Active Buffer Management in Datacenters

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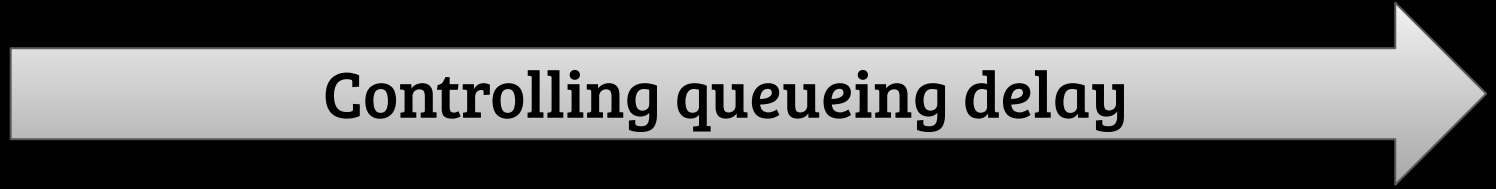
Active Queue Management (AQM)

Buffer Management (BM)

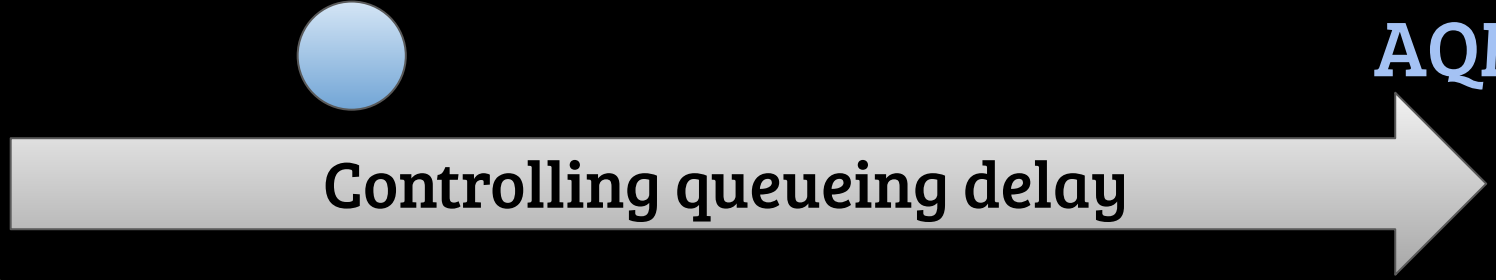
ABM

AQM



ABM

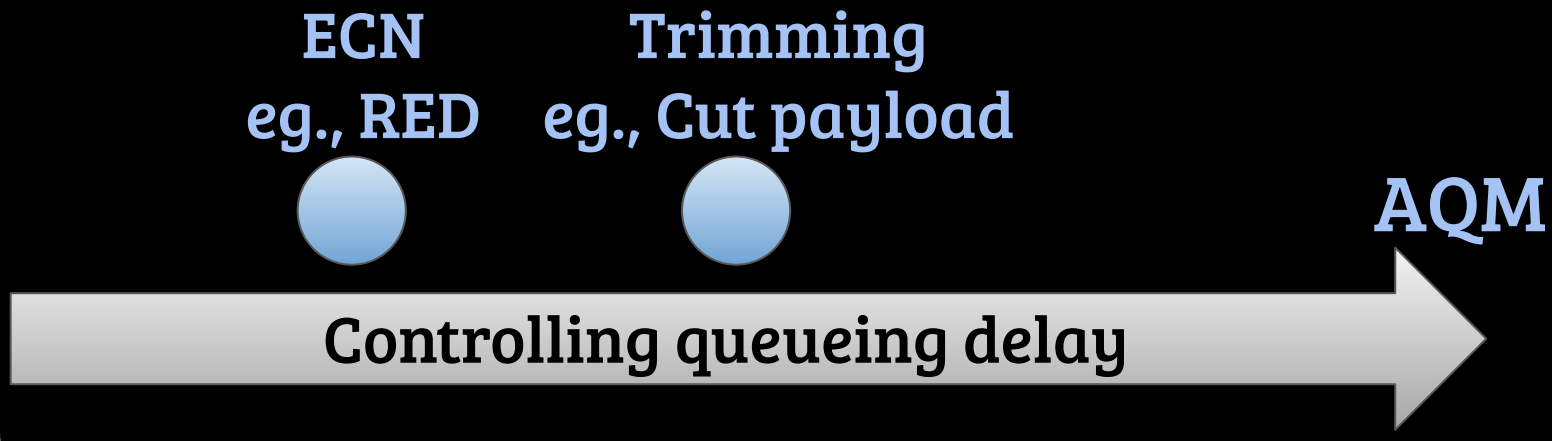
