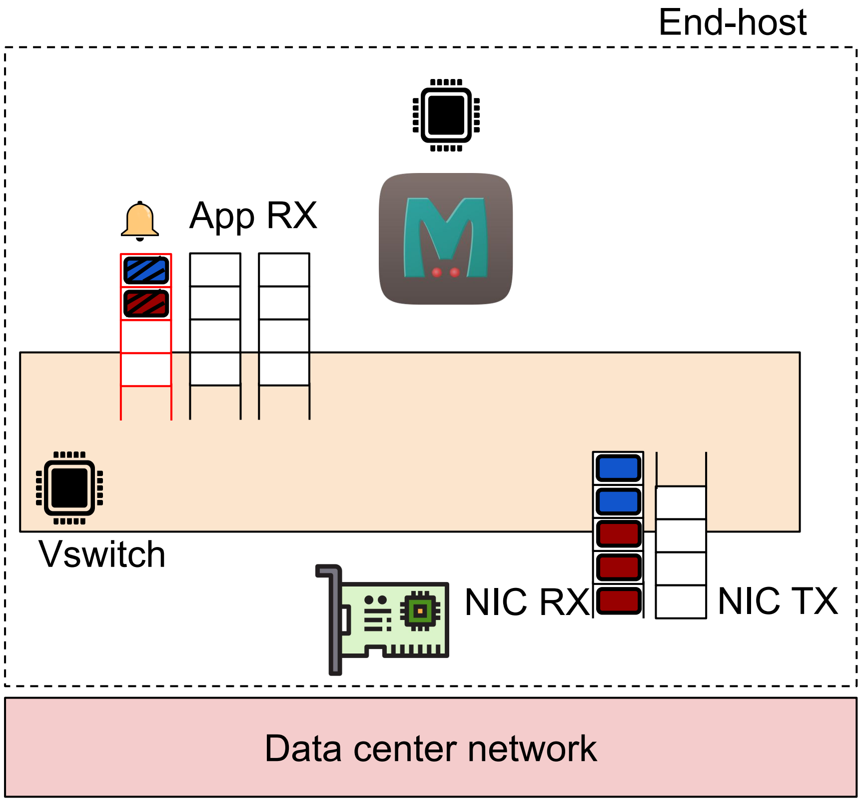

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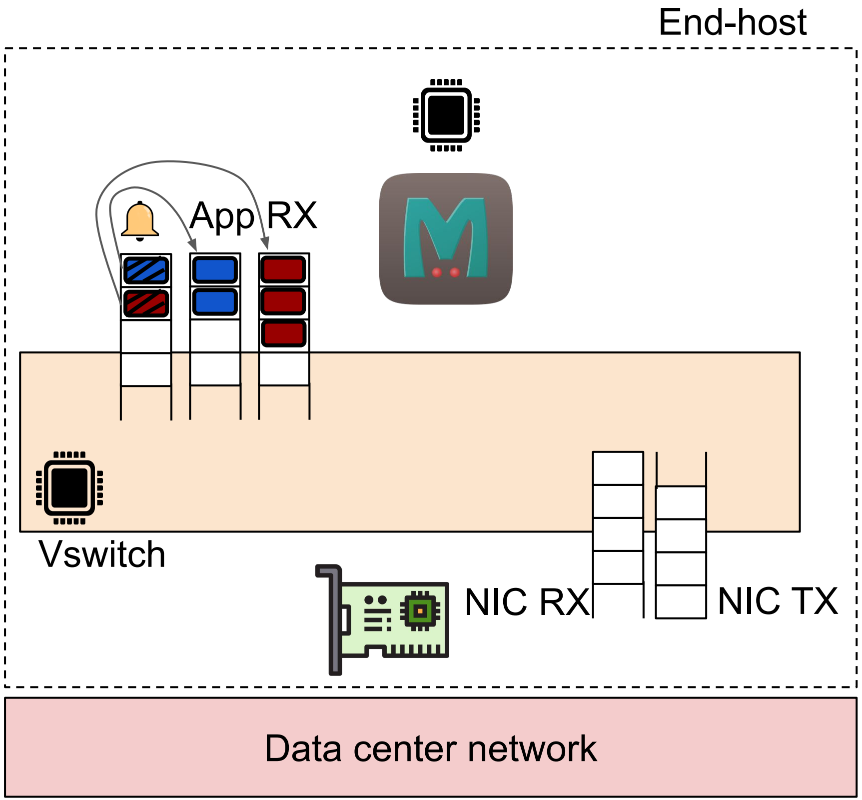

