REVERIE

Low Pass Filter-Based Switch Buffer Sharing for Datacenters with RDMA and TCP Traffic

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Traditional Datacenter Networking

- TCP-based applications
- Host-networking consumes CPU clock cycles (a lot!!)
- Loss-tolerant traffic

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Modern Datacenter Networking

- ~~TCP-based applications~~
  - RDMA-based applications
- ~~Host networking consumes CPU clock cycles (a lot!!)~~
  - Host networking is offloaded to the NIC
  - NIC implements the entire networking stack
- ~~Loss-tolerant traffic~~
  - Lossless traffic
  - Requires Priority Flow Control (PFC)

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Production Datacenter Networks

- A mix of RDMA and TCP traffic
- Switches use shared buffers
- Both RDMA and TCP *share* the limited buffer space at each switch in the network

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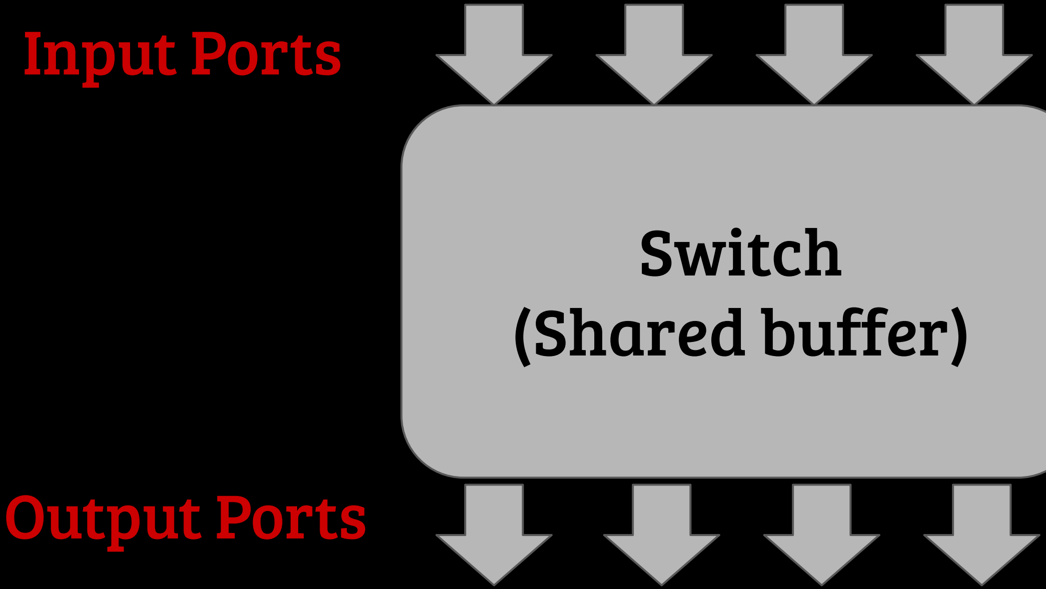
Switch Buffer Sharing with TCP



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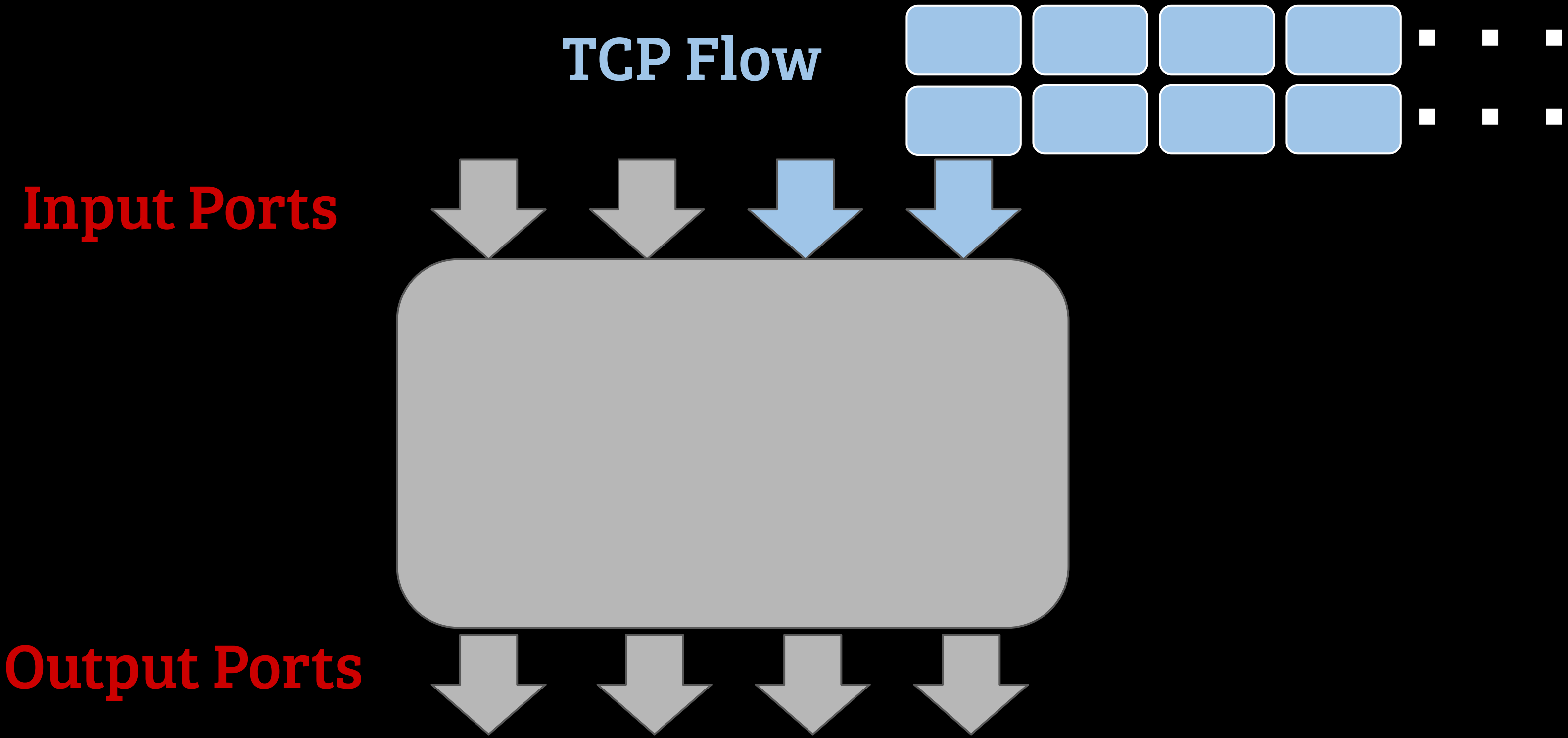

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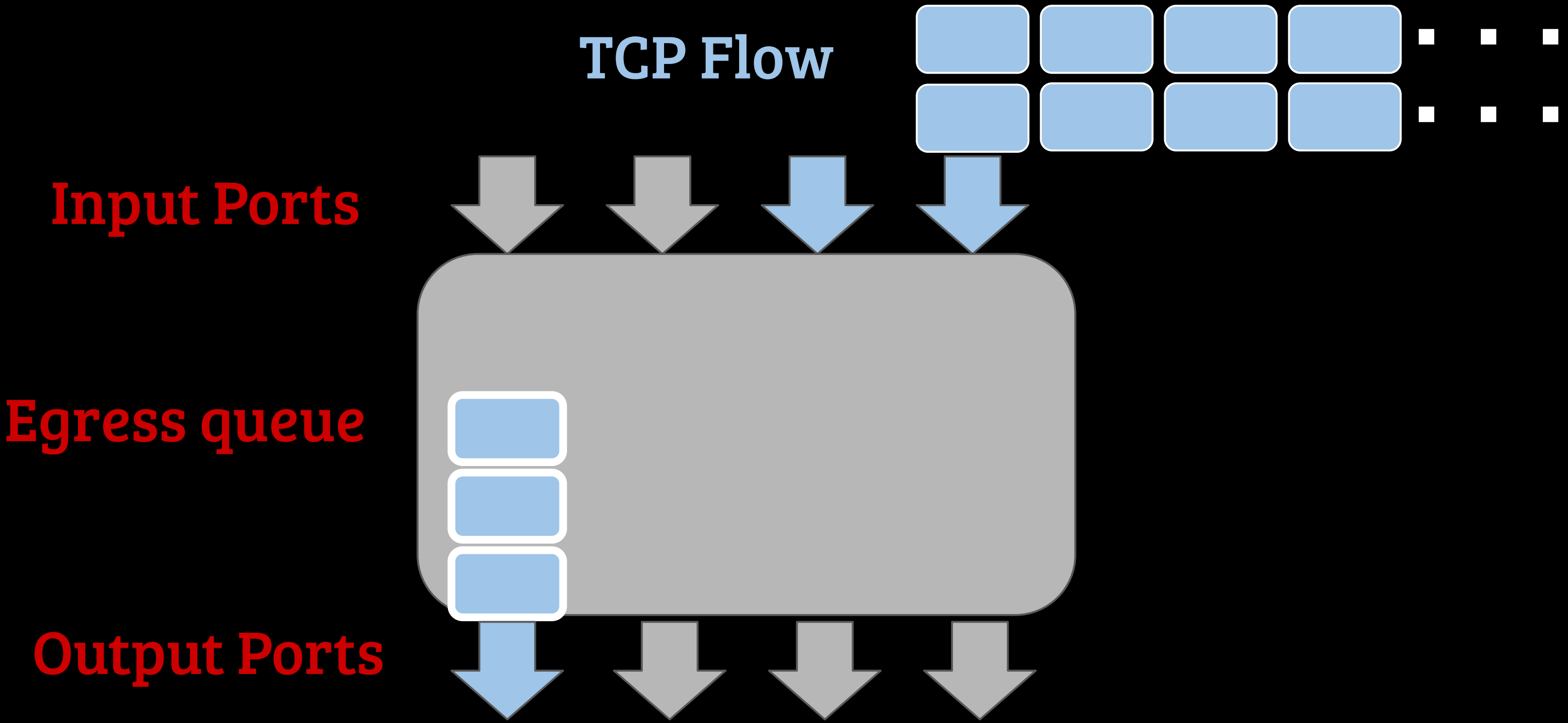

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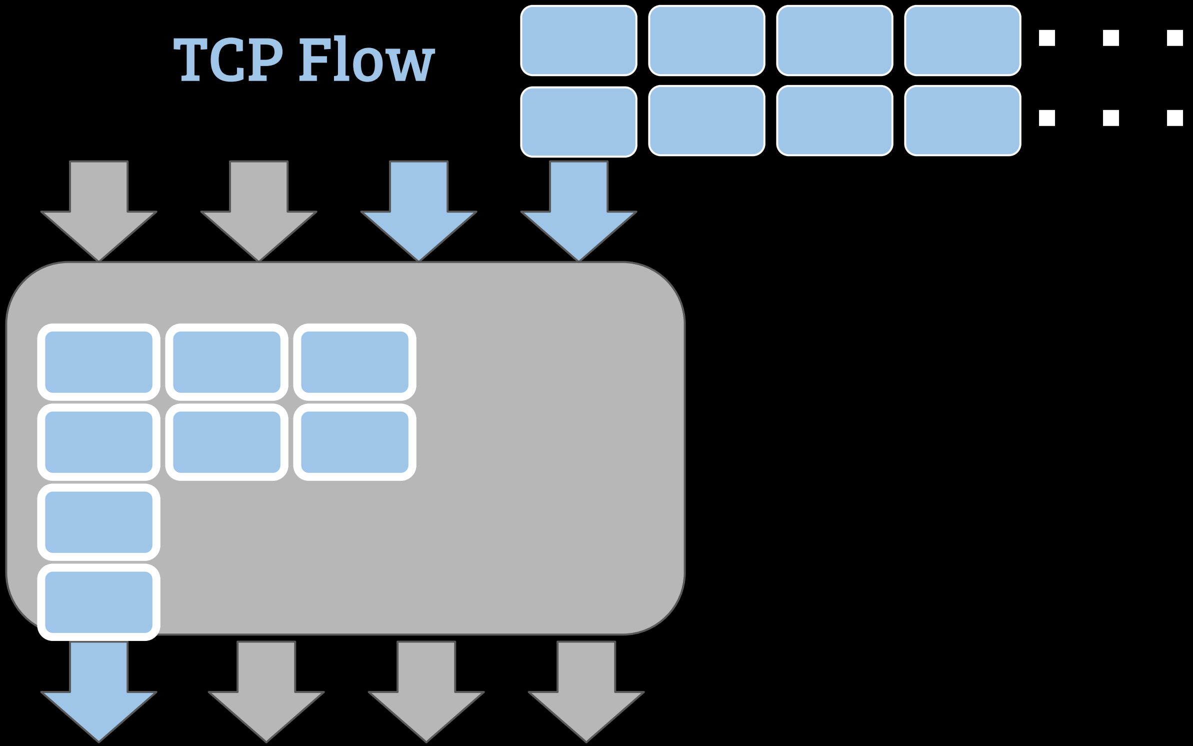