ECN
eg., RED



AQM

Controlling queueing delay

ABM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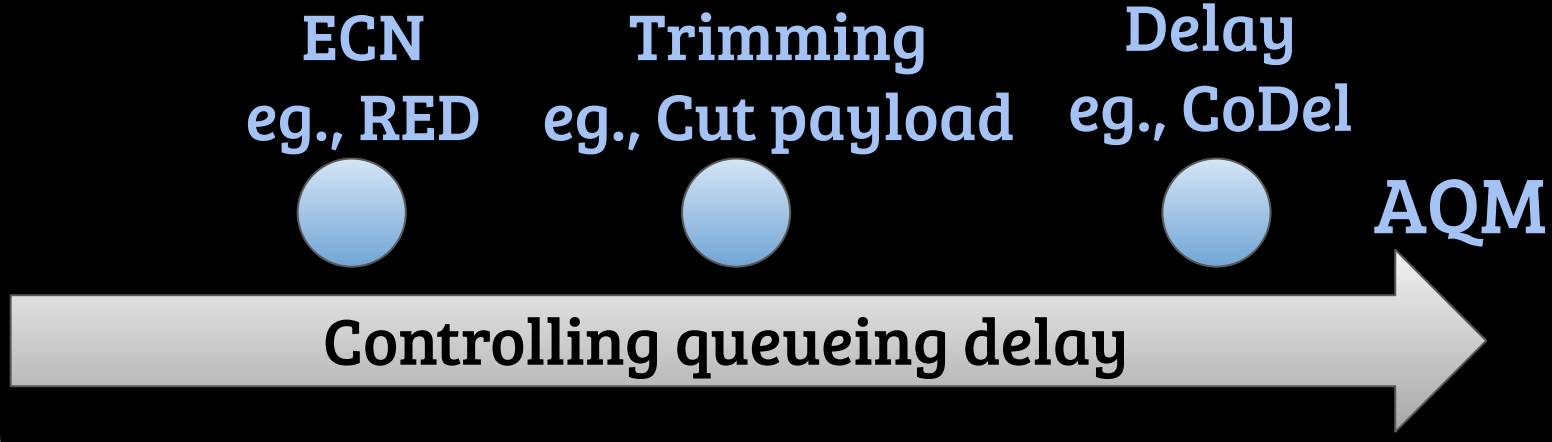
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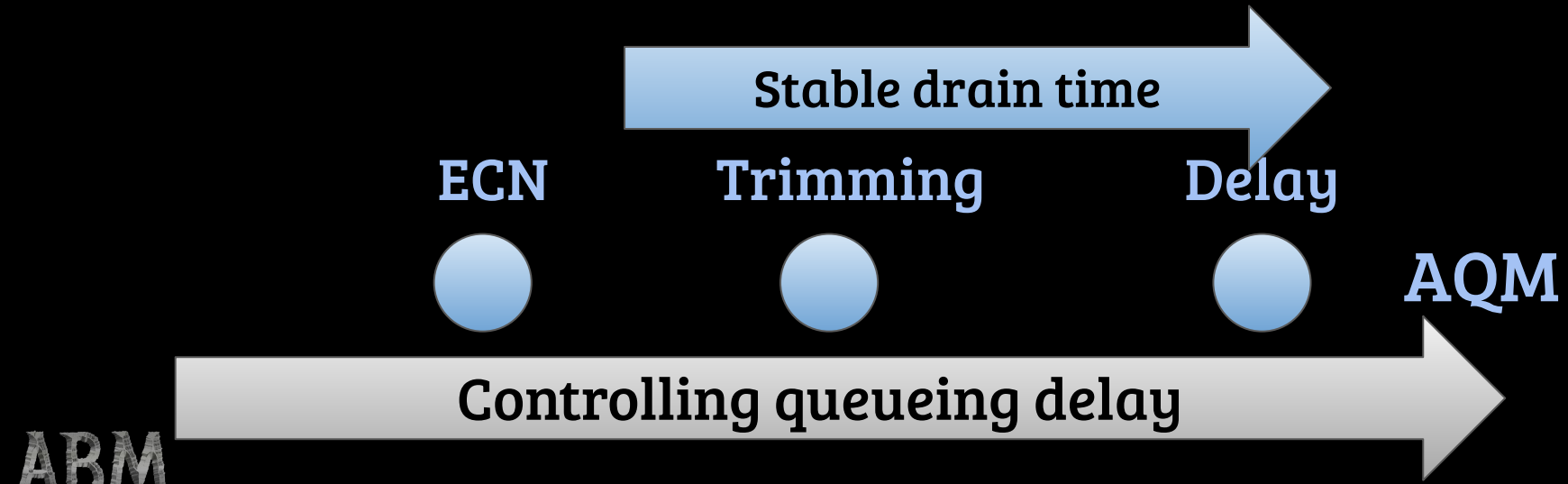
Stable drain time