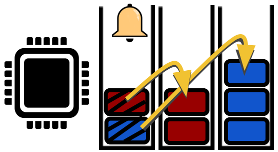

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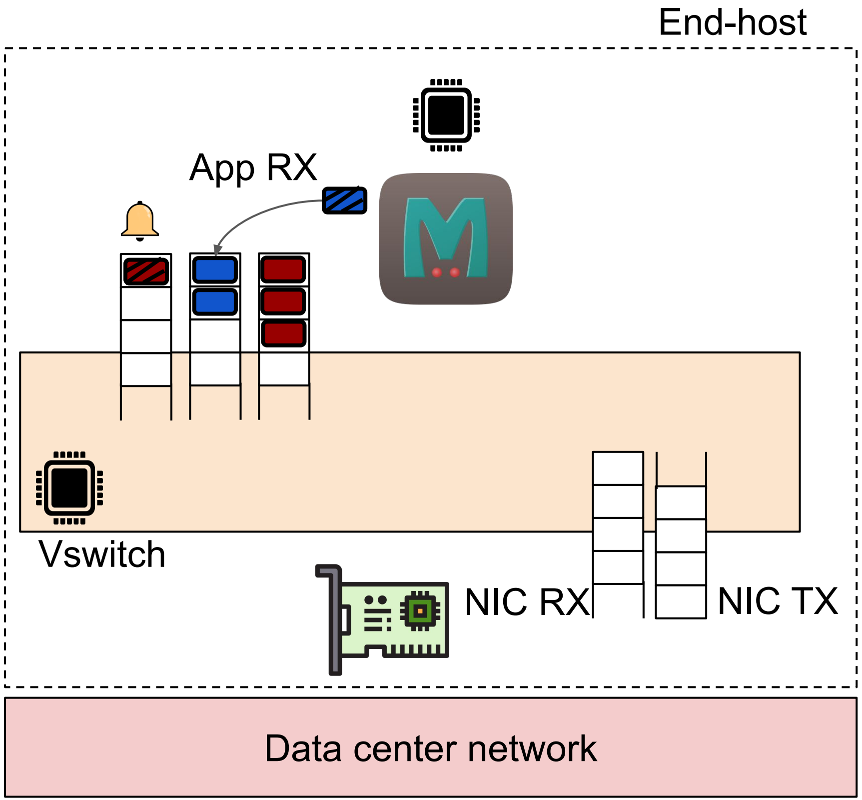

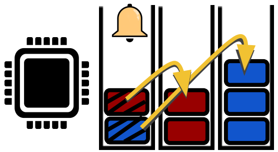

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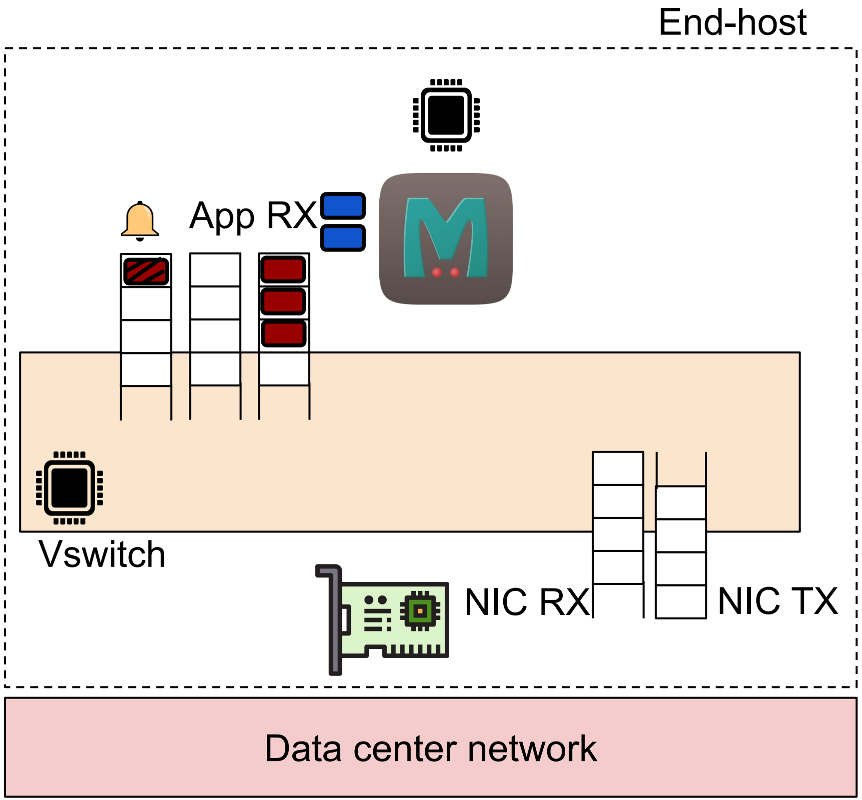

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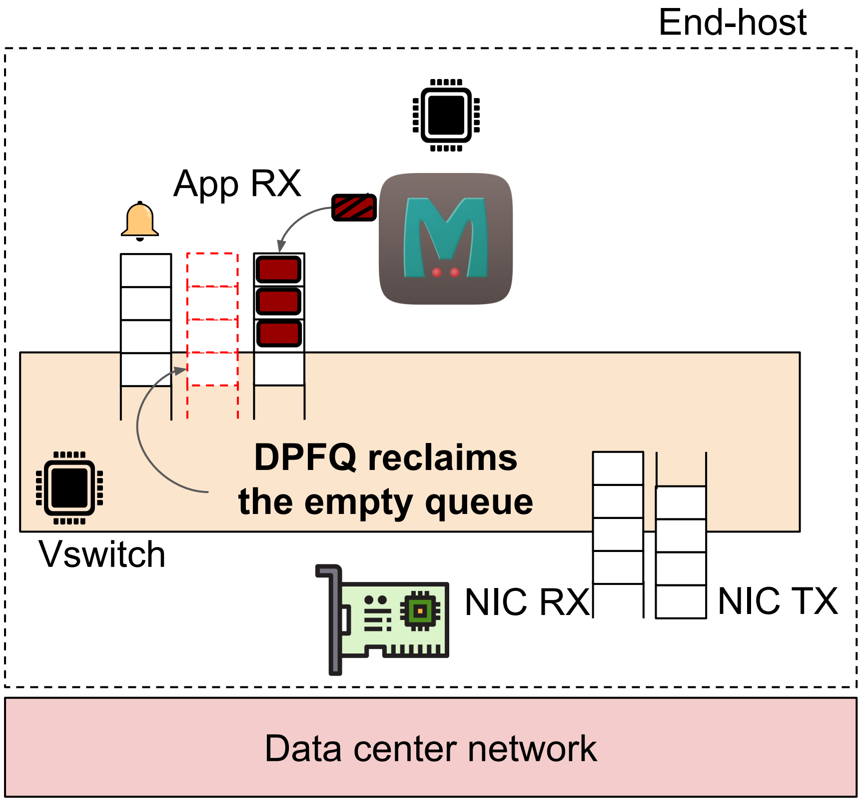