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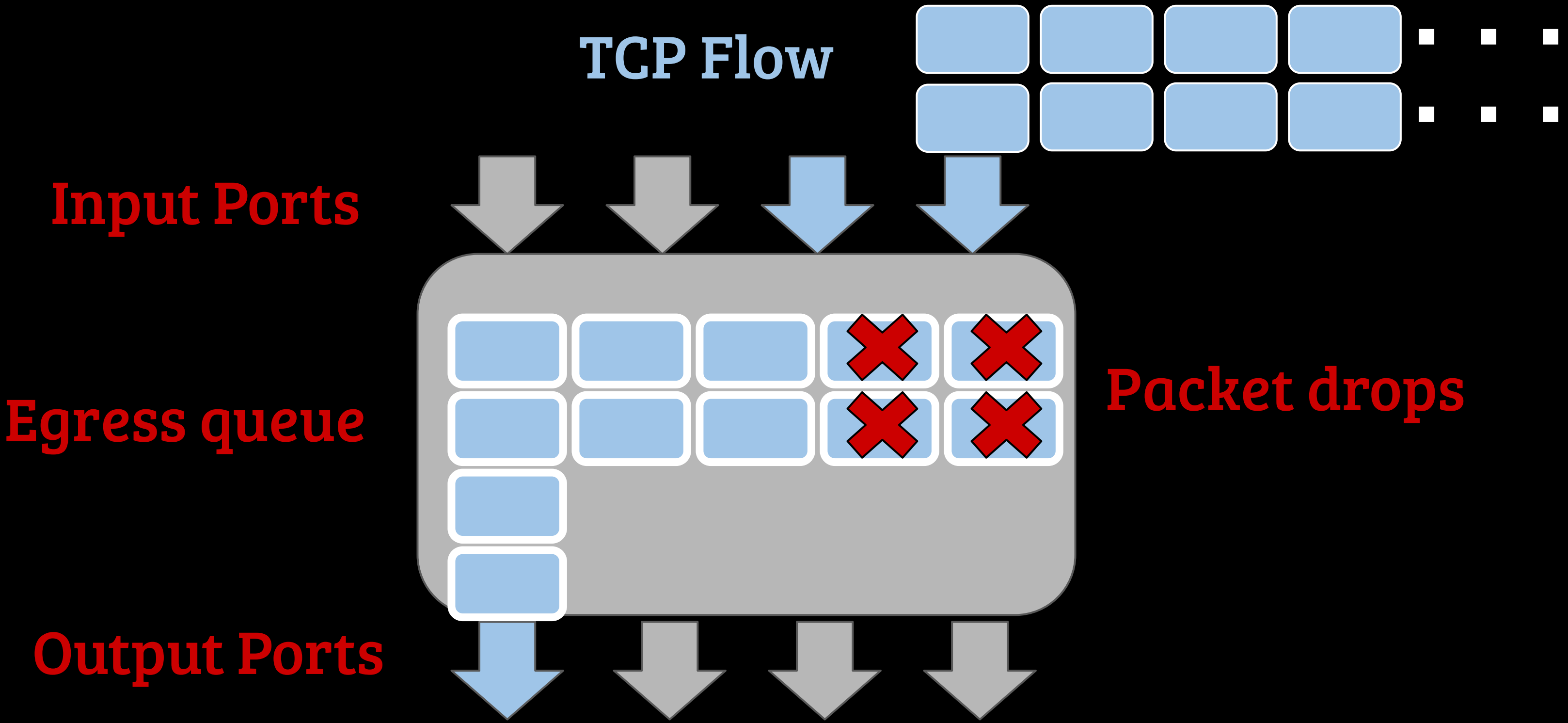

Switch Buffer Sharing with TCP

- Based on egress queue lengths and packet drops
- A buffer sharing algorithm assigns a threshold for each egress queue in a switch
- Packet accepted: Threshold > Queue length (egress)
- Packet dropped: Threshold < Queue length (egress)

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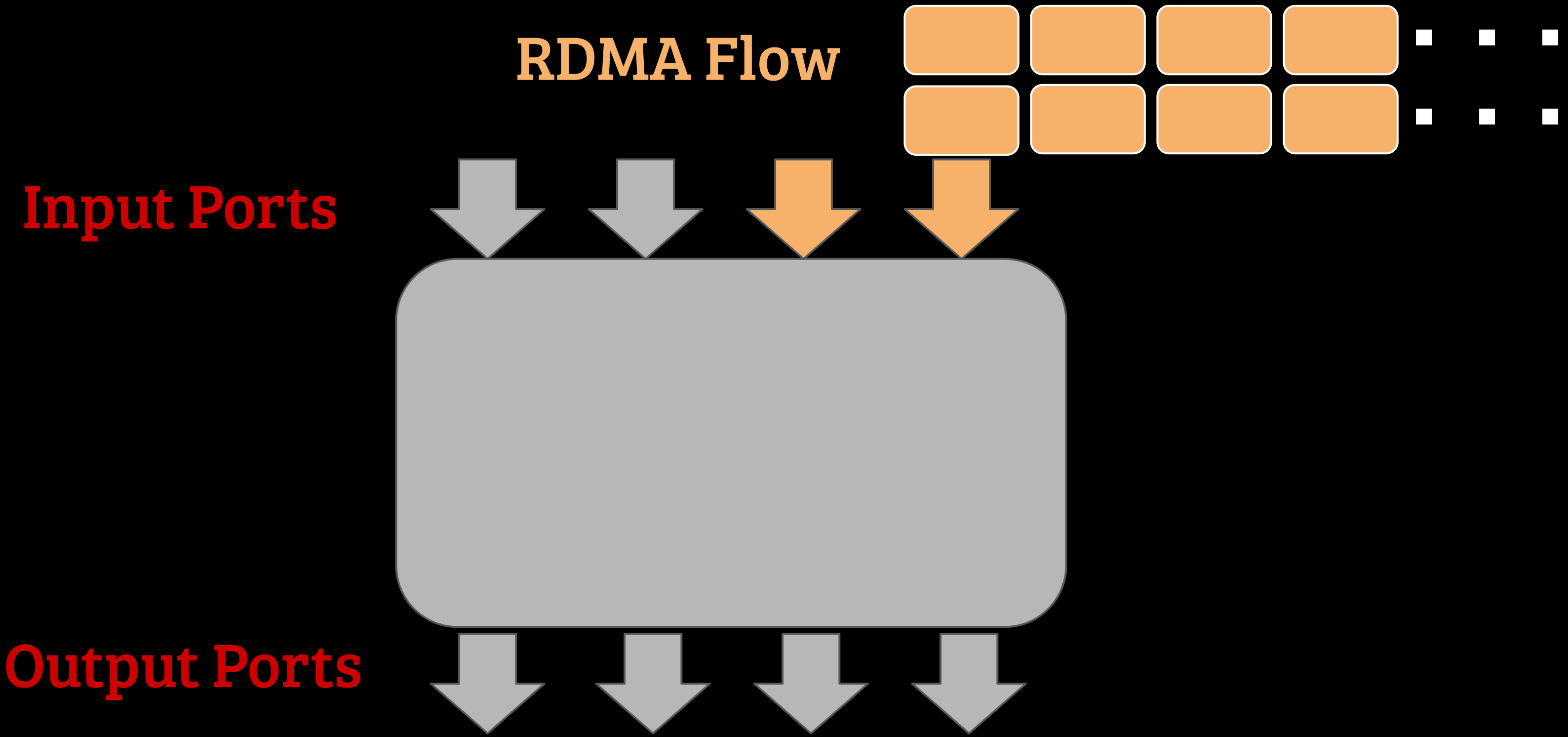
Switch Buffer Sharing with RDMA



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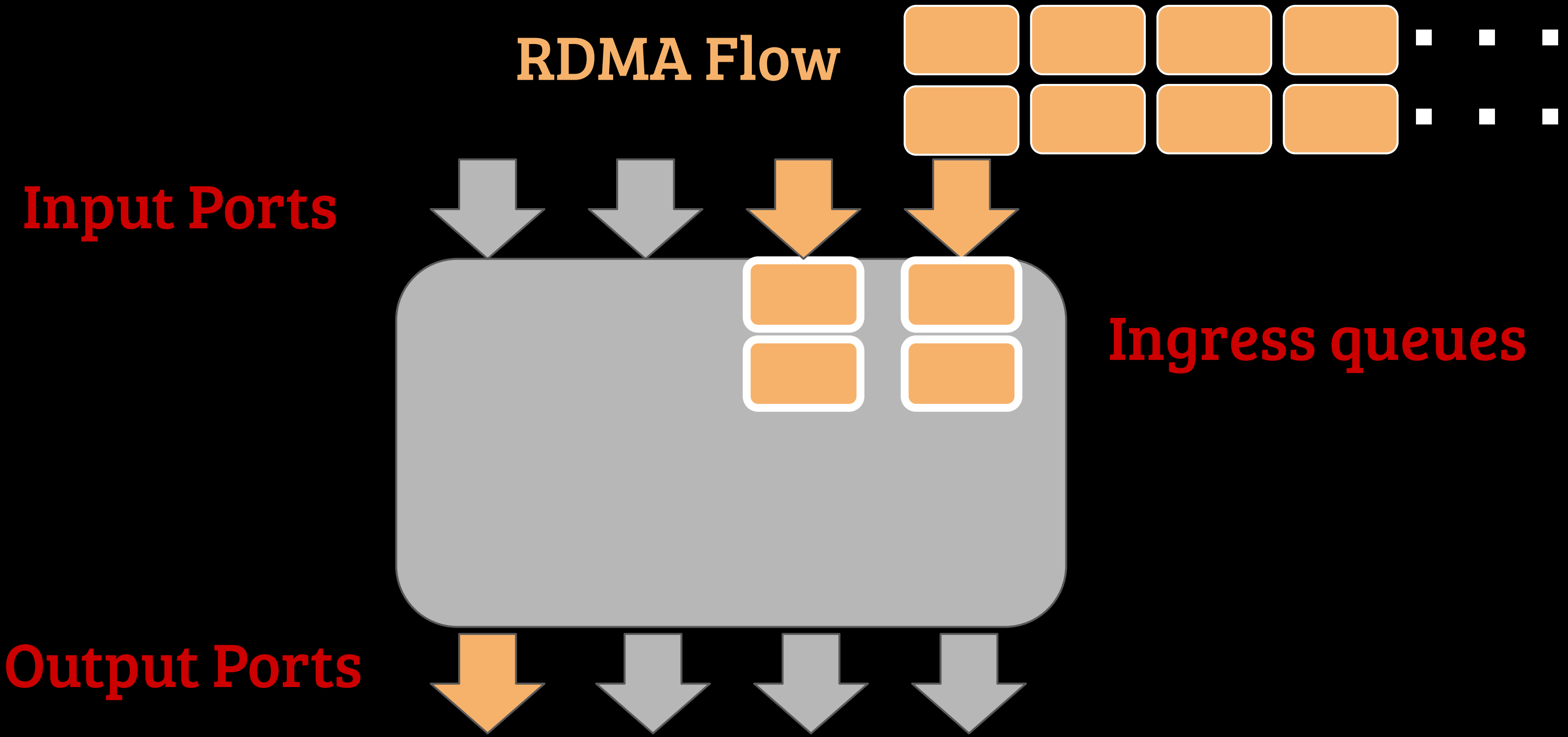

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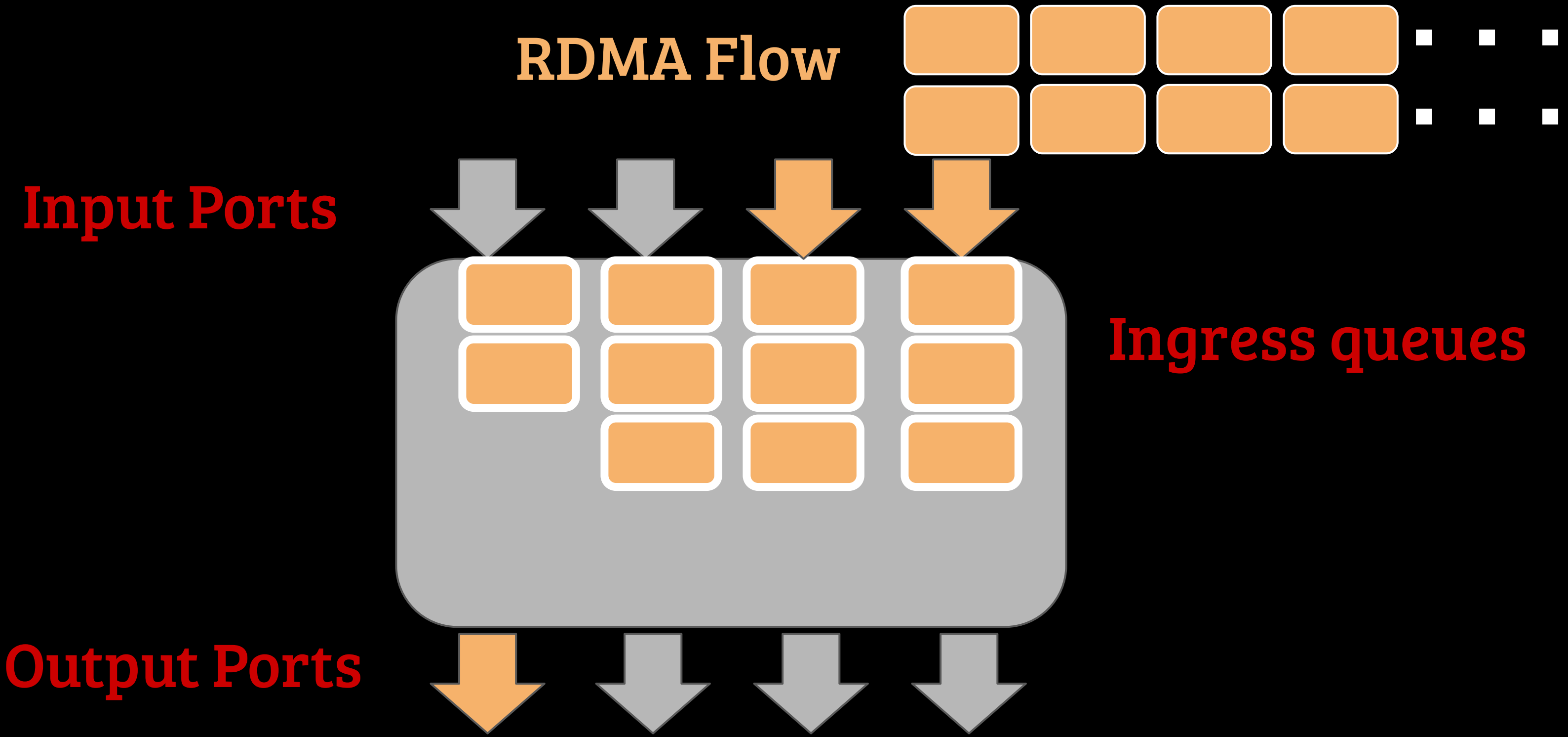