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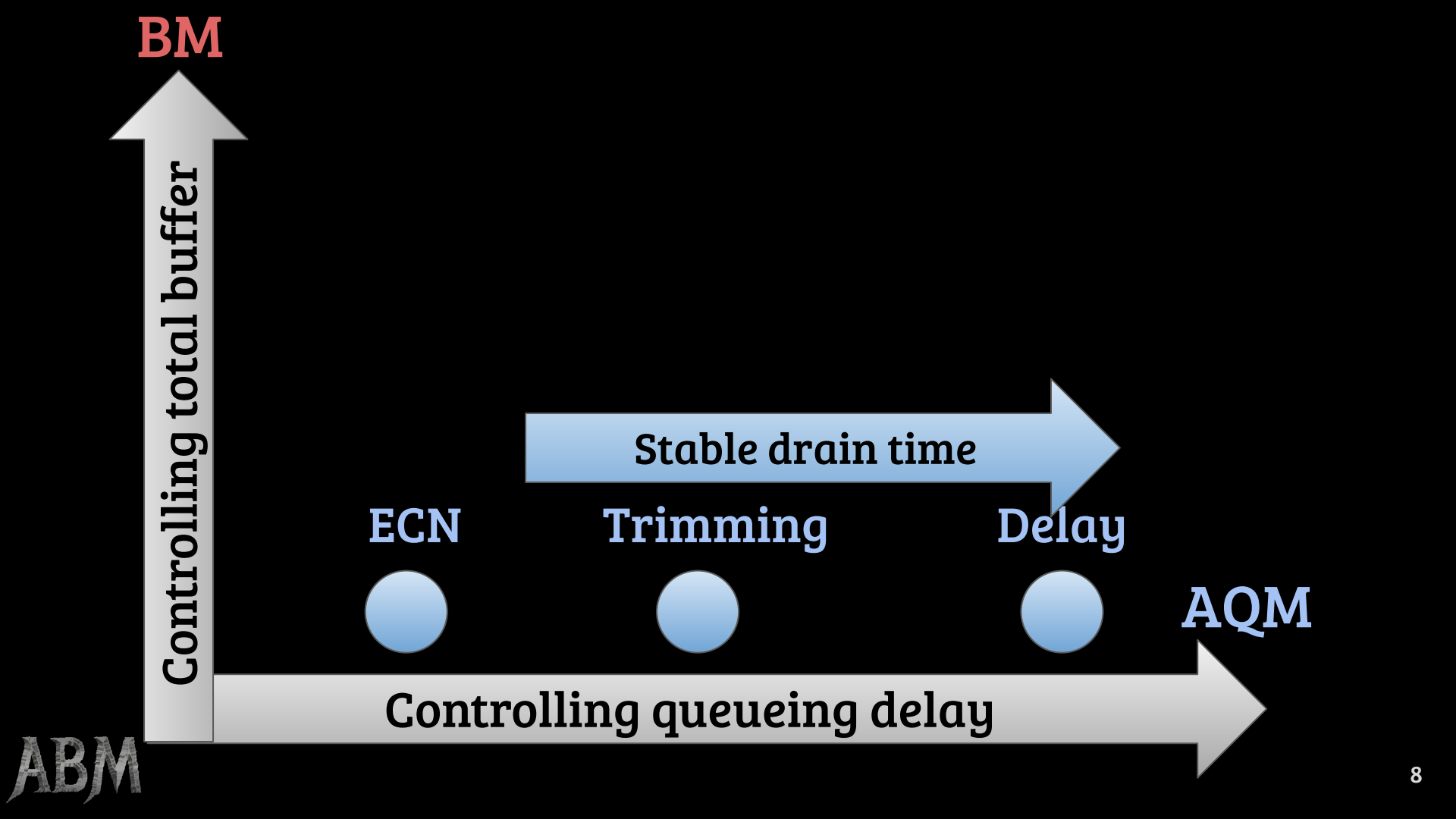
BM
Controlling total buffer
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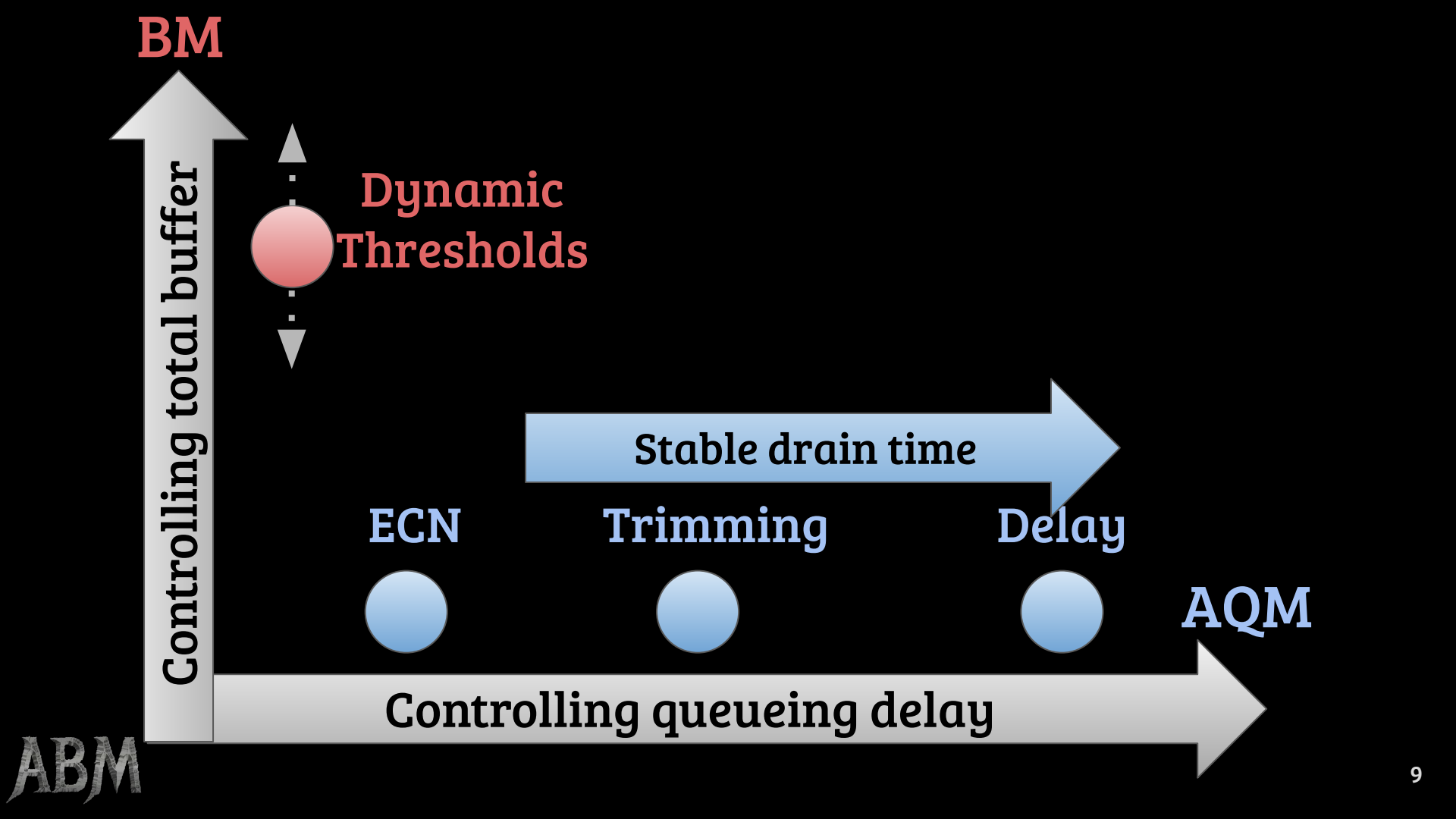
BM
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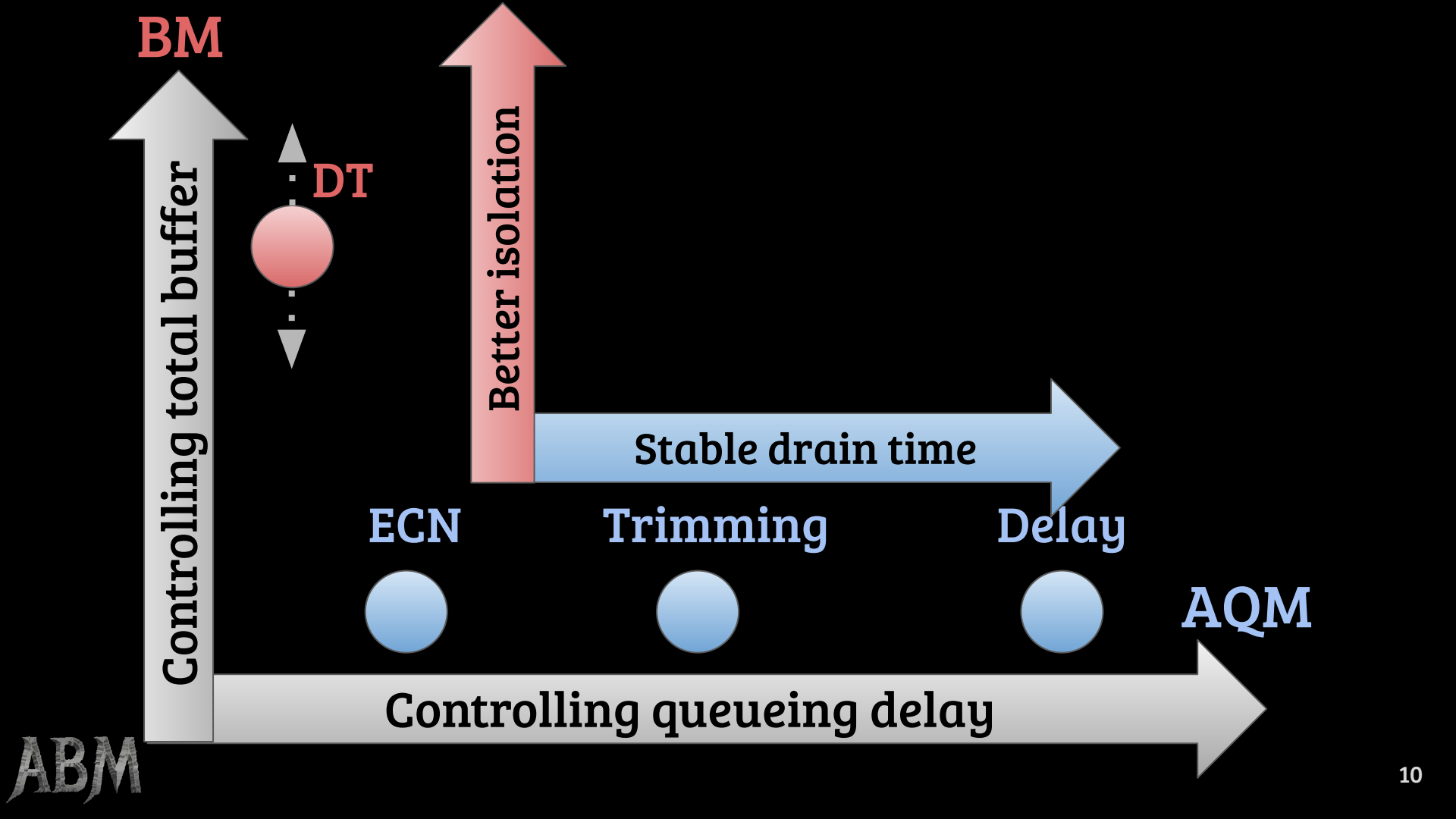