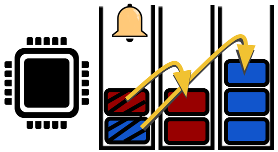

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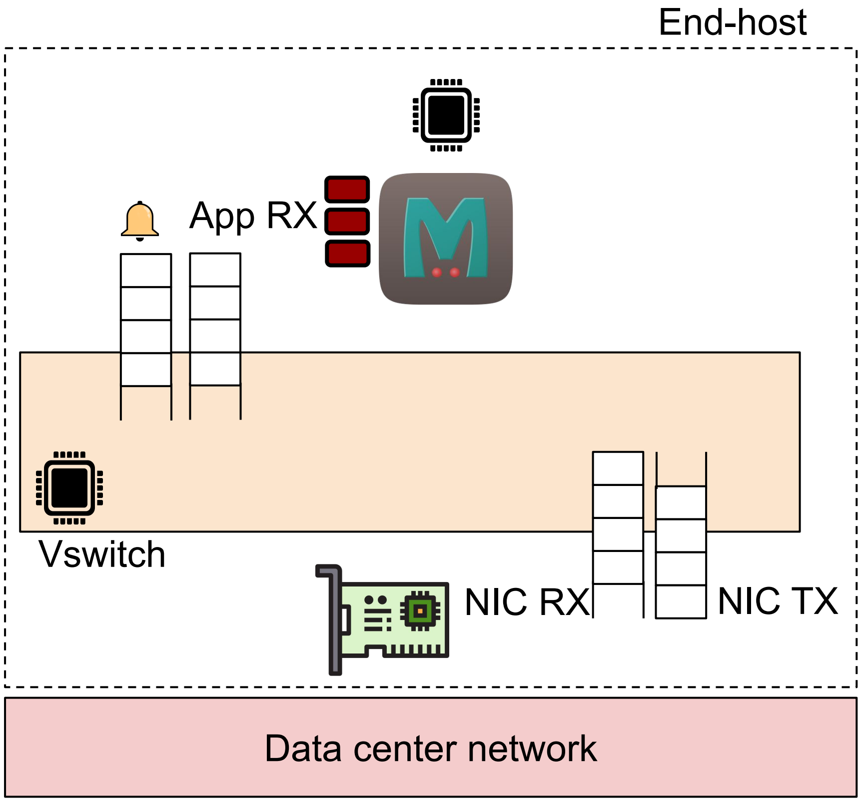

Three components of Backdraft

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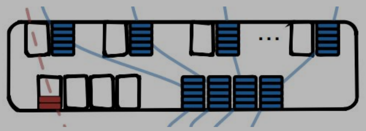
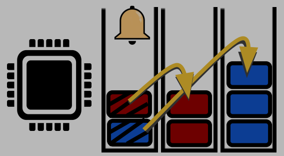


Avoids HOL blocking

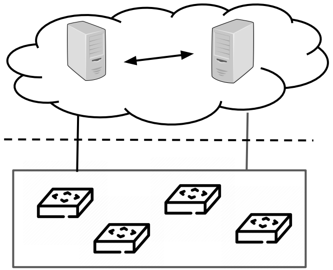
On-demand memory use

2) Doorbell queues



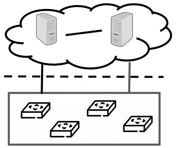
Avoids wasted CPU

3) Backdraft overlay network



Avoids packet loss

Prevents congestion spreading



Backdraft overlay network

Key idea

Utilizing the large buffering capacity at the end-hosts

Approach

Buffering packet at the end-hosts

Backdraft sends overlay PAUSE messages to the upstream virtual switch.

Upon receive of an overlay message, the vswitch stops reading the culprit flow messages.

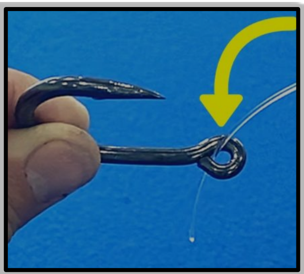
Backdraft overlay network can solve congestion spreading problem due to slow receivers where even BFC cannot solve.

Outline

Motivation

Backdraft design

Backdraft evaluation



Backdraft implementation

Backdraft is built on top of BESS.

Backdraft uses TCP acceleration service (TAS) as a user level TCP library.

[TAS: Kauffmann, et. al. EuroSys ’19]

Backdraft is about ~4K LOC.

Two questions we address in this talk

Can Backdraft solve problems with existing congestion control protocols that still are not solved?

How does Backdraft impact the real workload application performance?