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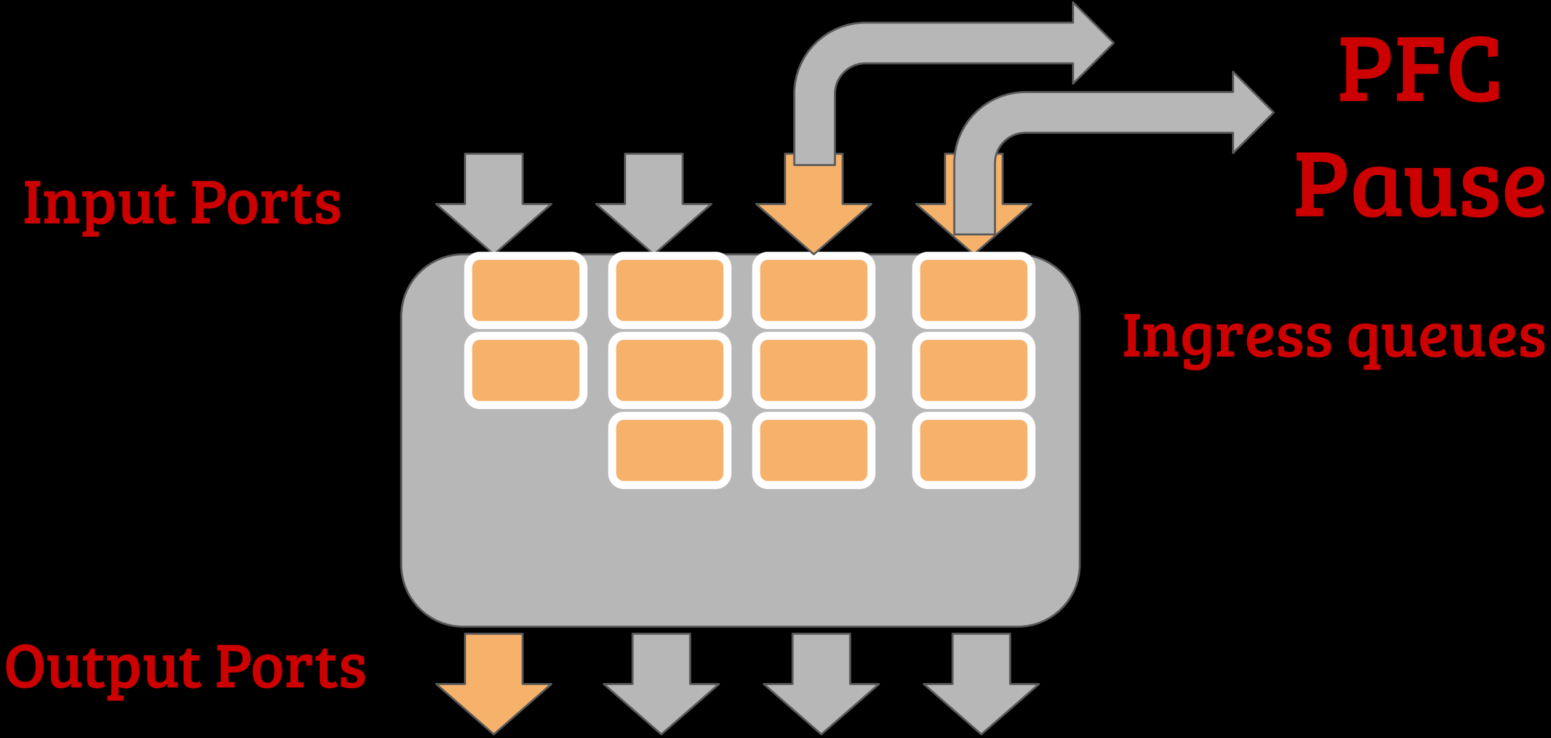

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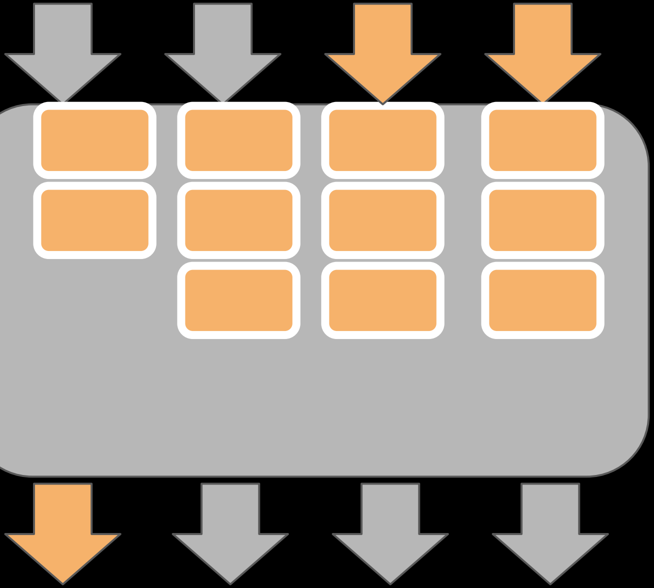
Switch Buffer Sharing with RDMA

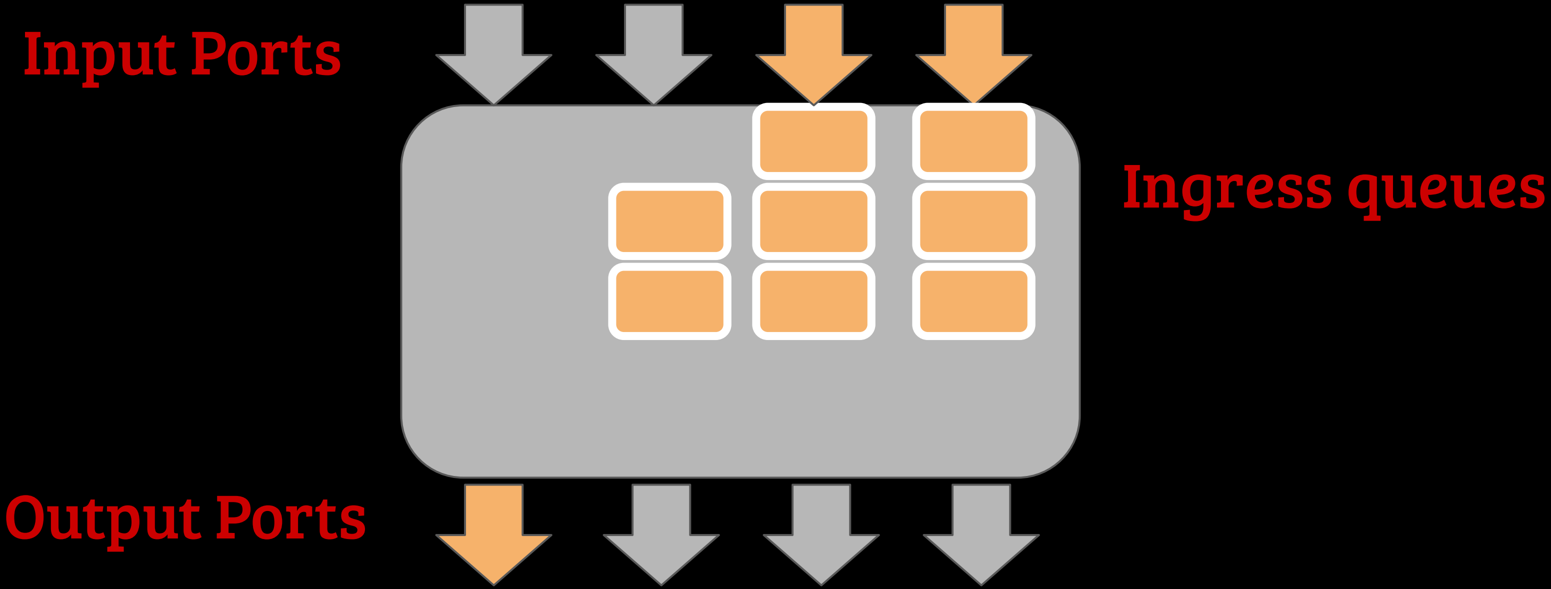
Input Ports

Ingress queues

Output Ports



Switch Buffer Sharing with RDMA



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Switch Buffer Sharing with RDMA

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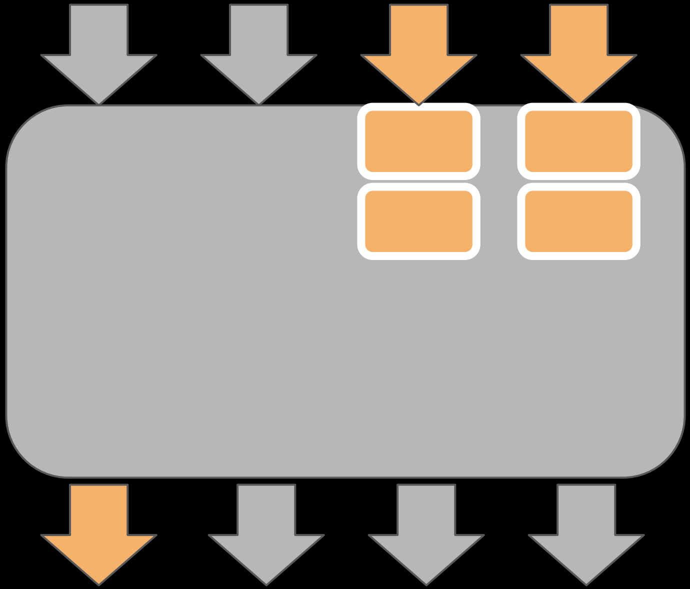

Ingress queues

Output Ports

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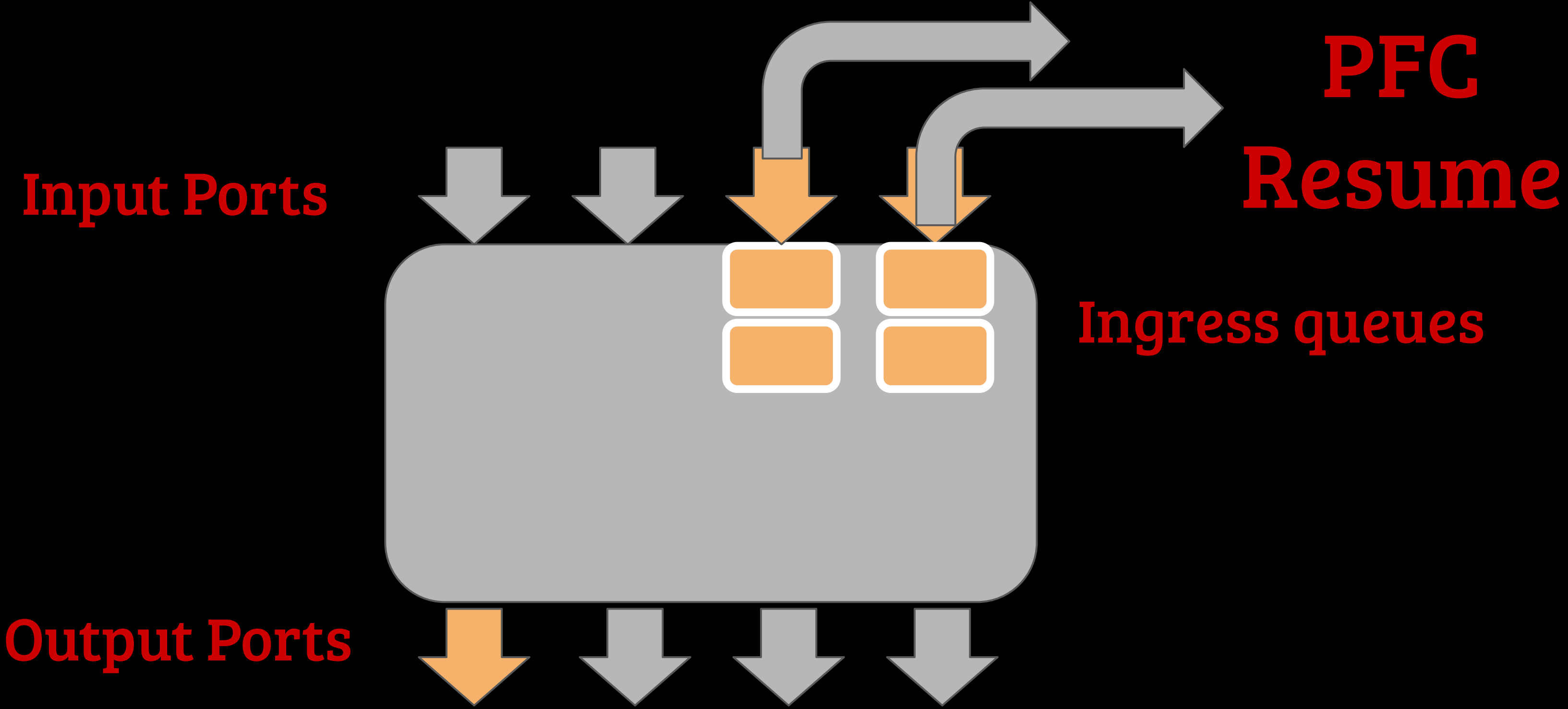
Switch Buffer Sharing with RDMA



Switch Buffer Sharing with RDMA

- ~~Based on egress queue lengths and packet drops~~
- Based on ingress queue lengths and PFC

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Switch Buffer Sharing with RDMA

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Switch Buffer Sharing with RDMA

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- Packets are always accepted

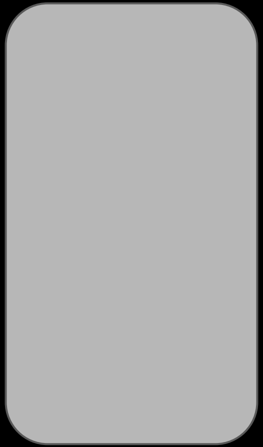
Switch Buffer Sharing with RDMA

- Based on ingress queue lengths and PFC
- A buffer sharing algorithm assigns a threshold for each ingress queue in a switch
- Packets are always accepted
- ~~Packet dropped: Threshold < Queue length (egress)~~
- PFC Pause: Threshold < Queue length (ingress)

Problem: Switch Buffer Sharing with RDMA + TCP

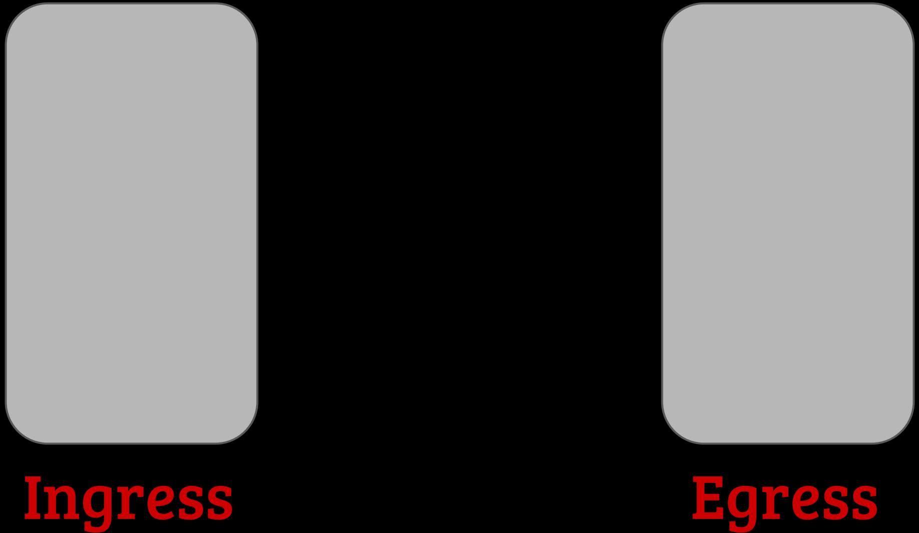
- Harmful interactions between RDMA and TCP
- Unfair buffer allocation
- Poor burst absorption