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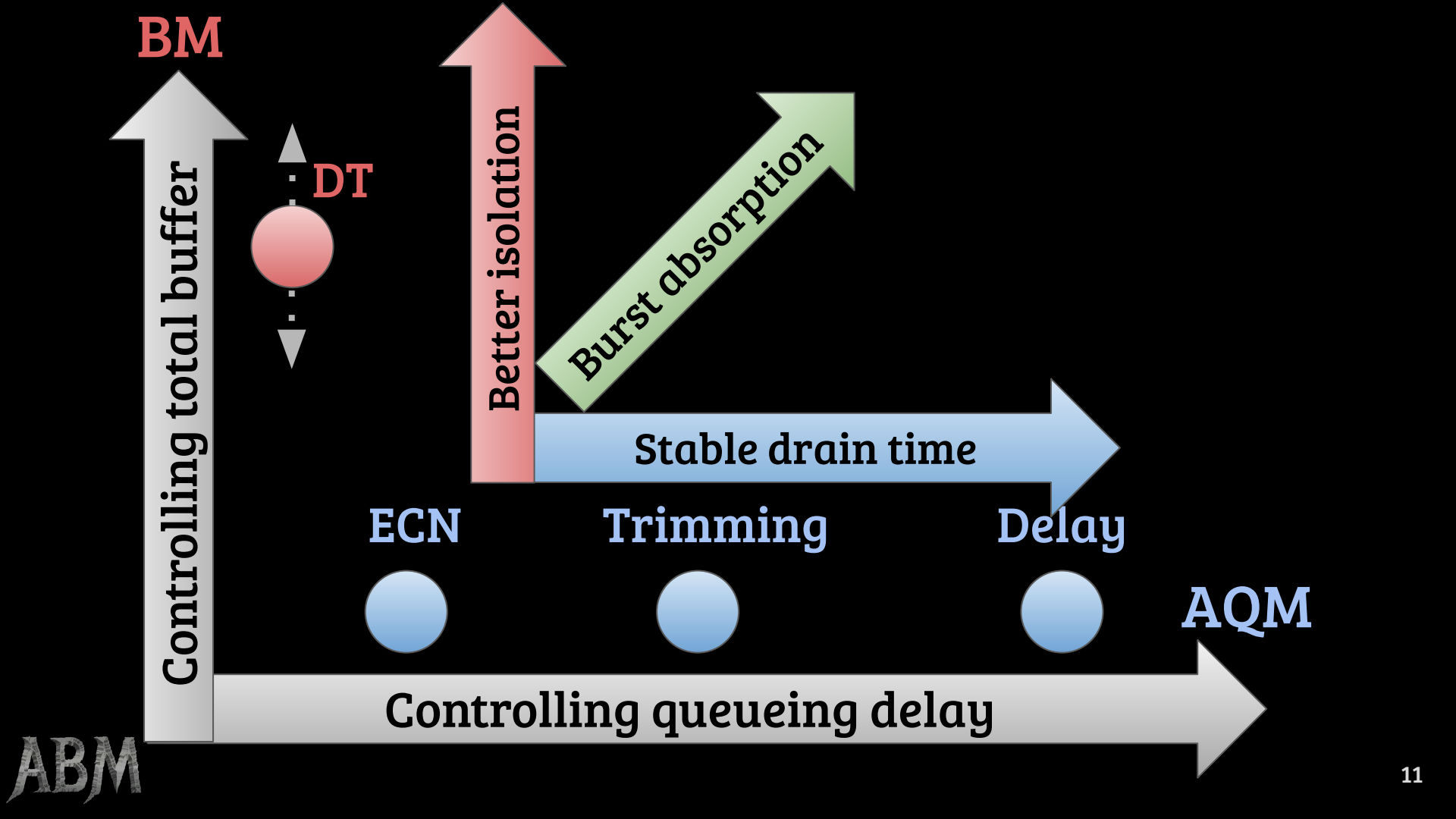
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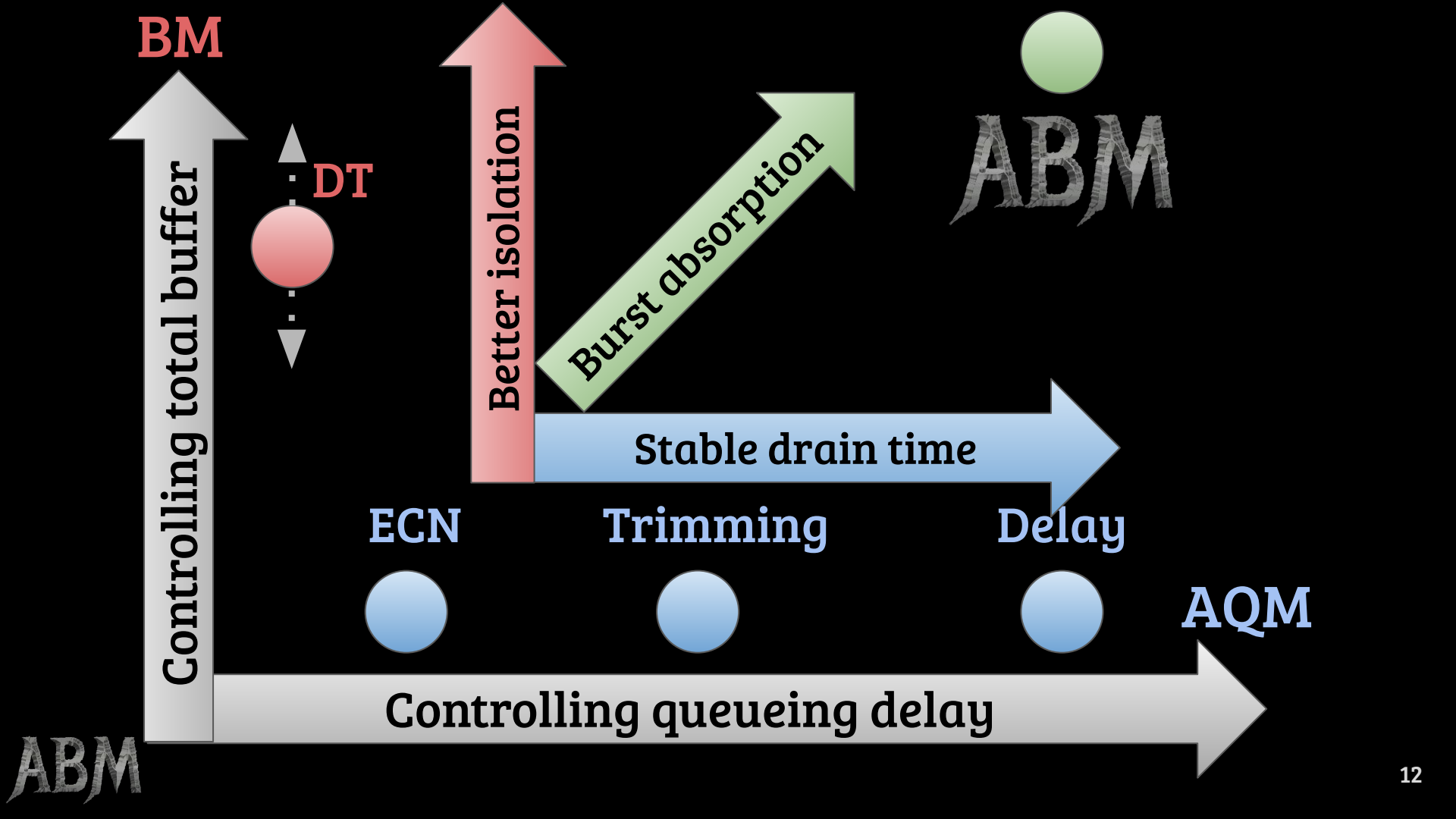
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What is ABM?