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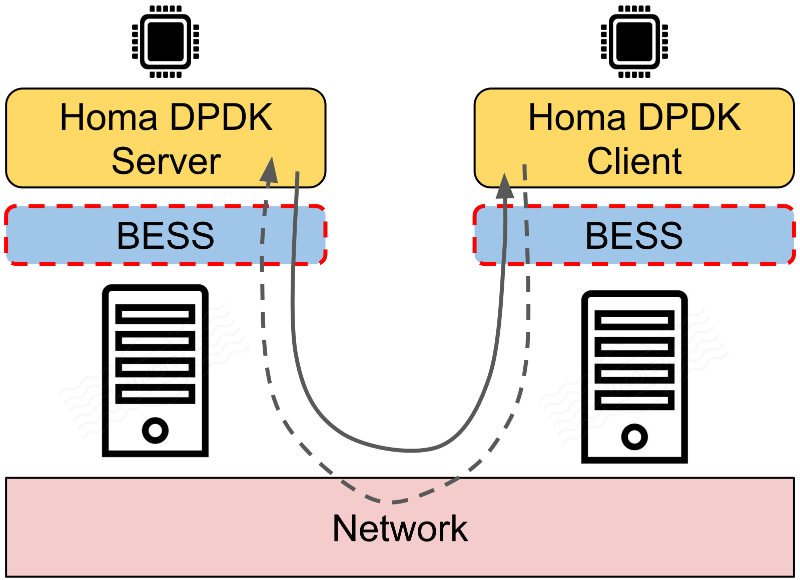
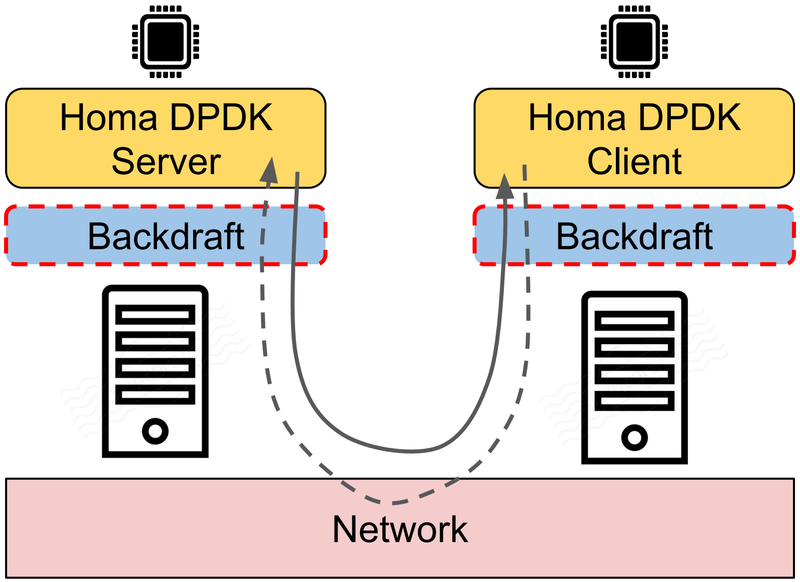
Can Backdraft solve problems with existing congestion control protocols that still are not solved?

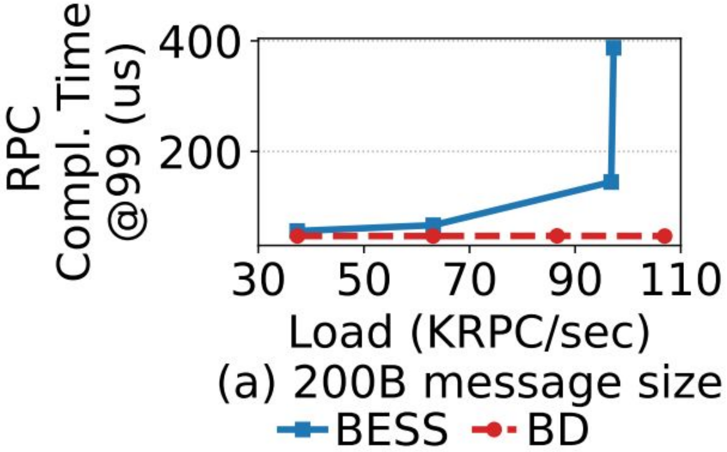
Homa experiment setup



Homa experiment setup



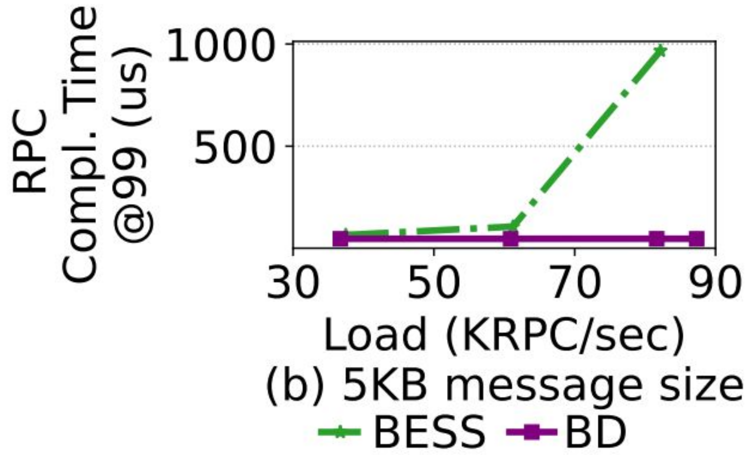
Backdraft complements Homa – RPC Completion time



(a) 200B message size

Homa (small RPC) achieves higher throughput when it runs on top of Backdraft.