Background: SONiC Buffer Model



Background: SONiC Buffer Model

- Two (logical) views of the buffer



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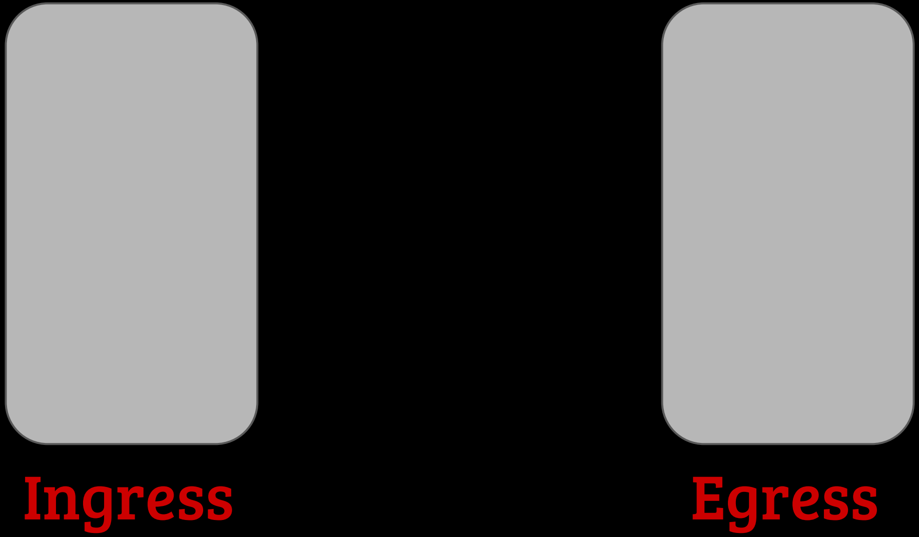
Background: SONiC Buffer Model

- Every packet is accounted both in ingress and egress



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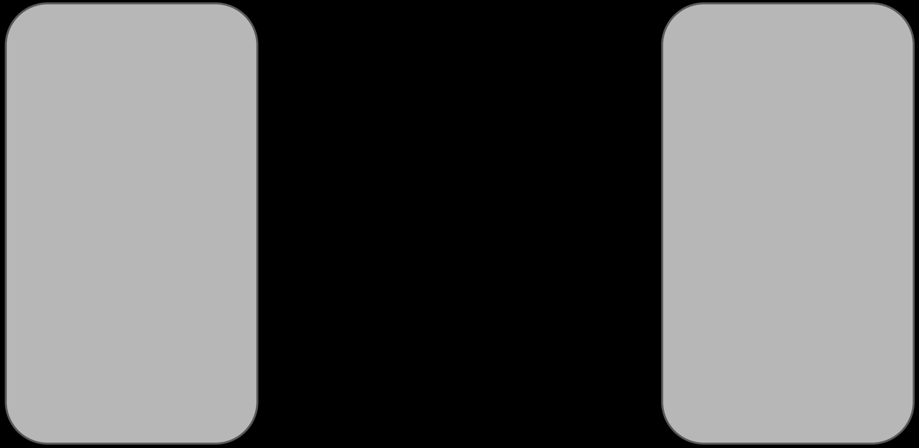
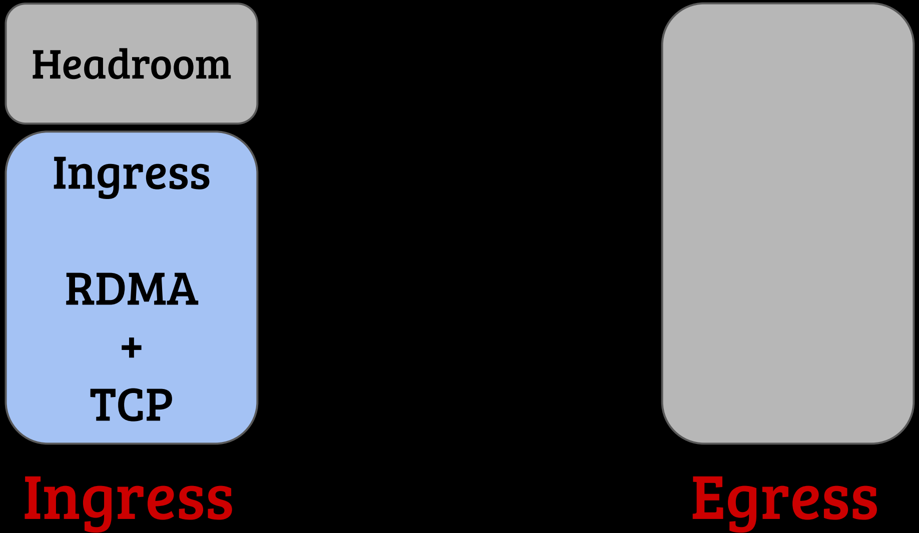
Background: SONiC Buffer Model

- Buffer is logically divided into pools



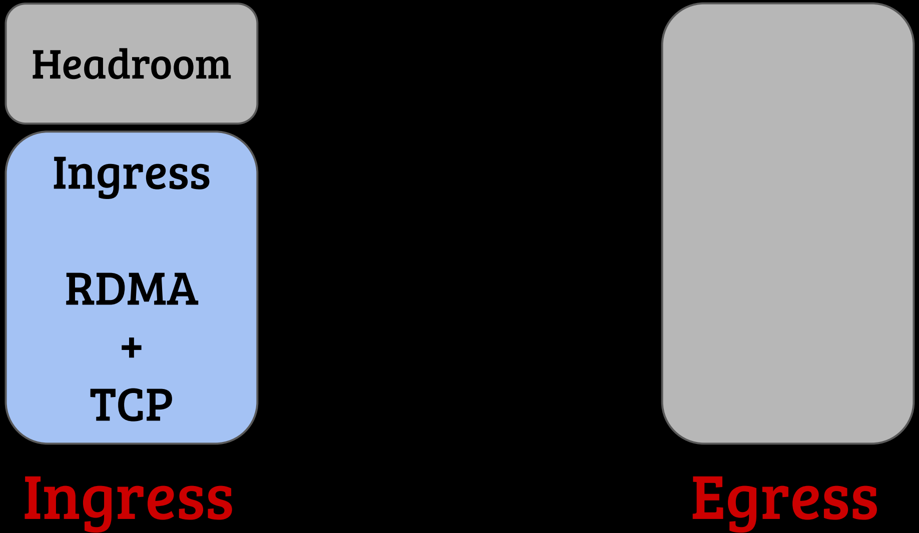
Background: SONiC Buffer Model

- Ingress pool is shared by both RDMA and TCP



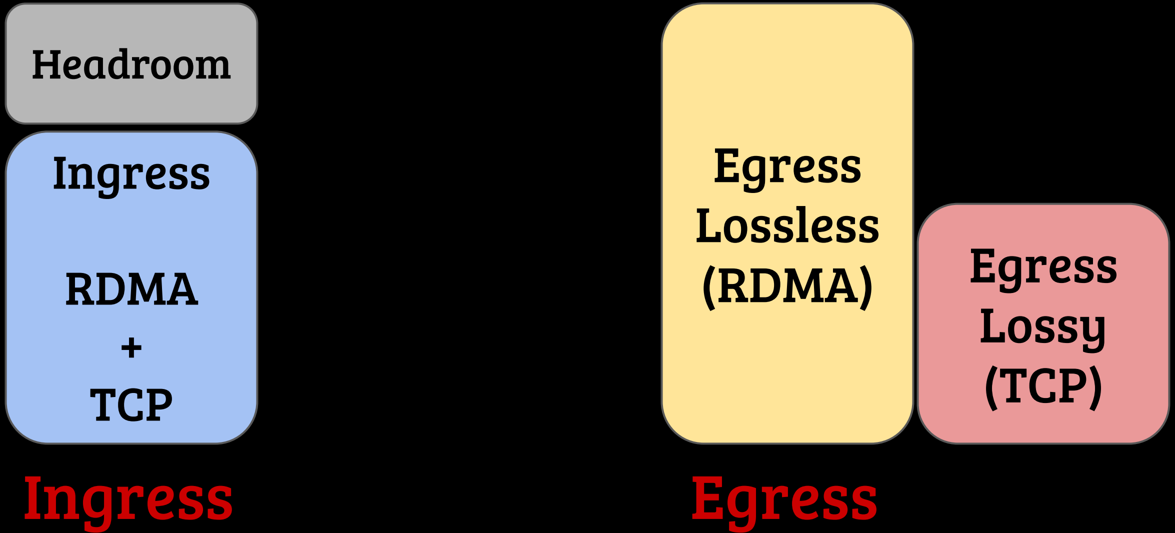
Background: SONiC Buffer Model

- Headroom pool in the ingress is reserved for RDMA



Background: SONiC Buffer Model

- Egress lossless (RDMA) and Egress lossy (TCP) pools



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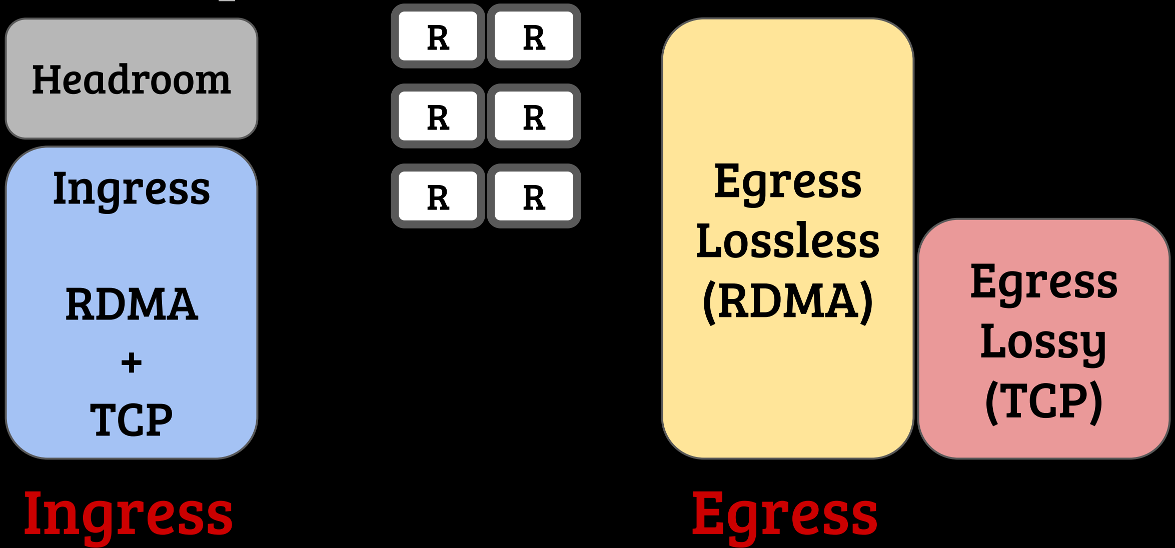
Background: SONiC Buffer Model

- Example: RDMA packets



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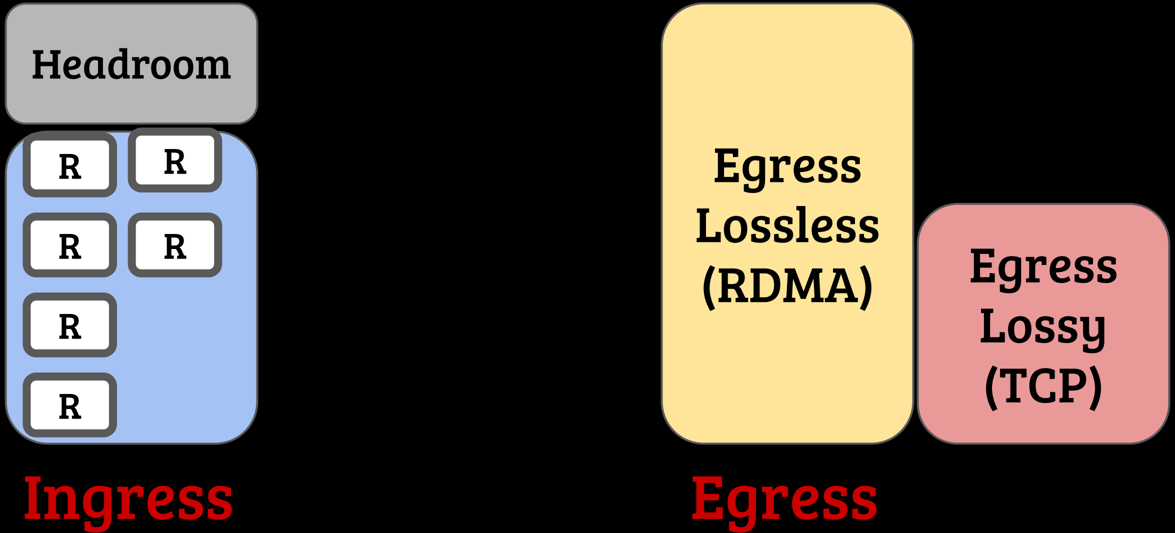