- A novel Buffer Sharing algorithm
  for datacenter switches

ABM

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- ~~Independent AQM and Buffer Management~~

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- **A**QM that depends on **B**uffer **M**anagement

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  - *Isolation across traffic priorities (eg., different SLAs)*

ABM

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- **A**ctive **B**uffer **M**anagement
  - *Isolation across traffic priorities (eg., different SLAs)*
  - *Bounded queue drain time (Queueing delay)*
  - *Better burst absorption*

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Background on Buffer Sharing

- Both BM and AQM calculate *drop thresholds*

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  - function of the shared buffer space

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ABM

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- BM calculates a threshold for every queue in a *device*
  - function of the shared buffer space
- AQM calculates thresholds for a single queue
  - function of queue statistics
- BM and AQM act independently

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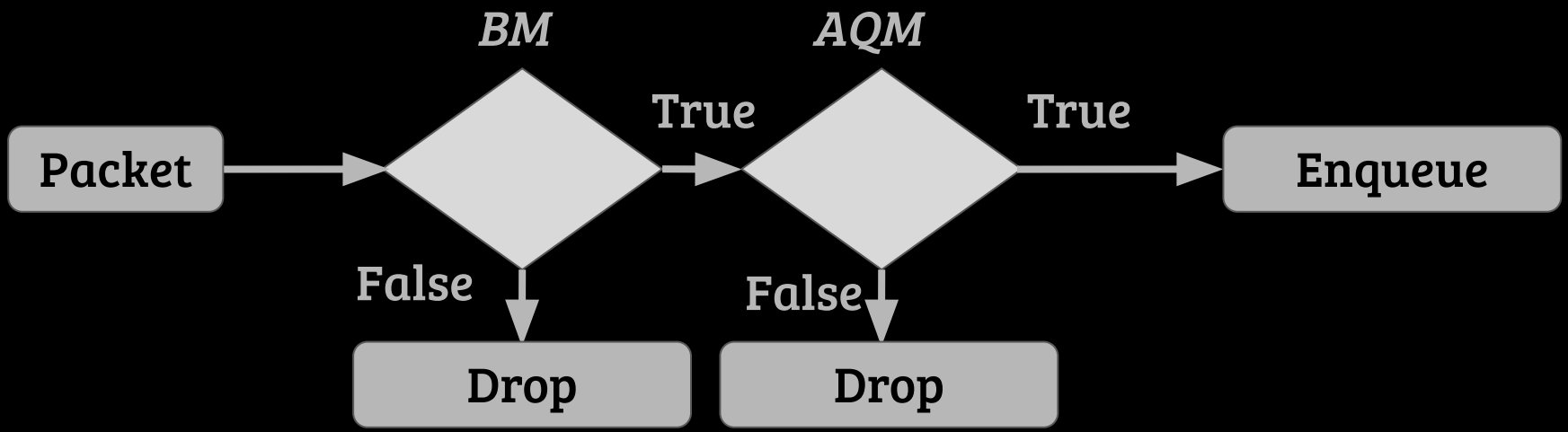
Hierarchical Admission Control Scheme



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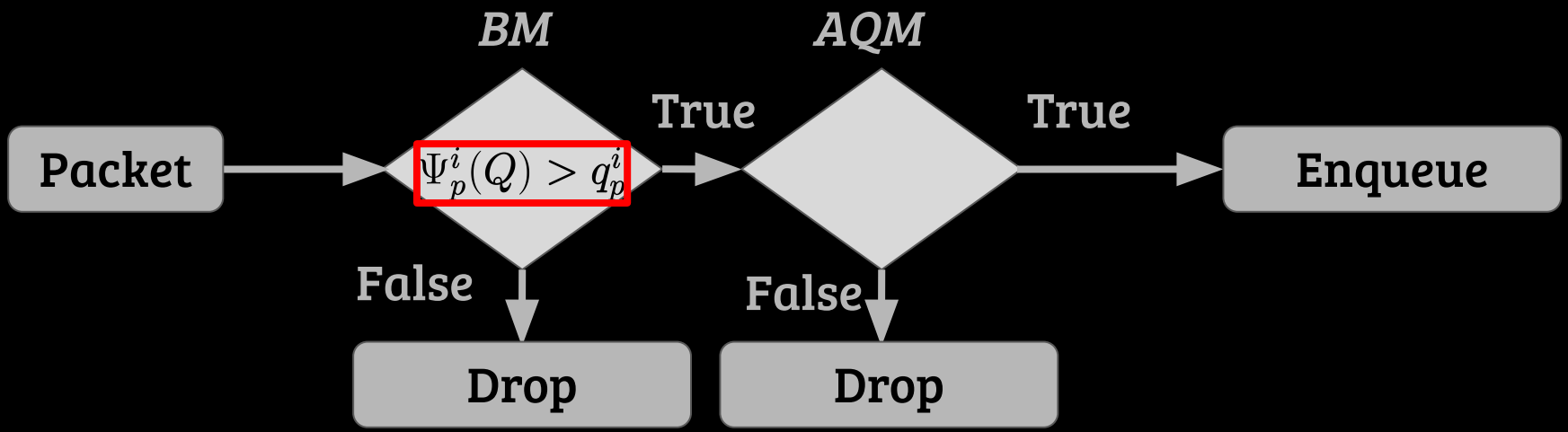
Hierarchical Admission Control Scheme



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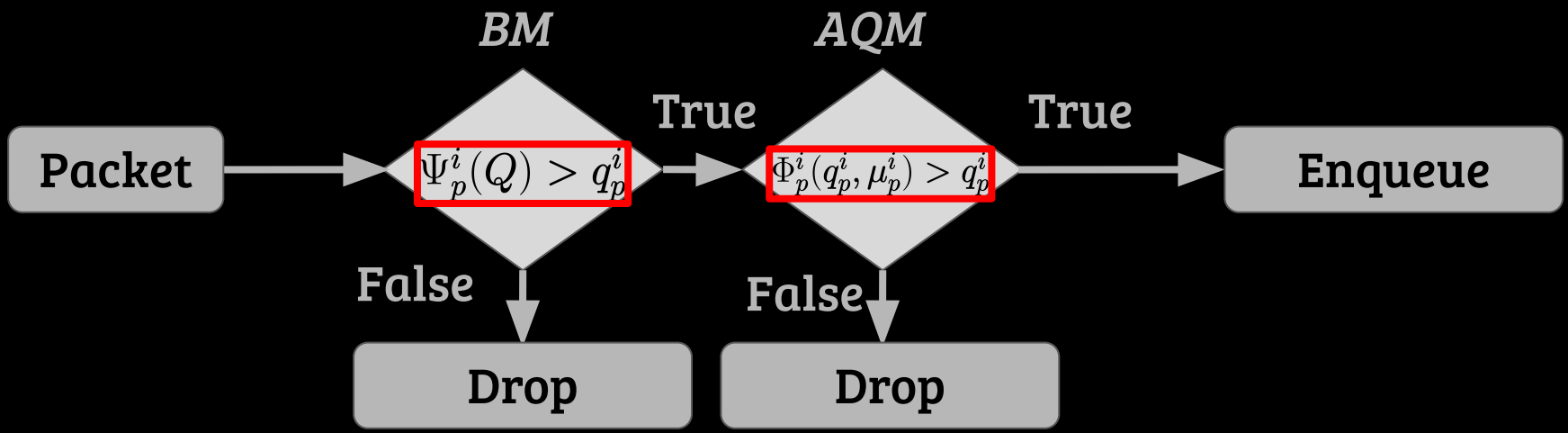