Backdraft complements Homa – RPC Completion time



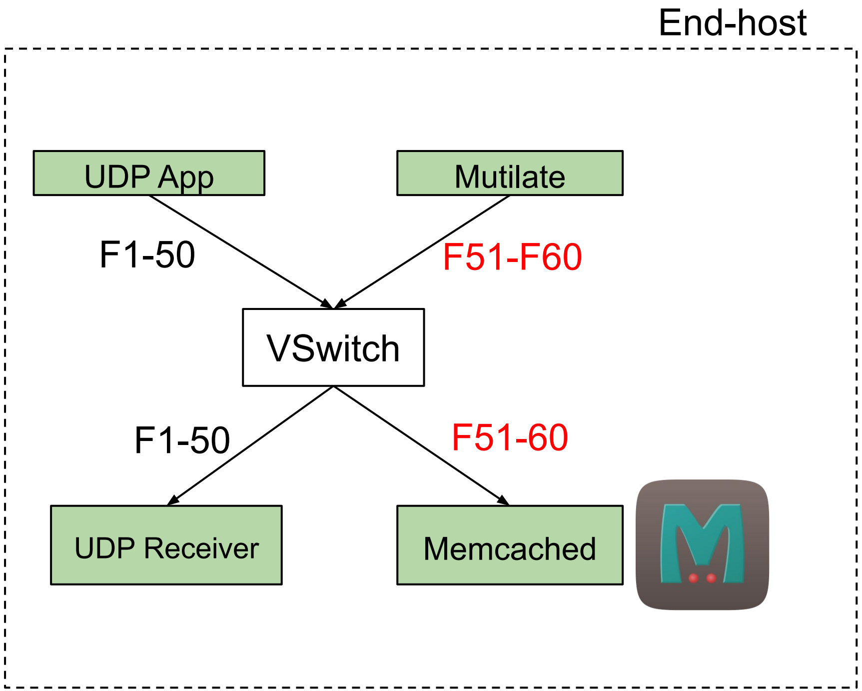
(b) 5KB message size

Homa (large RPC) achieves higher throughput when it runs on top of Backdraft.

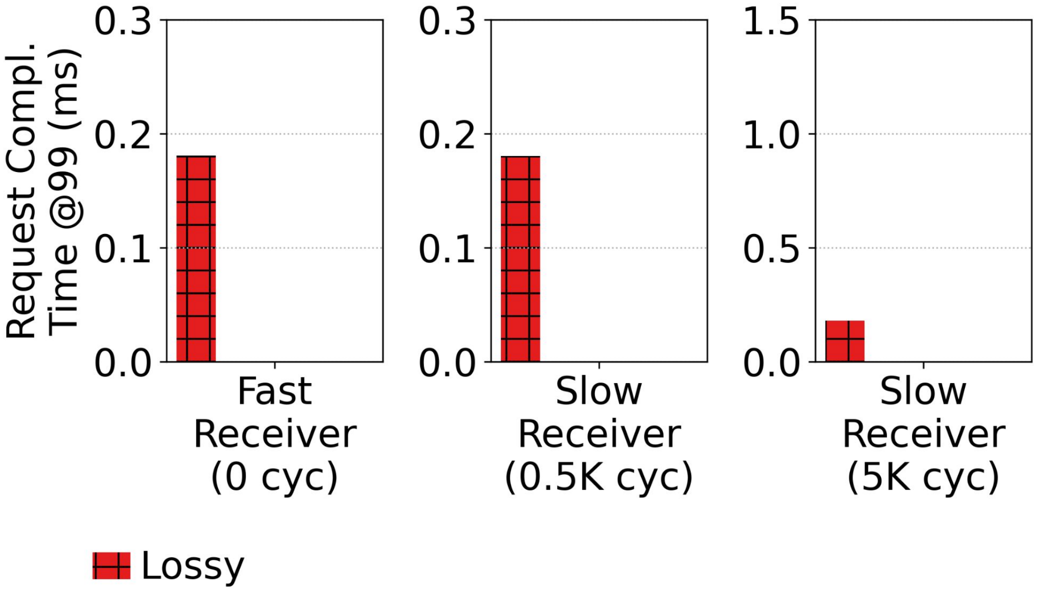
Can Backdraft solve problems with existing congestion control protocols that still are not solved?

How does Backdraft impact the real workload application performance?

Experiment setup



Evaluating different components of Backdraft - Request completion time



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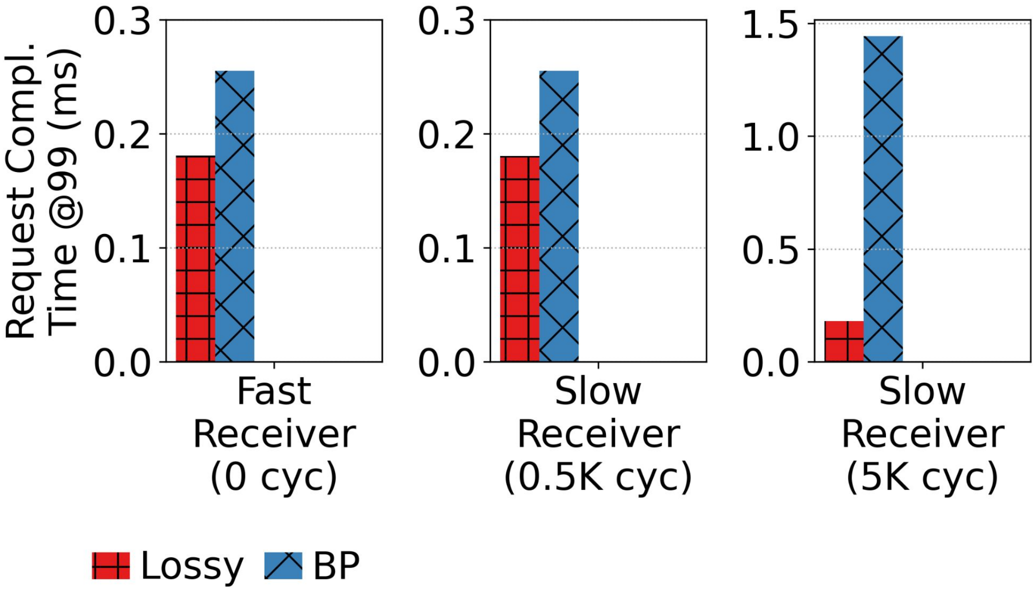