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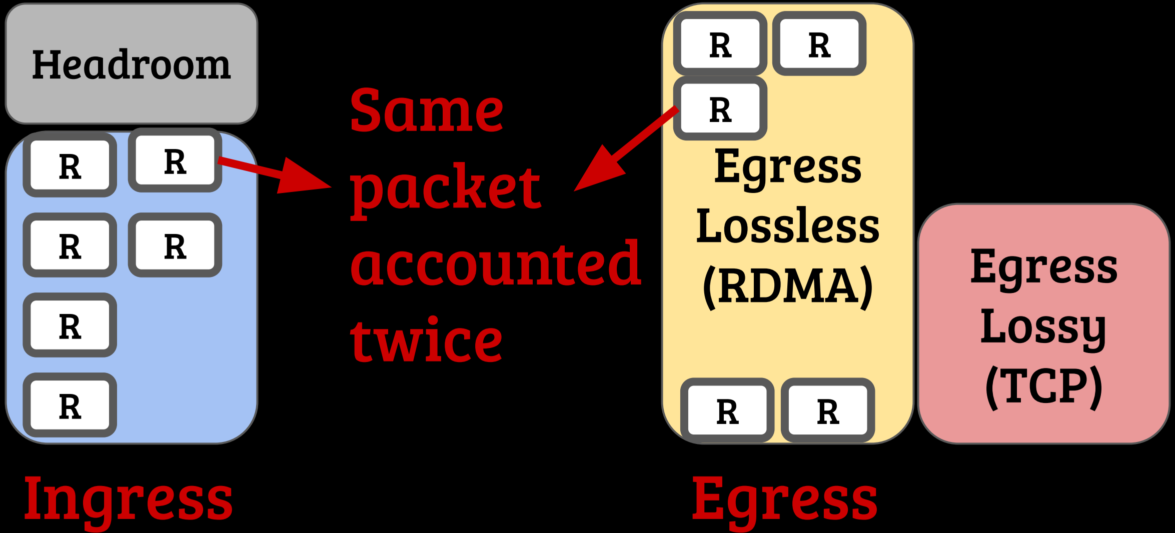

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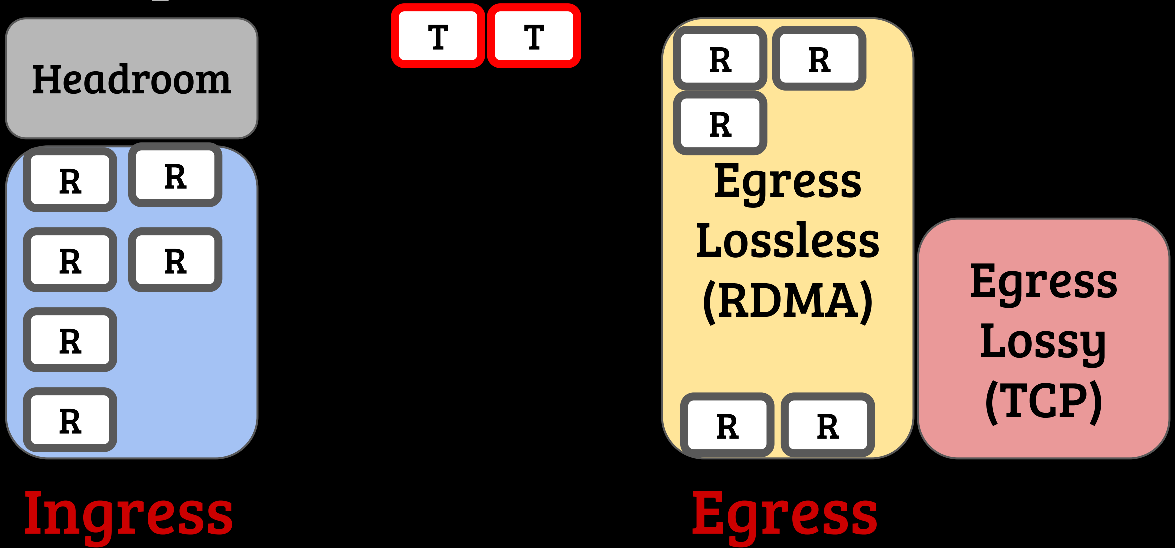
- Example: TCP packets



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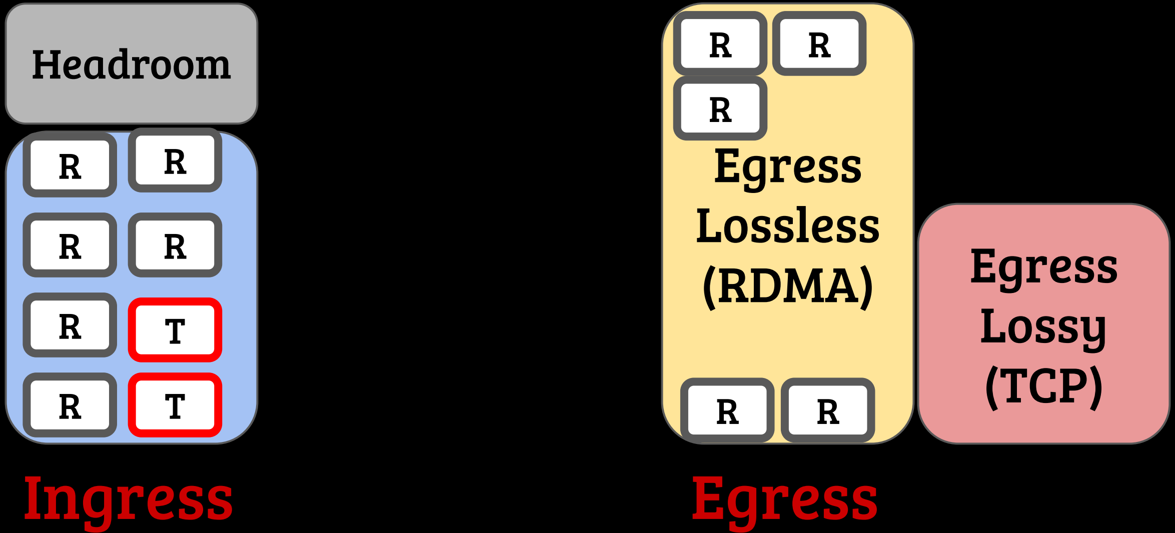

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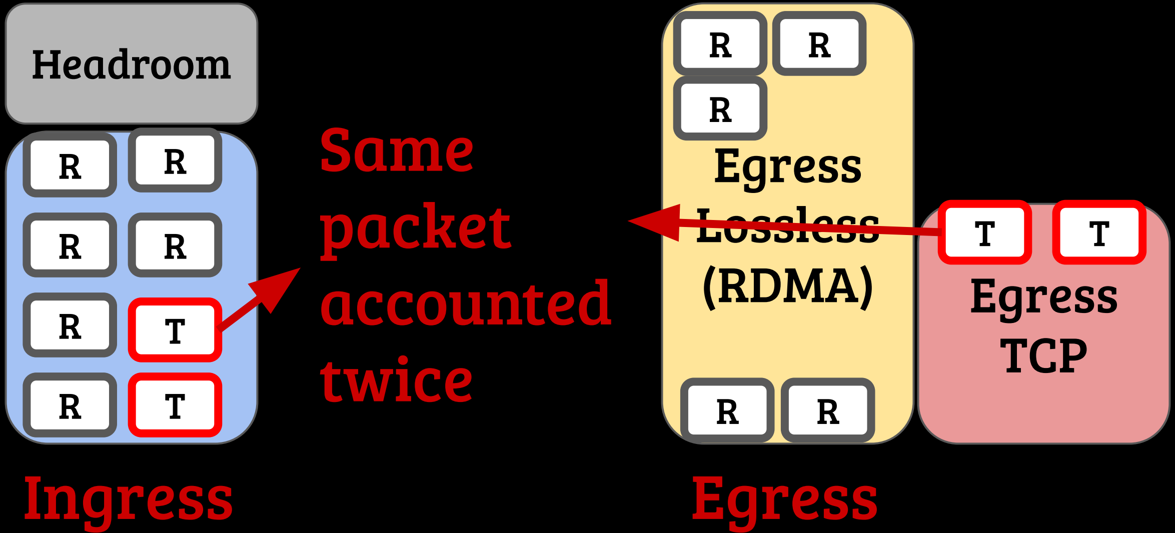
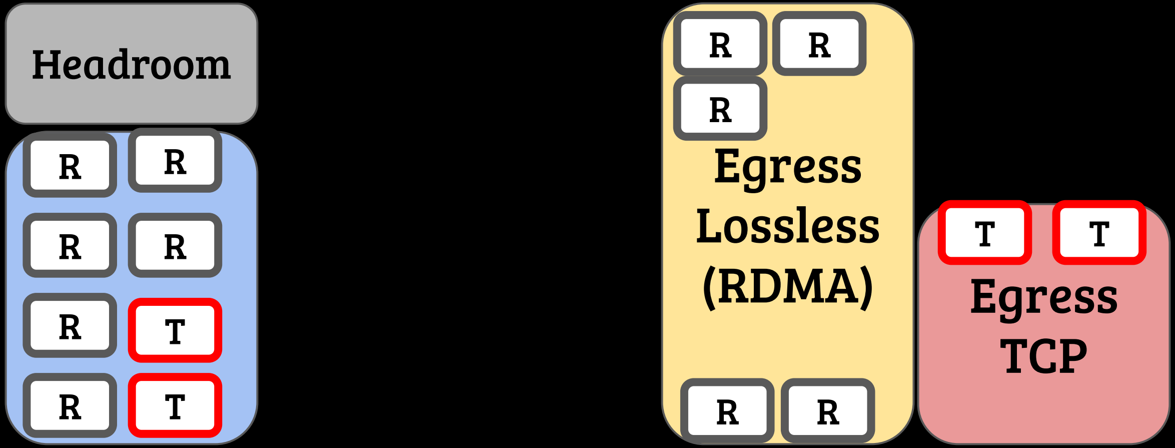


Background: SONiC Buffer Model

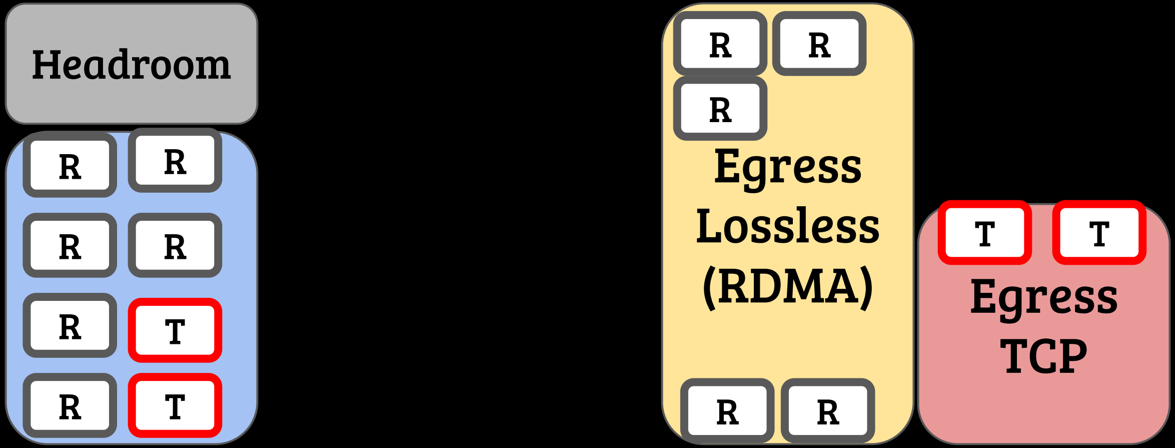
- Admission Control: Dynamic Thresholds in each pool



Ingress Egress

Background: SONiC Buffer Model

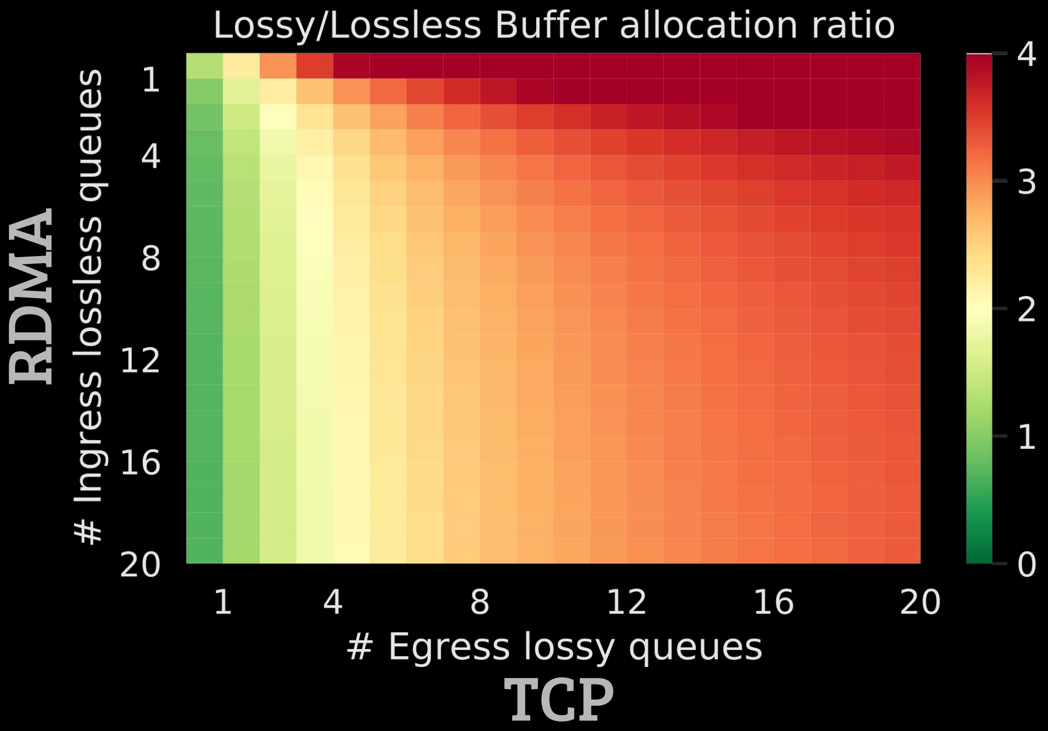
- Admission Control: $\alpha \times$ Remaining pool size