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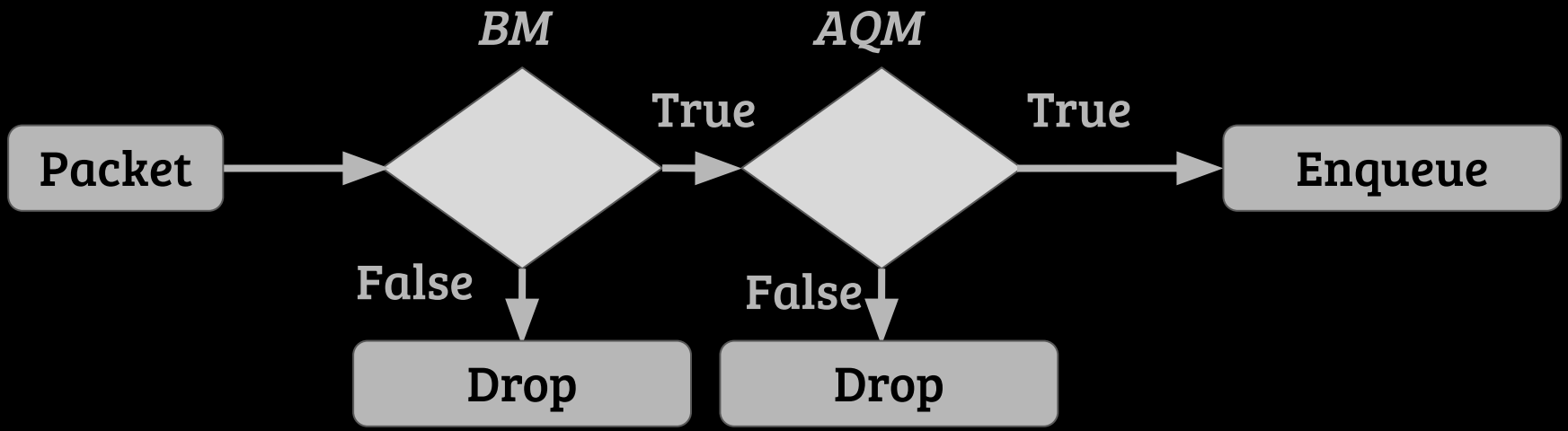
Hierarchical Admission Control Scheme

$$min\left(\underbrace{\Psi_p^i(Q)}_{BM}, \underbrace{\Phi_p^i(q_p^i, \mu_p^i)}_{AQM}\right)$$



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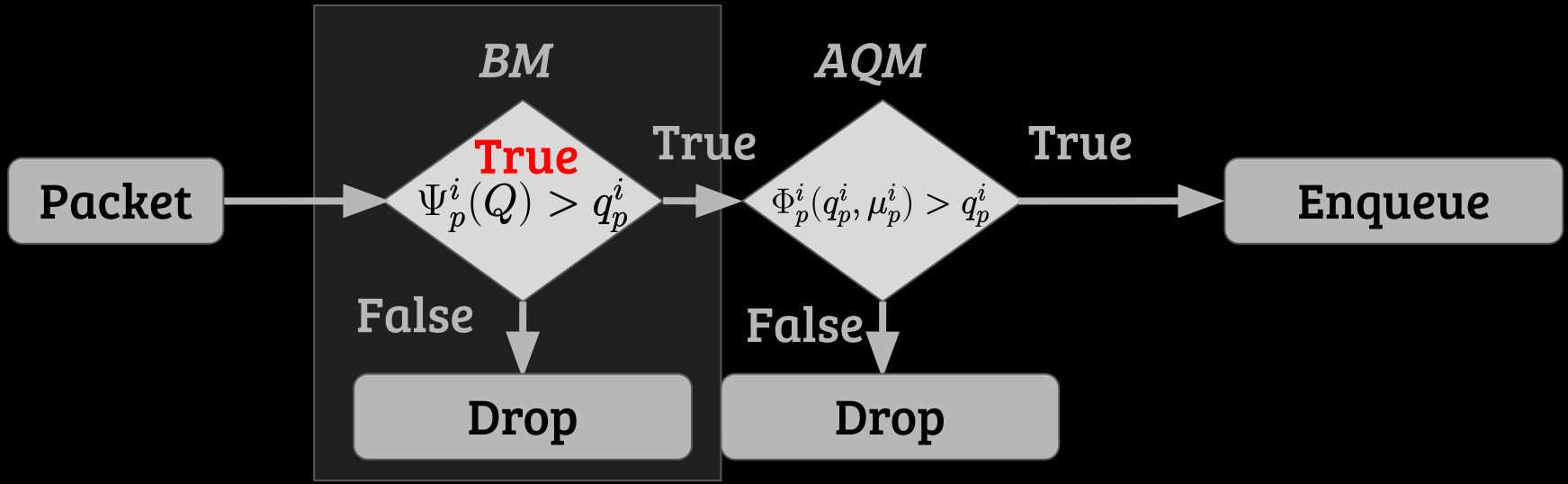
Large Buffers



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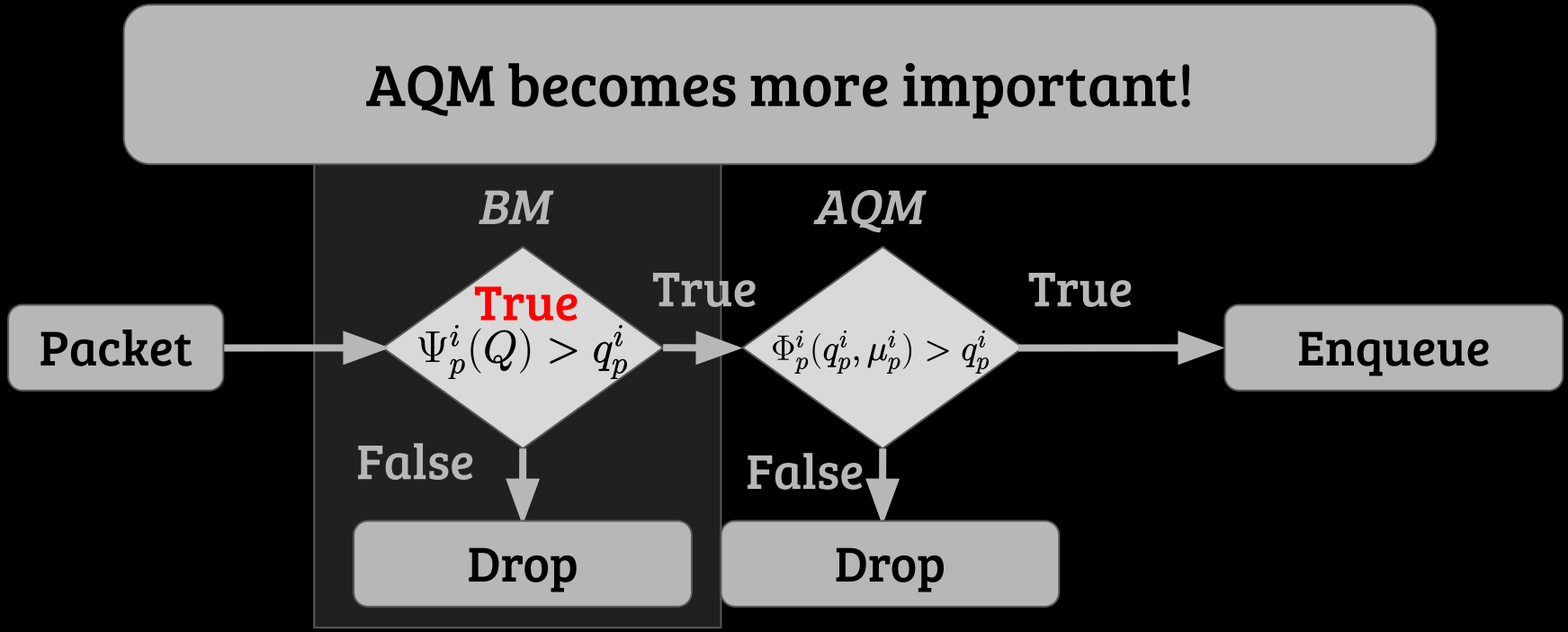