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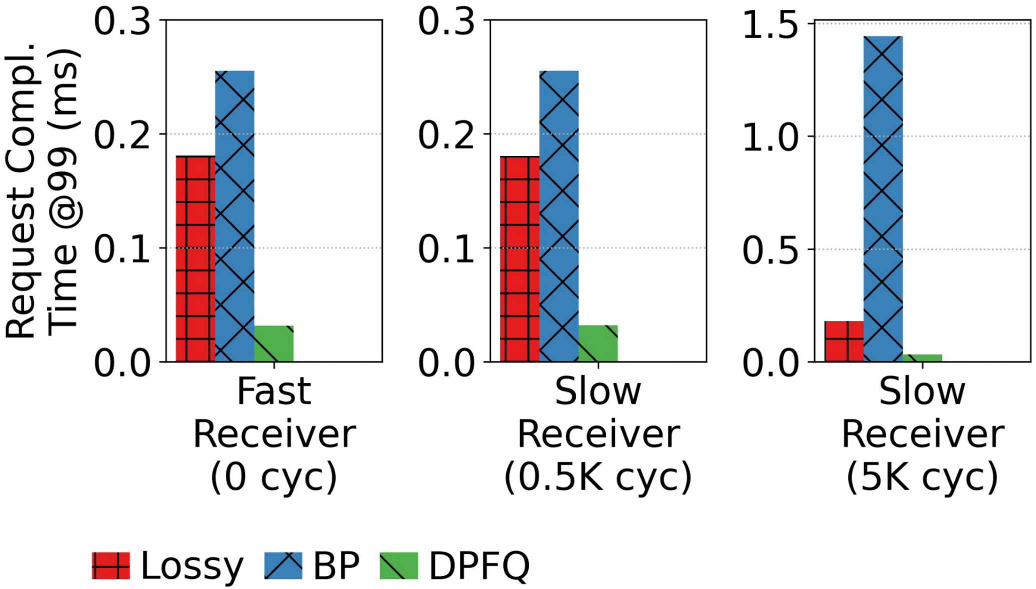

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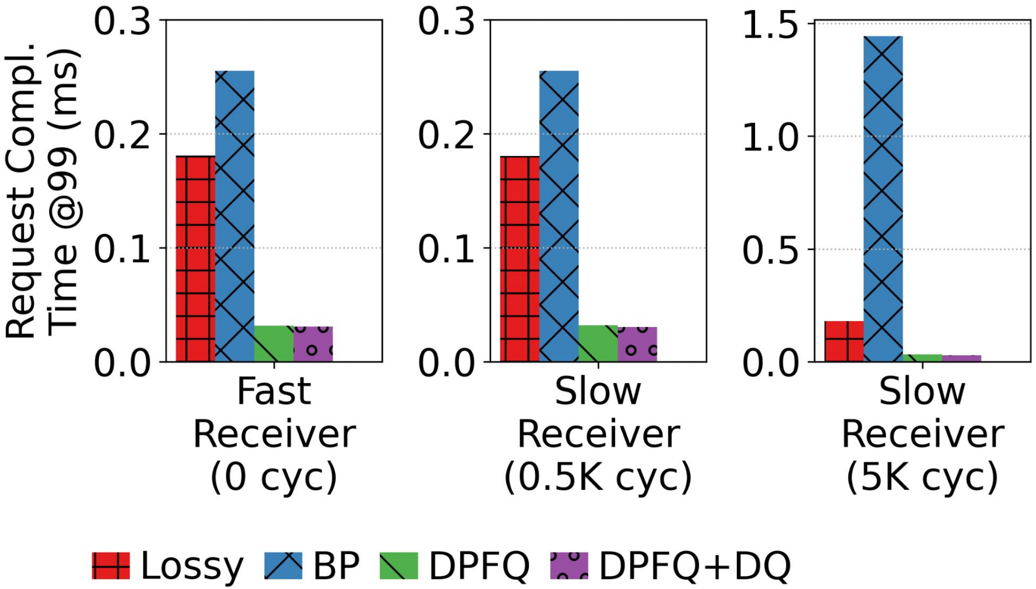