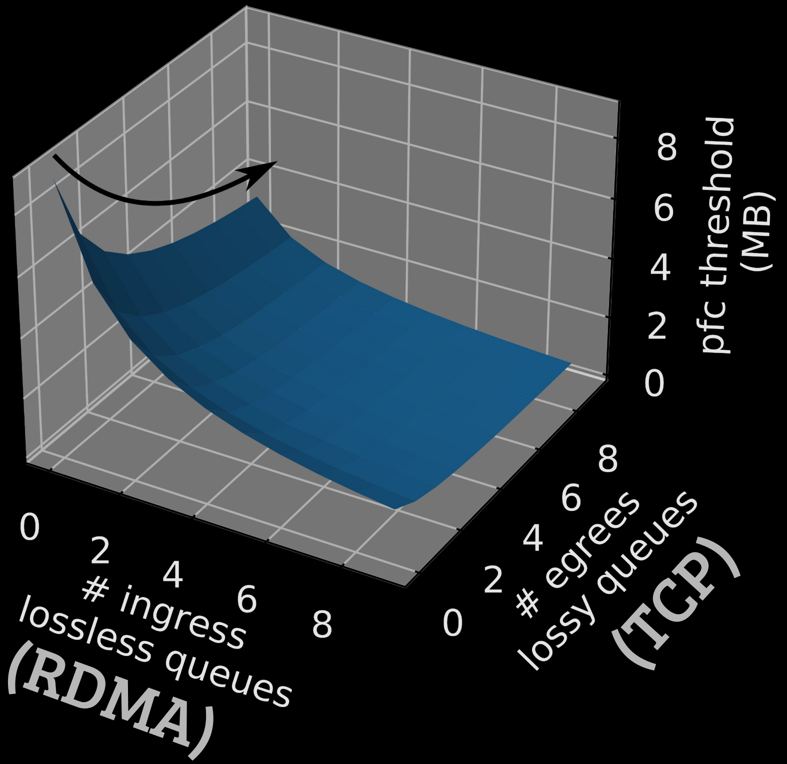
Ingress

Egress

Problem 1: TCP Gets More Buffer than RDMA under Contention



Problem 2: RDMA PFC Pause Due to TCP's Buffer Occupancy



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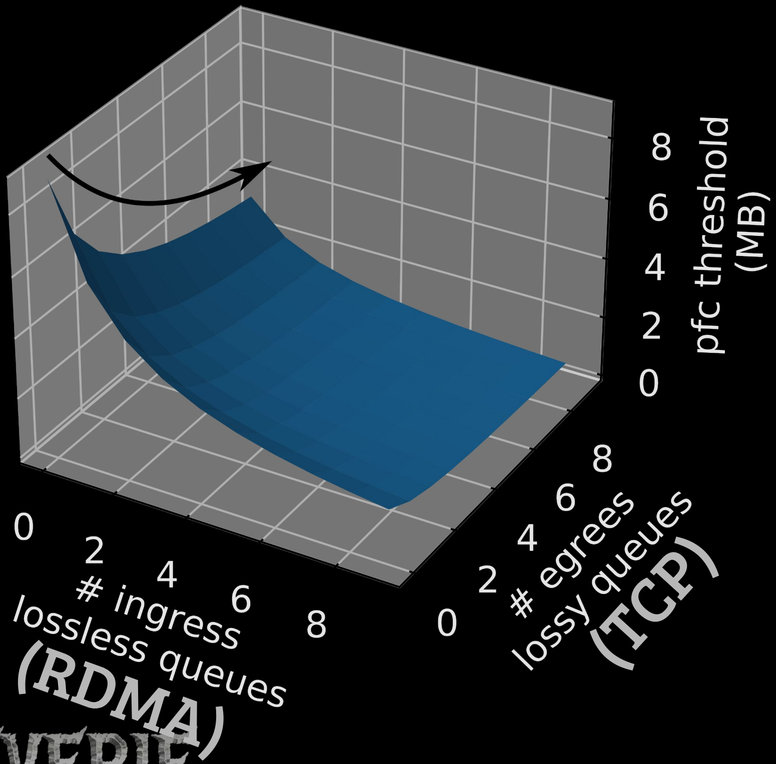

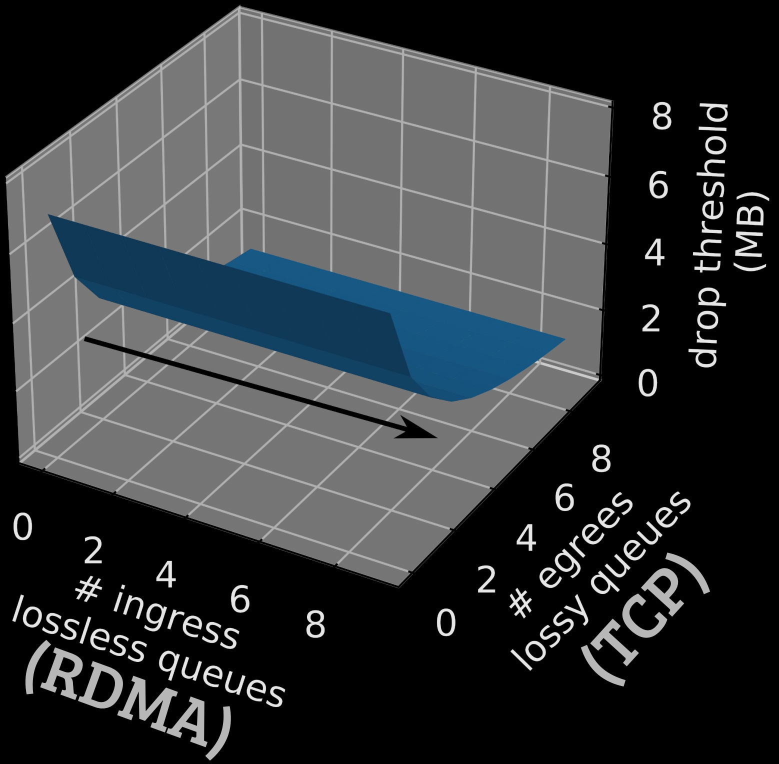

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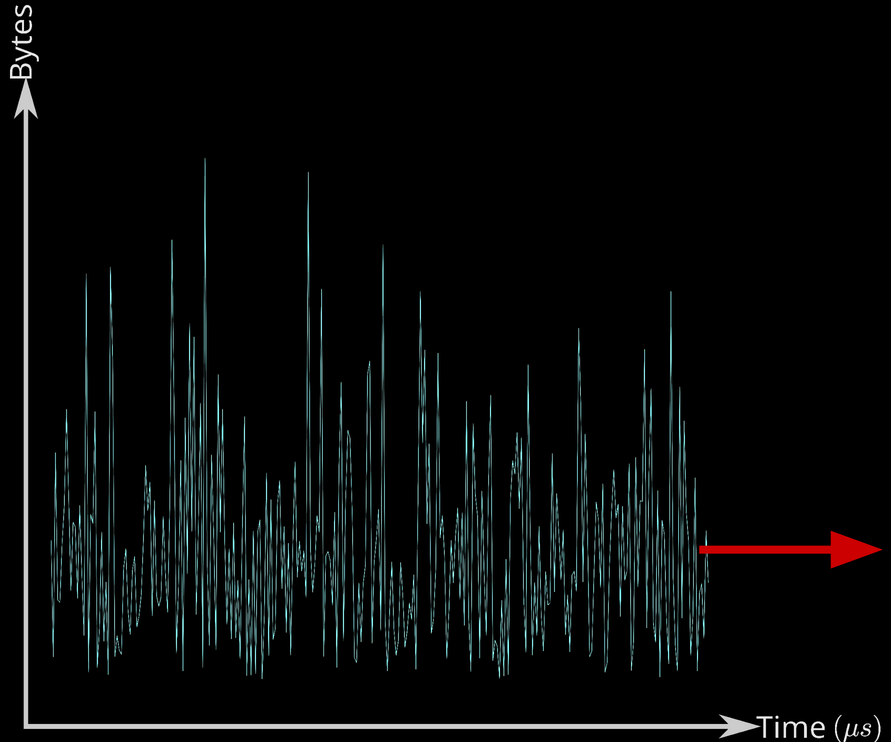
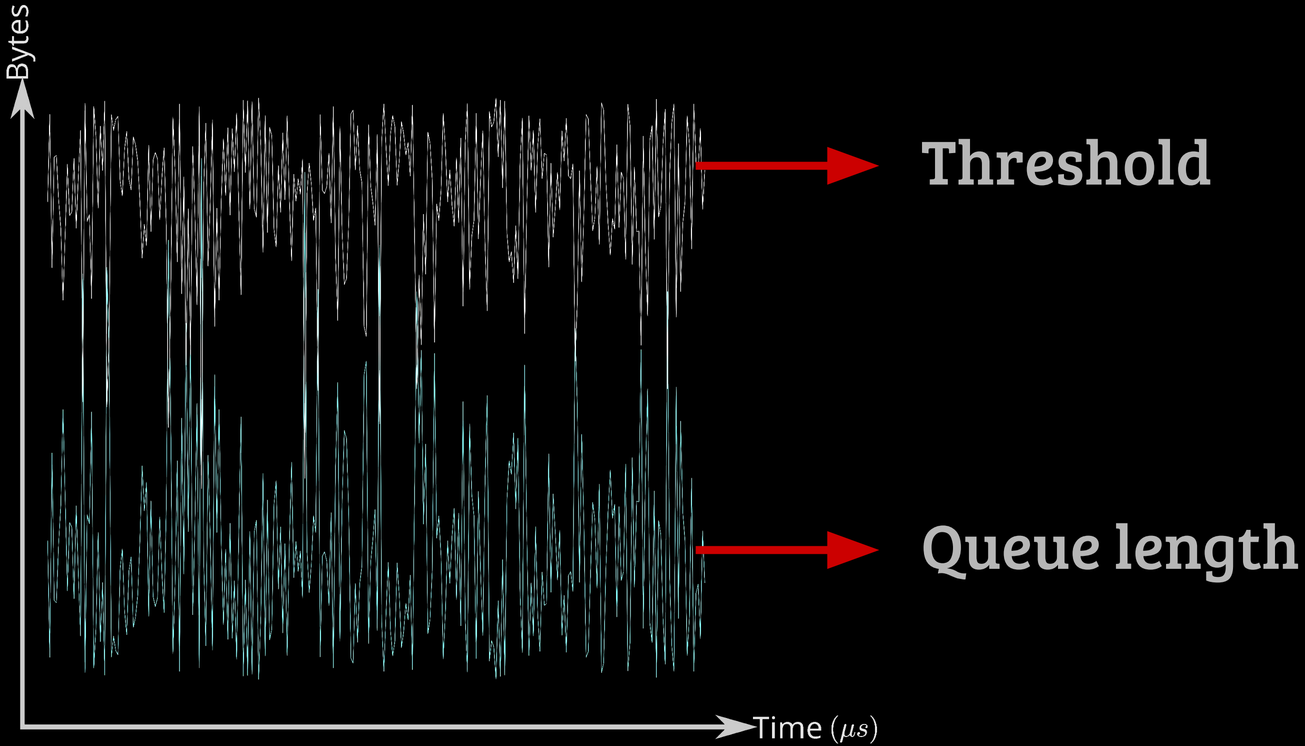
Problem 3: Poor Burst Absorption



Queue length

Problem 3: Poor Burst Absorption



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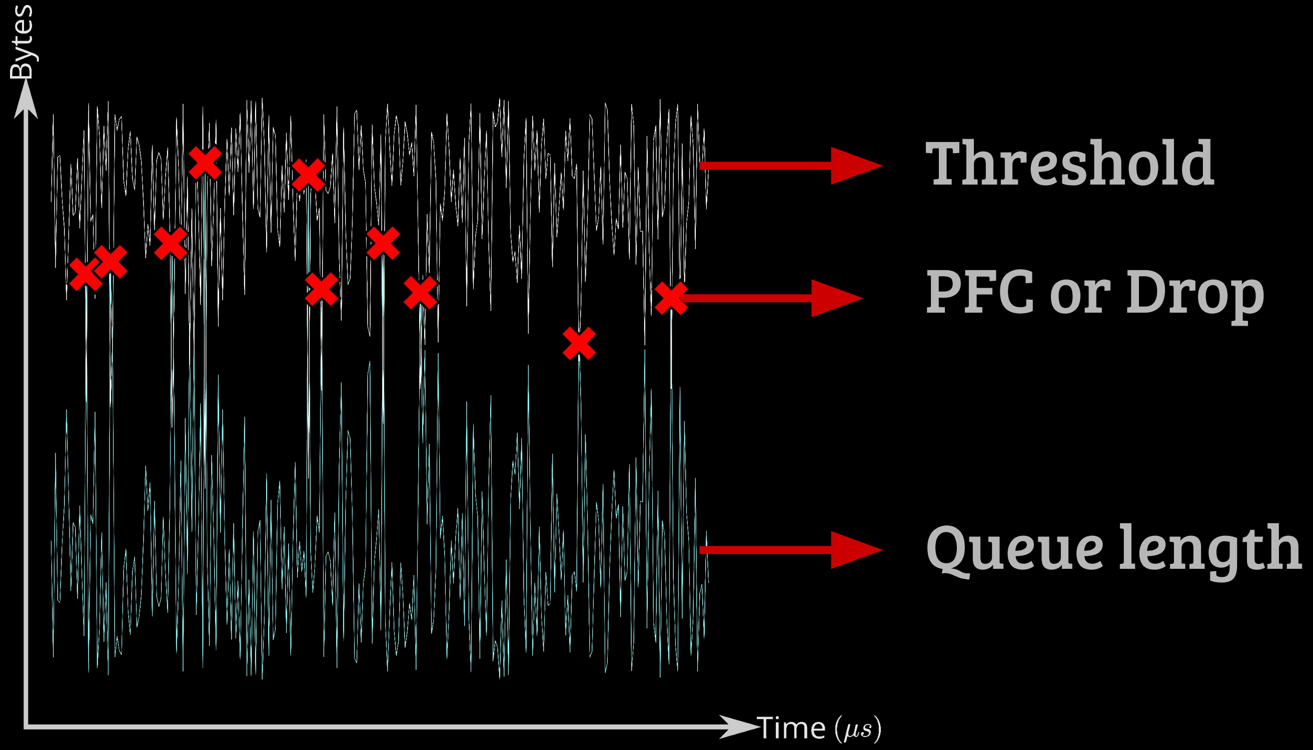