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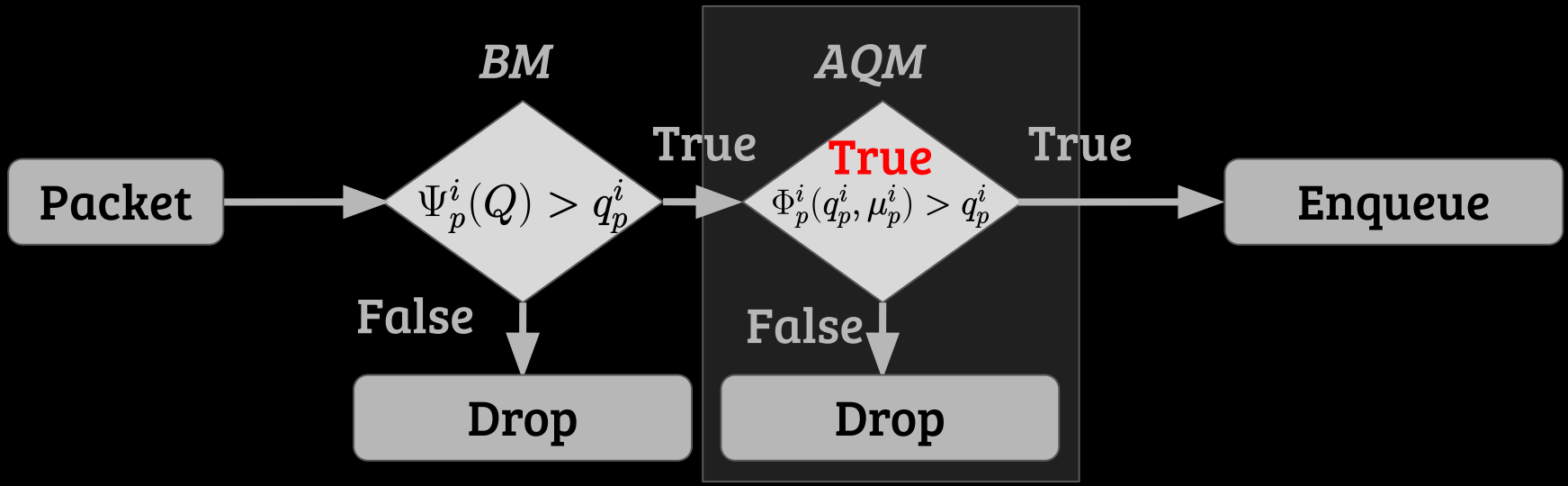
Shallow buffers



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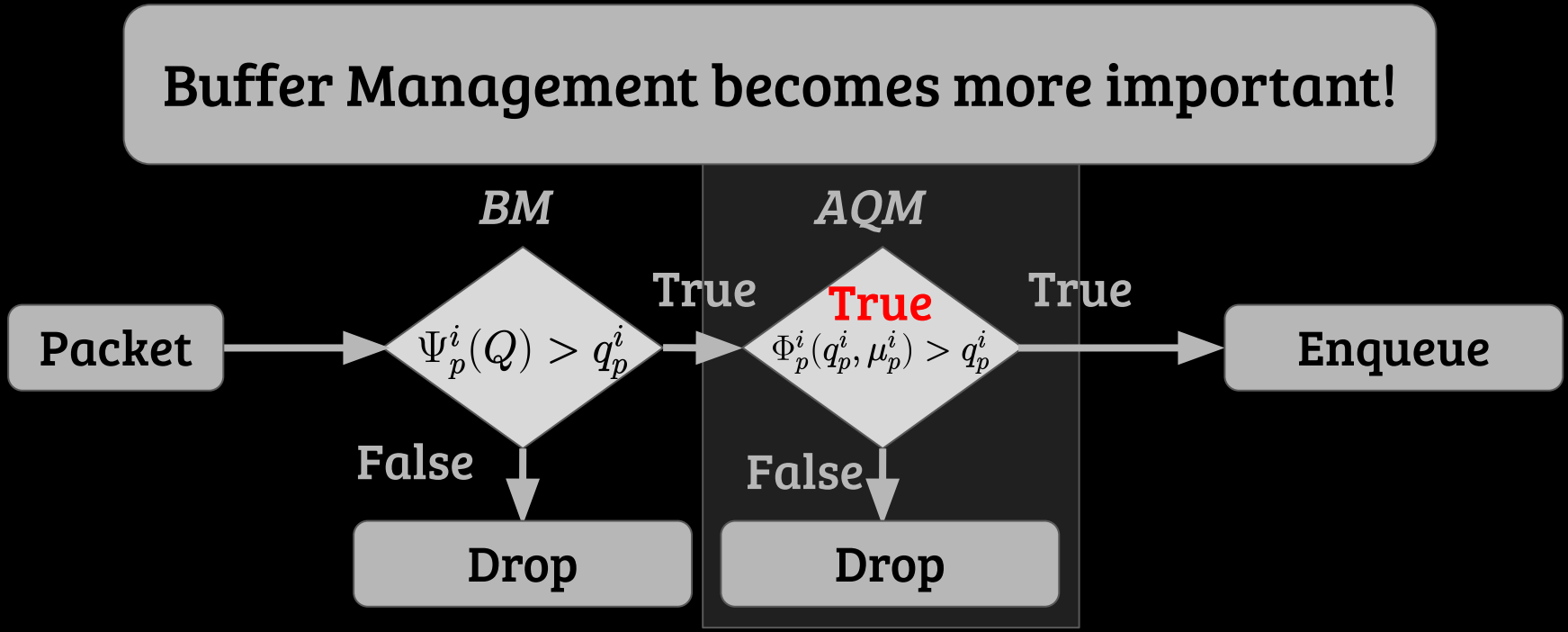

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Drawbacks of Dynamic Thresholds (State-of-the-art BM)

Threshold = alpha x (Remaining shared buffer)

$$T_p^i(t) = \alpha_p \cdot \underbrace{(B - Q(t))}_{Remaining}$$

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Drawbacks of Dynamic Thresholds (State-of-the-art BM)

Threshold = alpha x (Remaining shared buffer)