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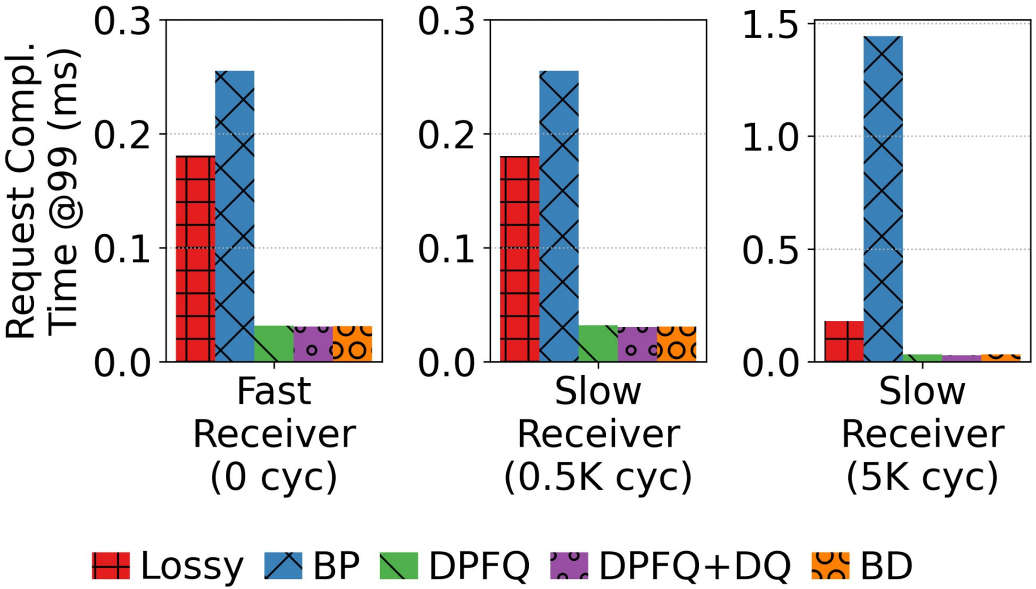
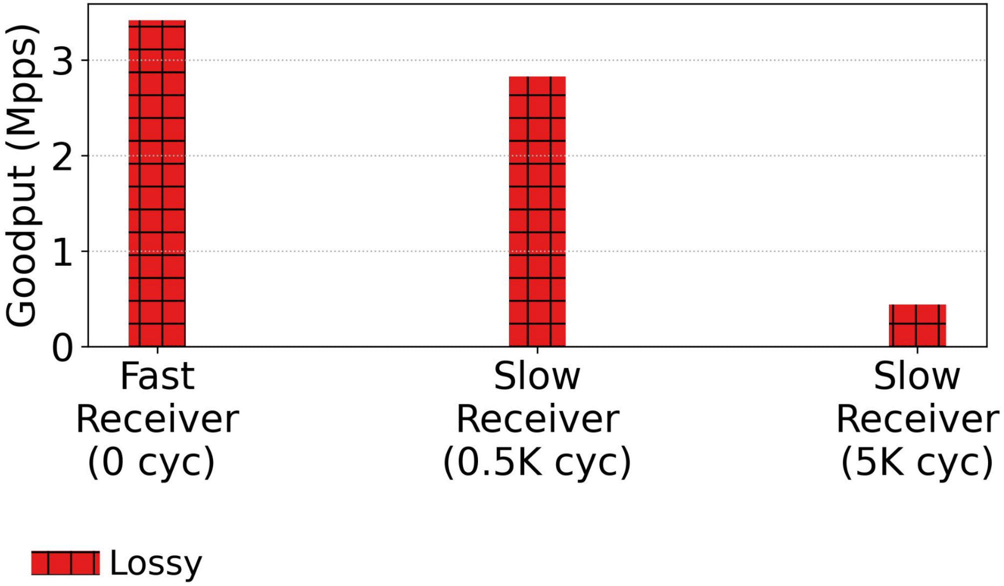


Evaluating different components of Backdraft - Goodput



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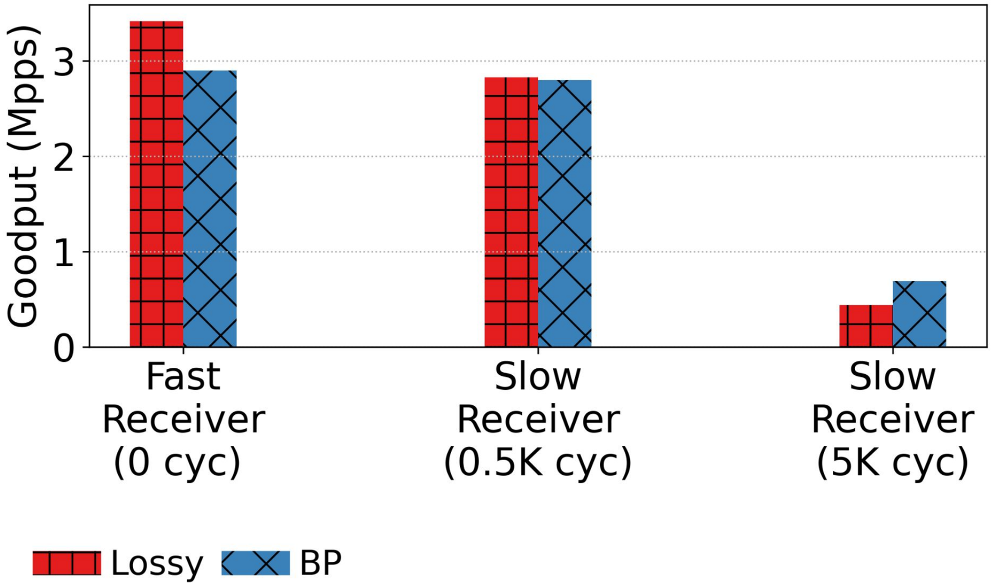