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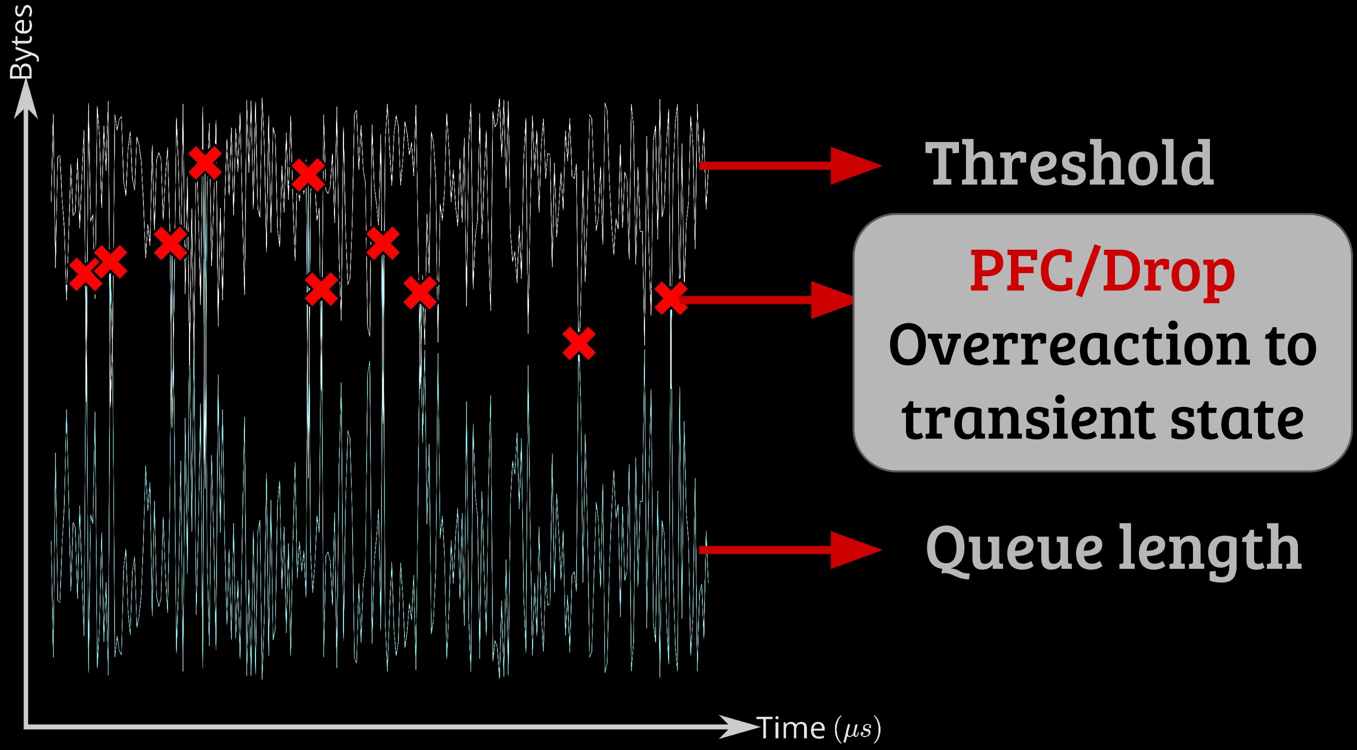

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Can we isolate RDMA and TCP while improving burst absorption?

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Reverie

- Achieves isolation across RDMA and TCP
- Improves burst absorption

Reverie

- Single shared buffer pool for RDMA and TCP

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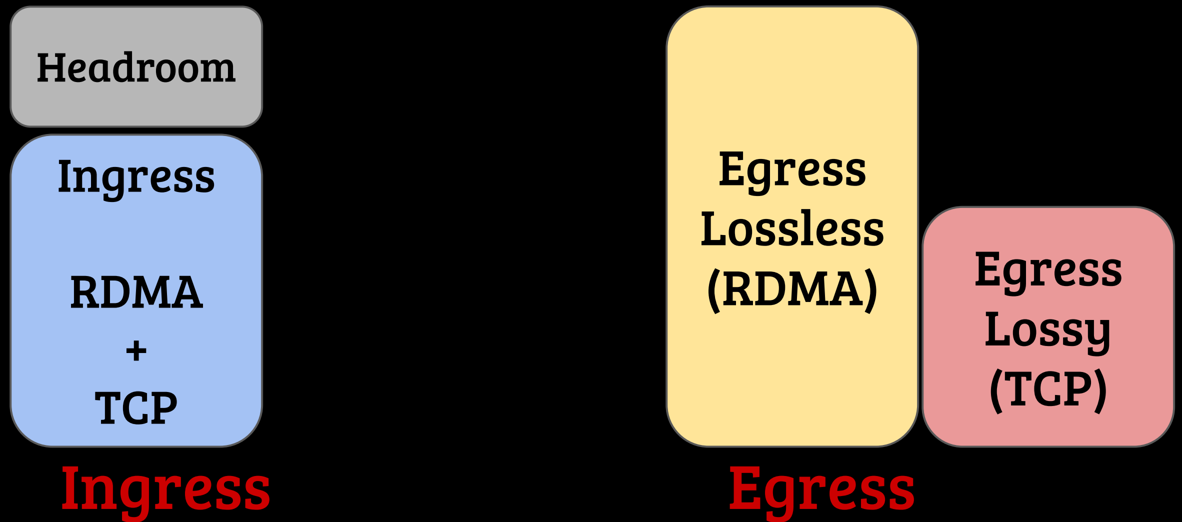

Reverie

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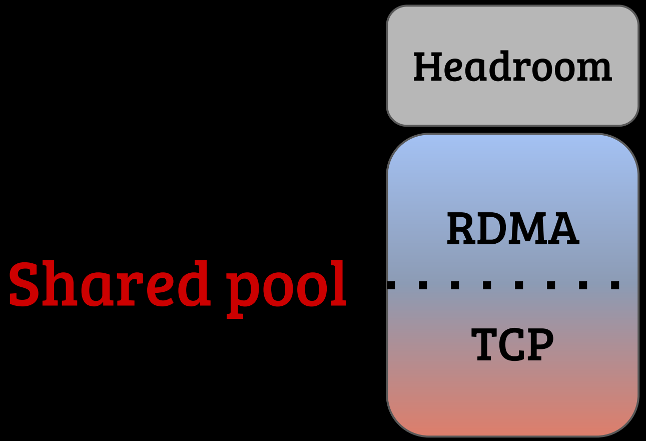
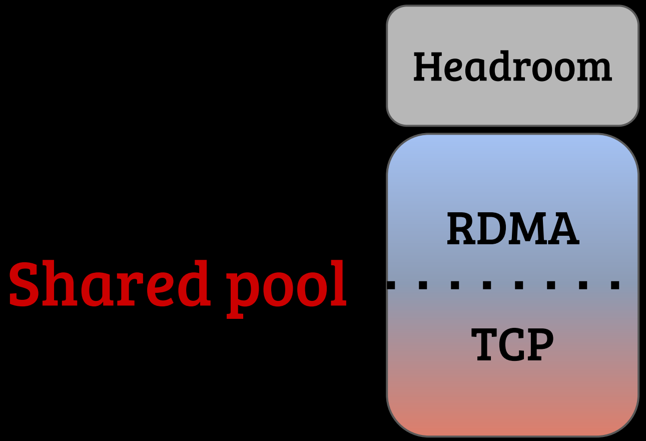


Reverie

- Single shared buffer pool for RDMA and TCP
- Consolidated ingress and egress buffer views
  - Birds-eye view of the buffer



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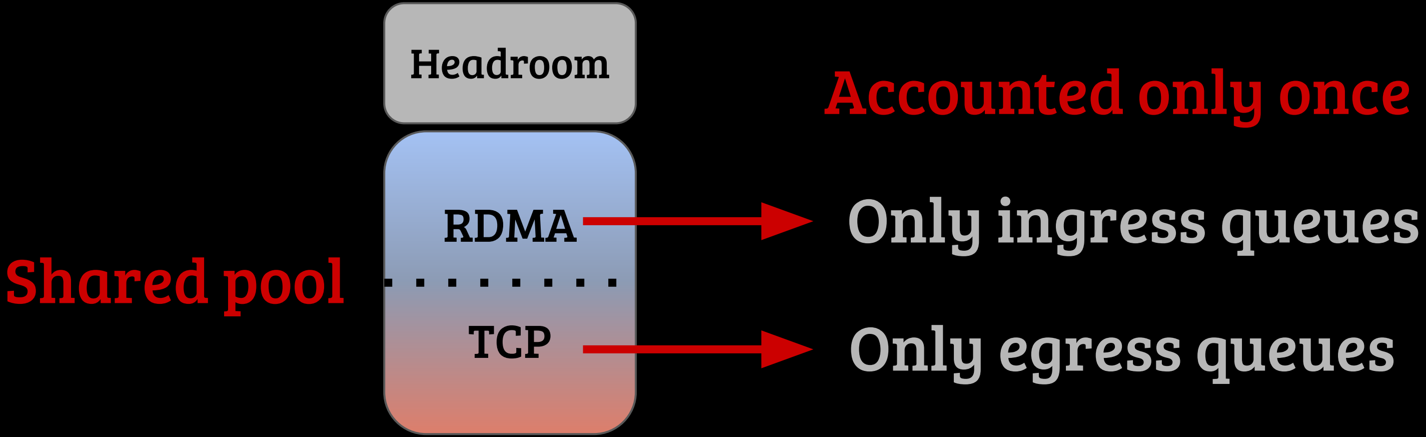

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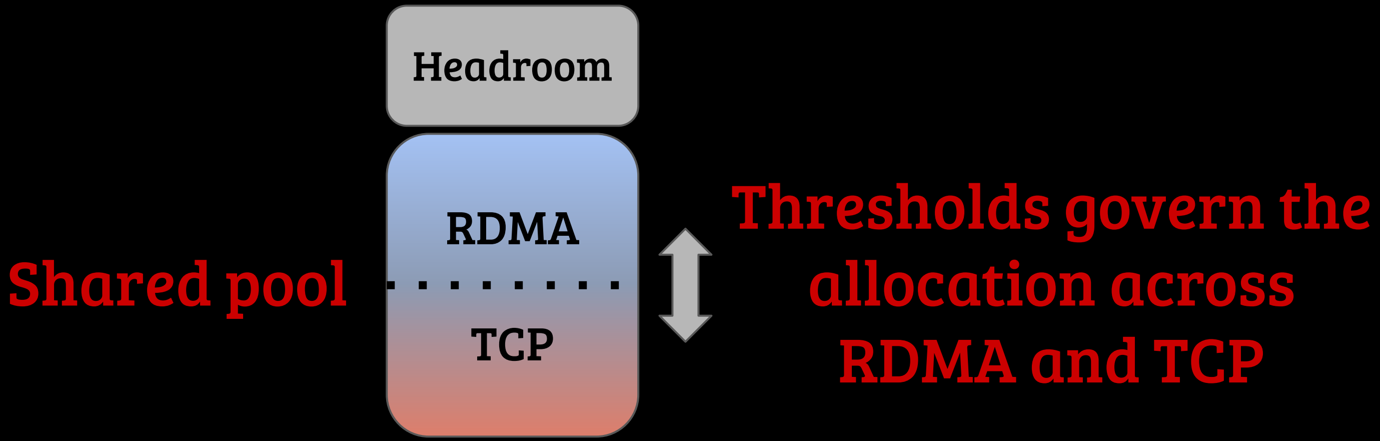


Reverie

- Threshold: $\boxed{\alpha_p}$ □ (Remaining shared pool) □ $\frac{1}{n_p}$

Configurable parameter for each queue
e.g., α_r for RDMA (ingress queues) and
α_t for TCP (egress queues)

Reverie

- Threshold: α_p □ $\boxed{\text{(Remaining shared pool)}}$ □ $\frac{1}{n_p}$

$\downarrow$

Shared pool size — total shared occupancy

Reverie

- Threshold: α_p □ (Remaining shared pool) □ $\frac{1}{\boxed{n_p}}$

$$\big\downarrow$$

Number of congested queues of type p

Reverie

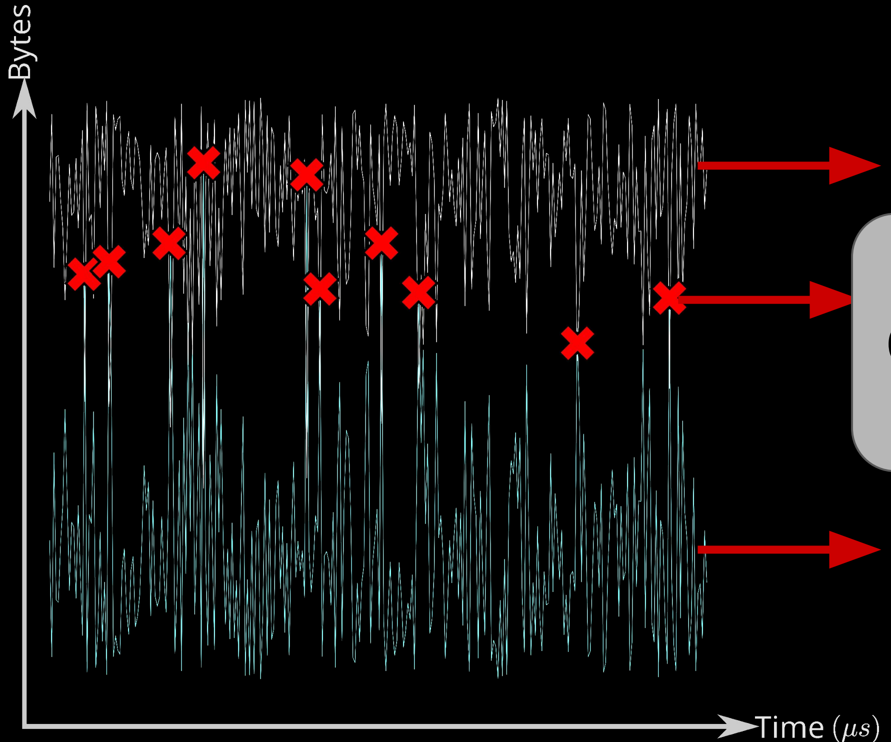
- Threshold: $\underbrace{\alpha_p \;\square\; (\text{Remaining shared pool}) \;\square\; \frac{1}{n_p}}_{\text{RDMA vs TCP}}$

Isolation ✅
Fair allocation ✅

Reverie

- Single shared buffer pool for RDMA and TCP
- Consolidated ingress and egress buffer views
  - Birds-eye view of the buffer
- Low pass filter-based admission control
  - High burst absorption

Reverie

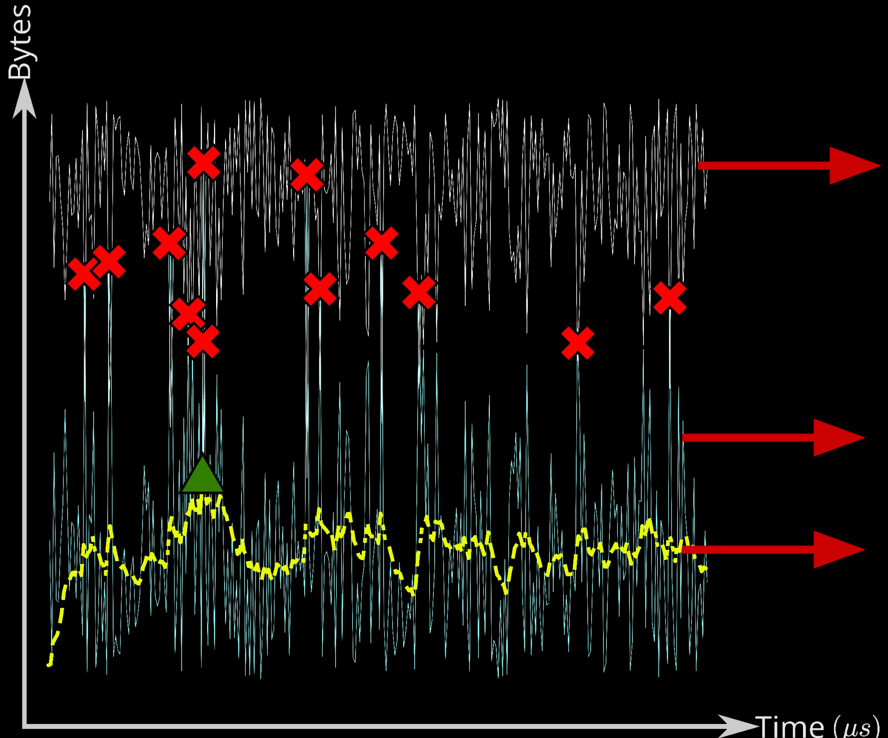


Threshold

PFC/Drop
Overreaction to transient state

Queue length

Reverie



Threshold

~~Queue length~~

Low-pass filtered Queue length

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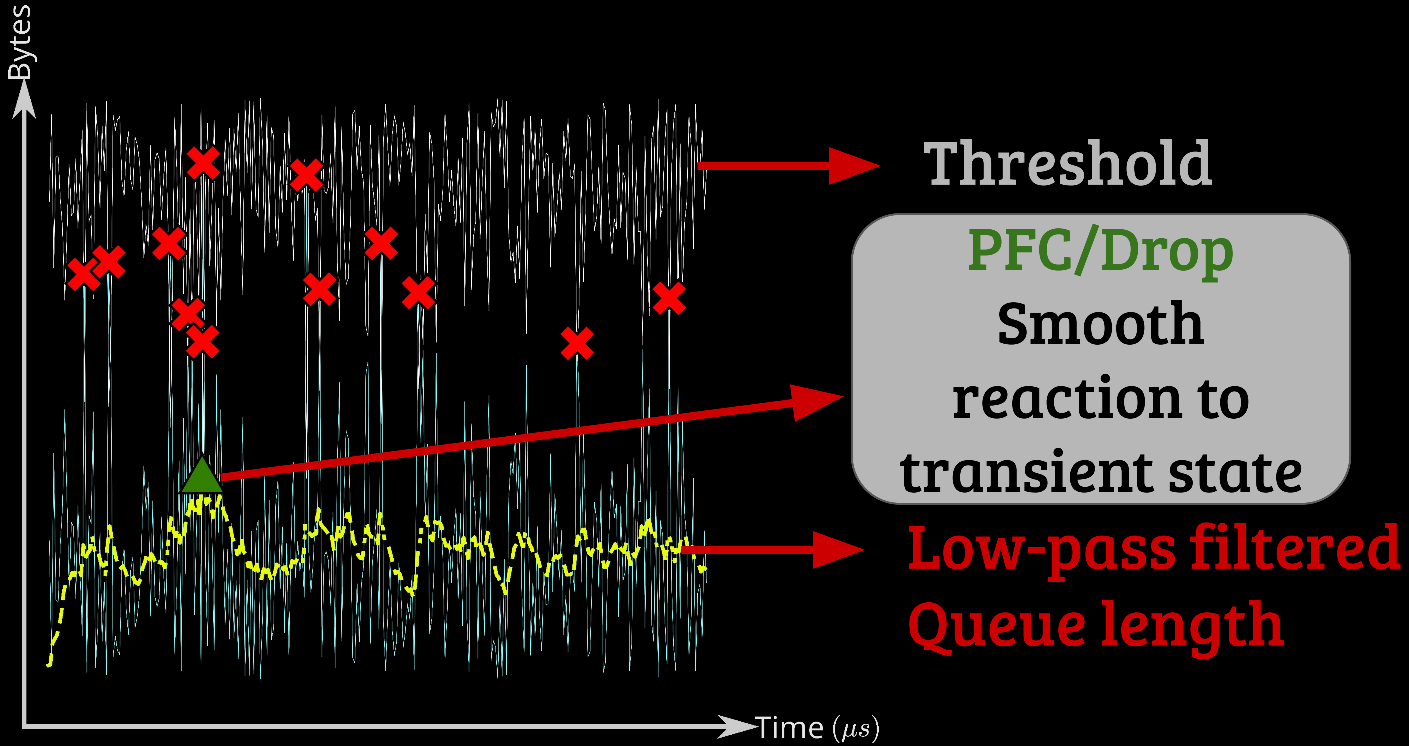
Reverie


Bytes
Time (μs)
Threshold
PFC/Drop
Smooth reaction to transient state
Low-pass filtered Queue length

Reverie's properties

- Fair allocation across RDMA and TCP
- Steady-state isolation
- Improved burst absorption
- (Formal proofs in the paper)

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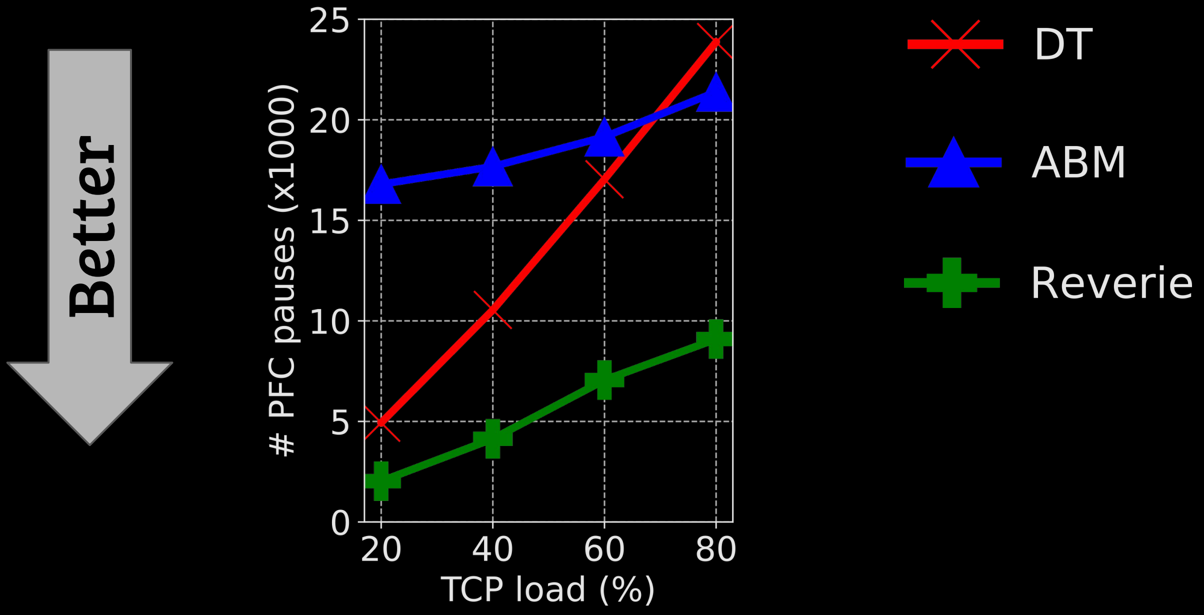
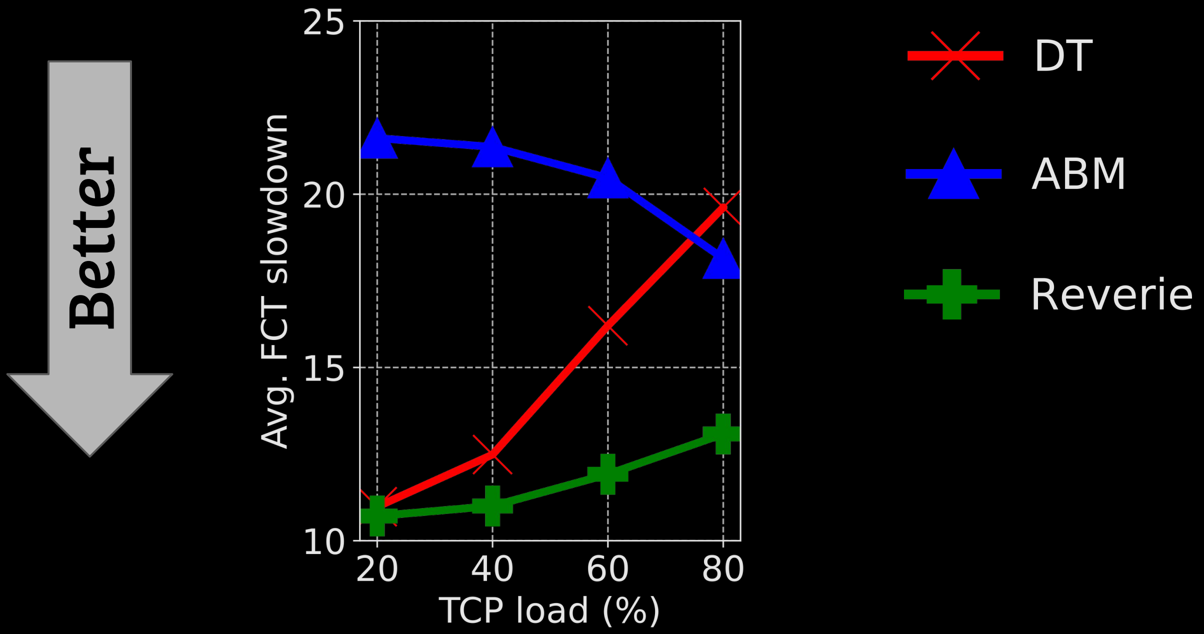
Evaluation

- Packet-level simulations using NS3
- 256 servers, 4 spine switches and 16 ToR switches
- 25Gbps NICs
- Websearch workload + Synthetic incast workload
- Shared buffer at the switches
  - Dynamic Thresholds (SONiC model)
  - ABM (SONiC model)
  - Reverie

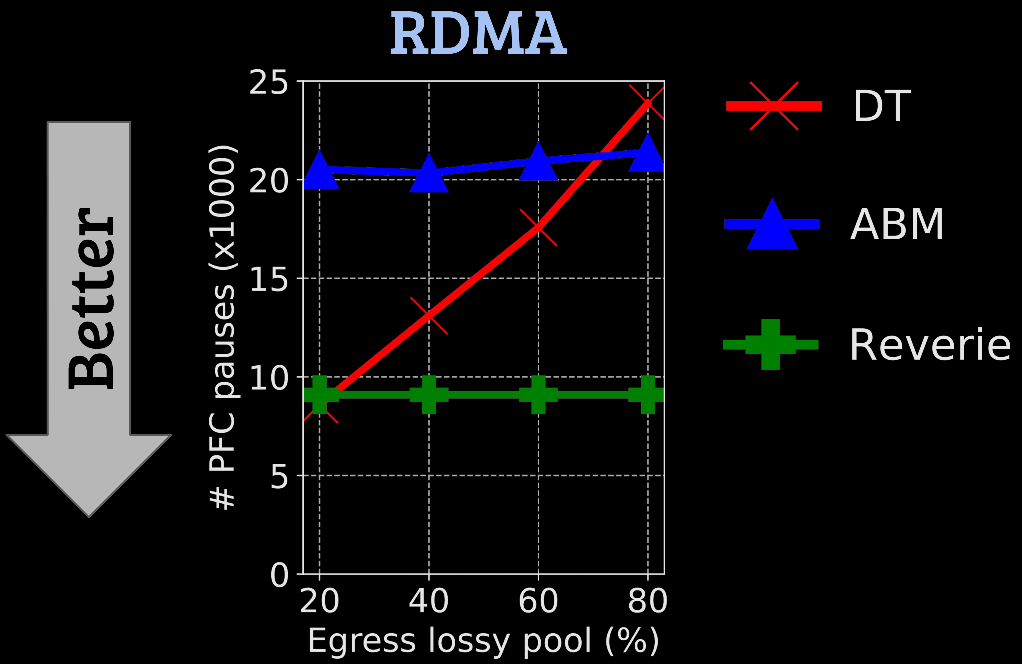
Reverie Reduces the Interactions Between TCP and RDMA

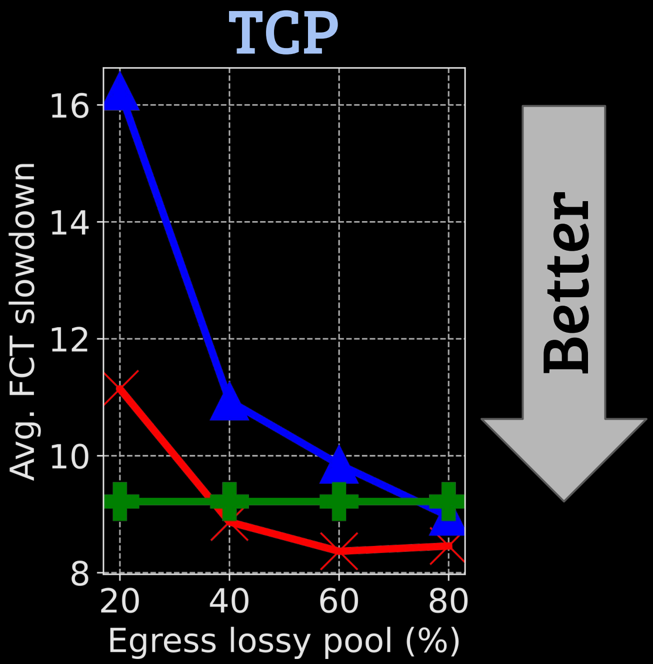


Reverie Improves Burst Absorption for RDMA



Reverie Improves the Performance of both RDMA and TCP





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Conclusion

- Existing buffer sharing techniques cannot serve the diverse buffer needs of RDMA and TCP
- Reverie achieves isolation between RDMA and TCP
- Reverie improves burst absorption for RDMA and TCP
- Reverie improves flow completions for RDMA and TCP
- Source code: https://github.com/inet-tub/ns3-datacenter

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Thank You