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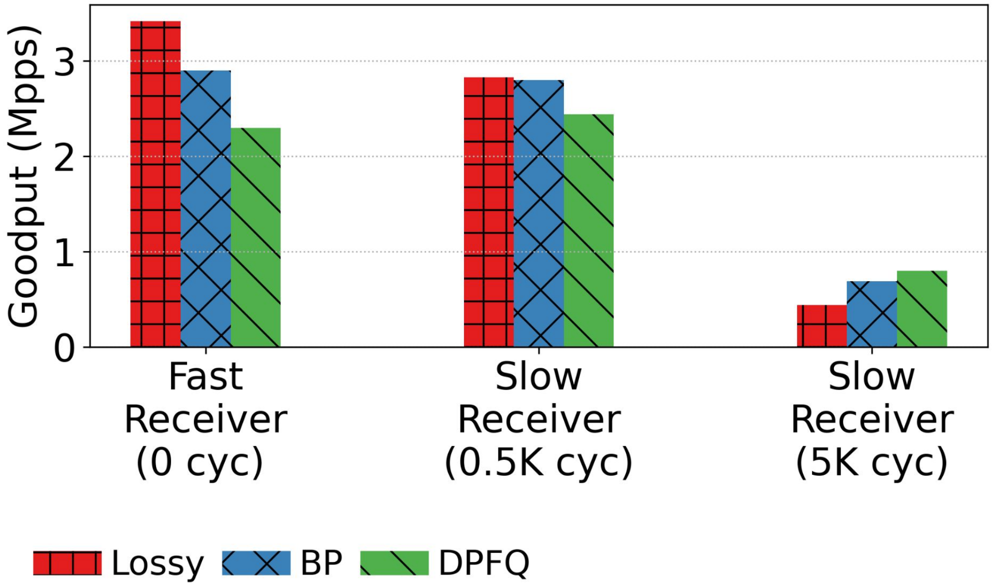

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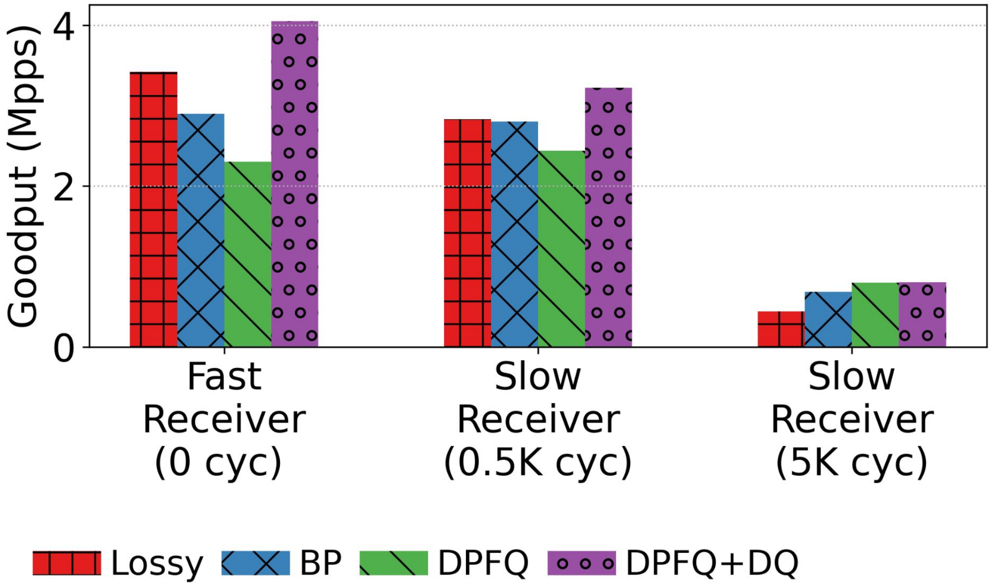

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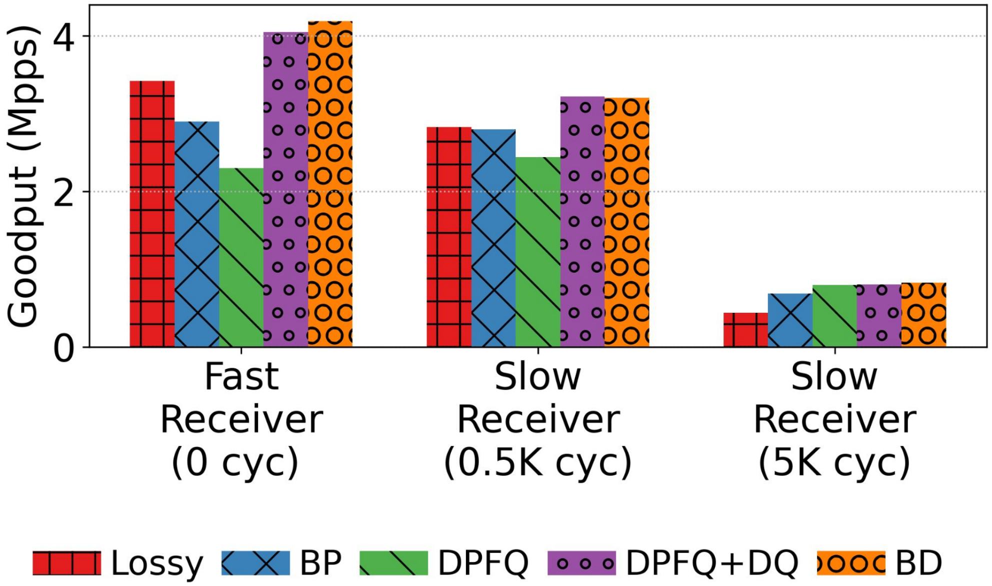

Backdraft Takeaways

Fork me on GitHub

Slow receivers are pervasive

1. Dynamic per-flow queuing
2. Doorbell queues
3. Overlay network

Backdraft can achieve up to 20x better tail latency compared to lossy approach

We ❤ open source

https://github.com/Lossless-Virtual-Switching/Backdraft