$$T_p^i(t) = \alpha_p \cdot \underbrace{(B - Q(t))}_{Remaining}$$

- Priority inversion (No isolation)
- Oblivious to buffer drain time

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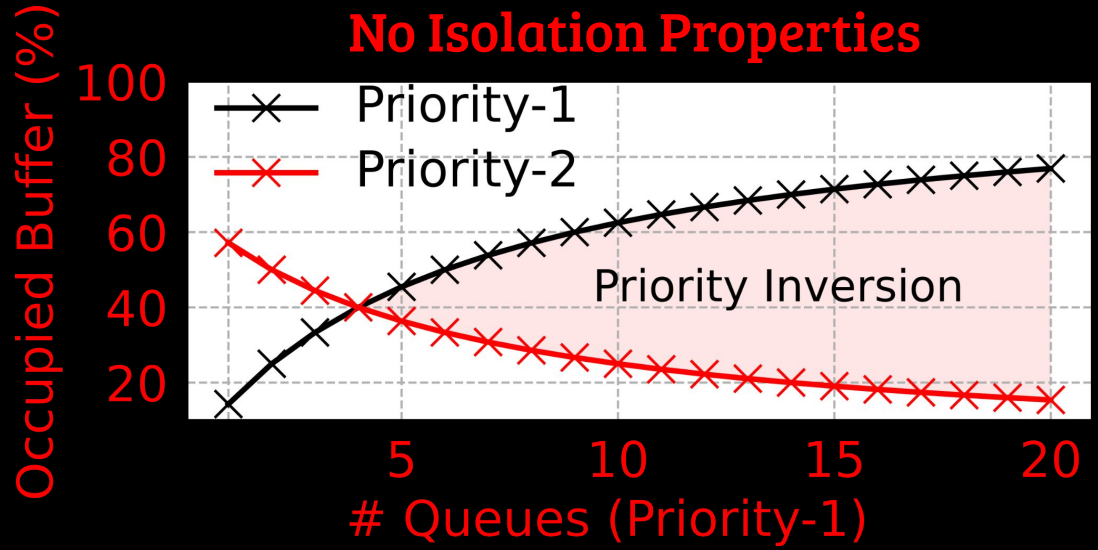
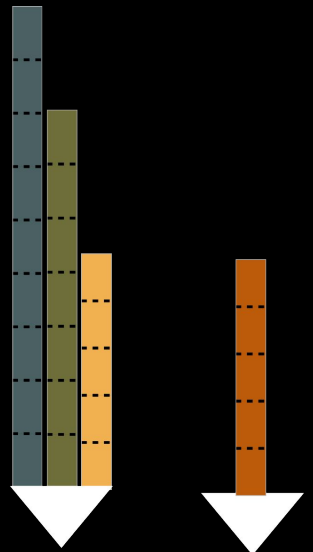
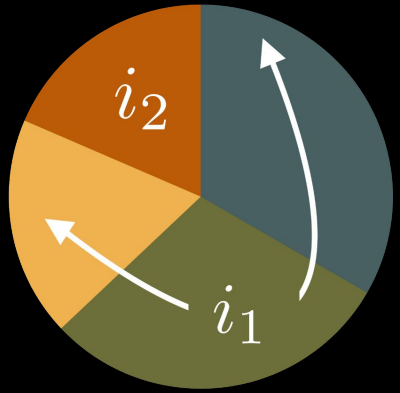
Drawbacks of Dynamic Thresholds (State-of-the-art BM)



Drawbacks of Dynamic Thresholds (State-of-the-art BM)

Oblivious to drain rate





Ports: i_1 i_2

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Drawbacks of Dynamic Thresholds (State-of-the-art BM)

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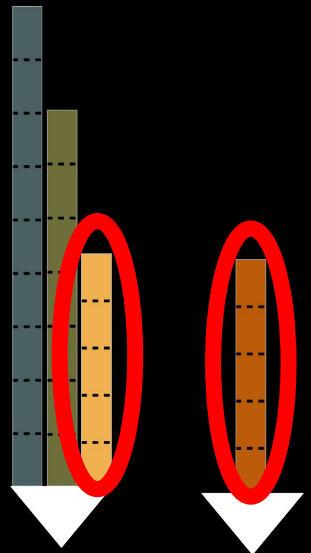

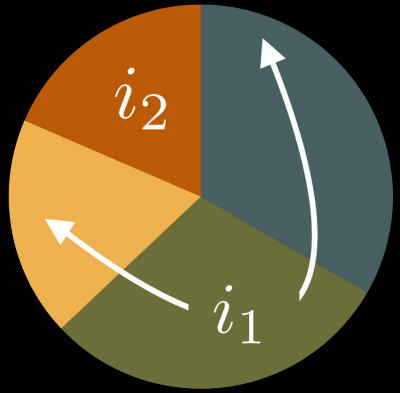

Ports: i_1 i_2

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Benefits and Drawbacks of Existing Approaches

- BM can in-principle offer isolation across queues
  - oblivious to buffer drain time
- AQM can in-principle offer bounded queue drain time
  - cannot fundamentally satisfy the isolation property

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Our Goals

- Isolation across traffic priorities
- Bounded drain time
- Better burst absorption
  - requires both isolation and bounded drain time

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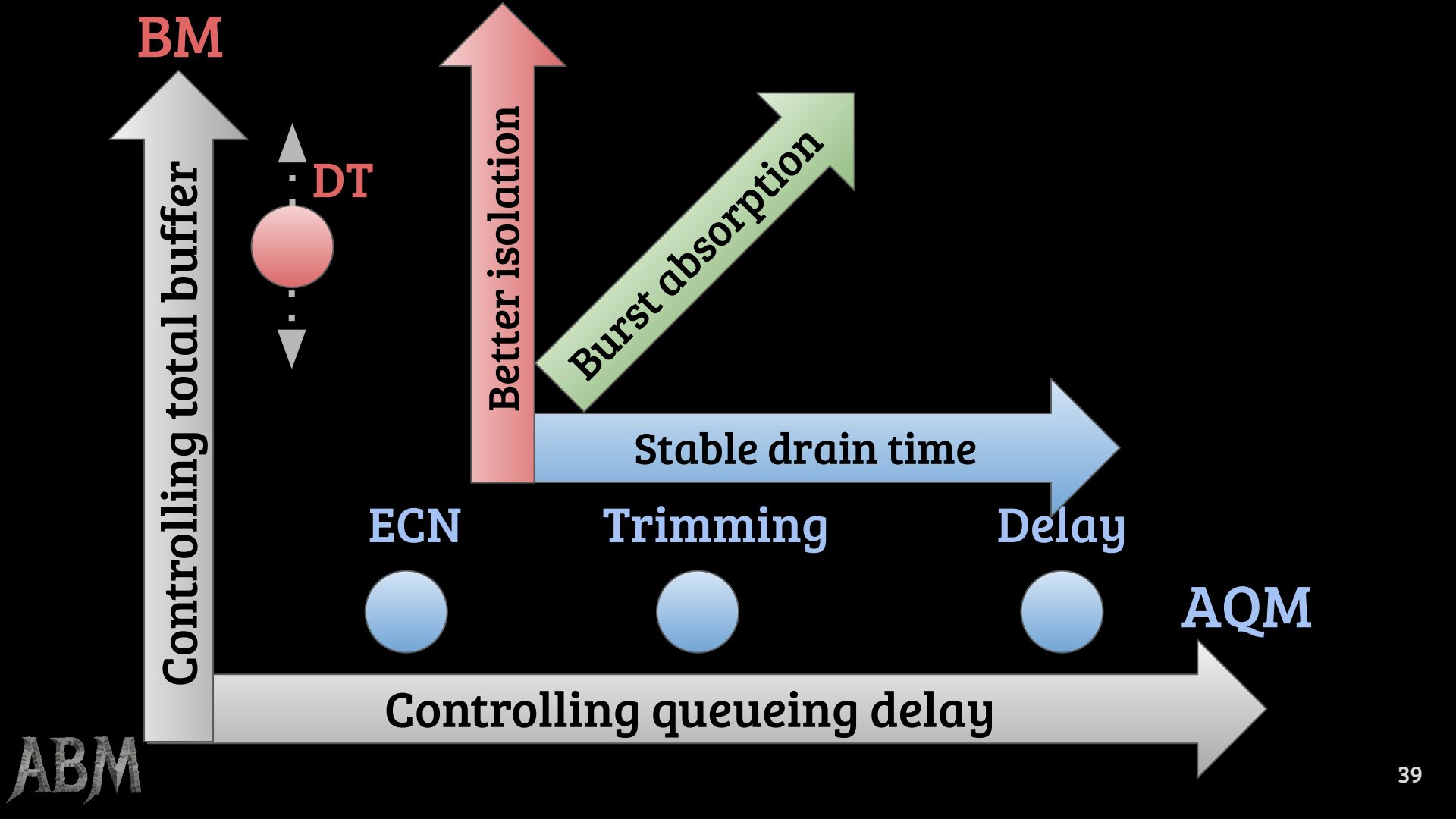
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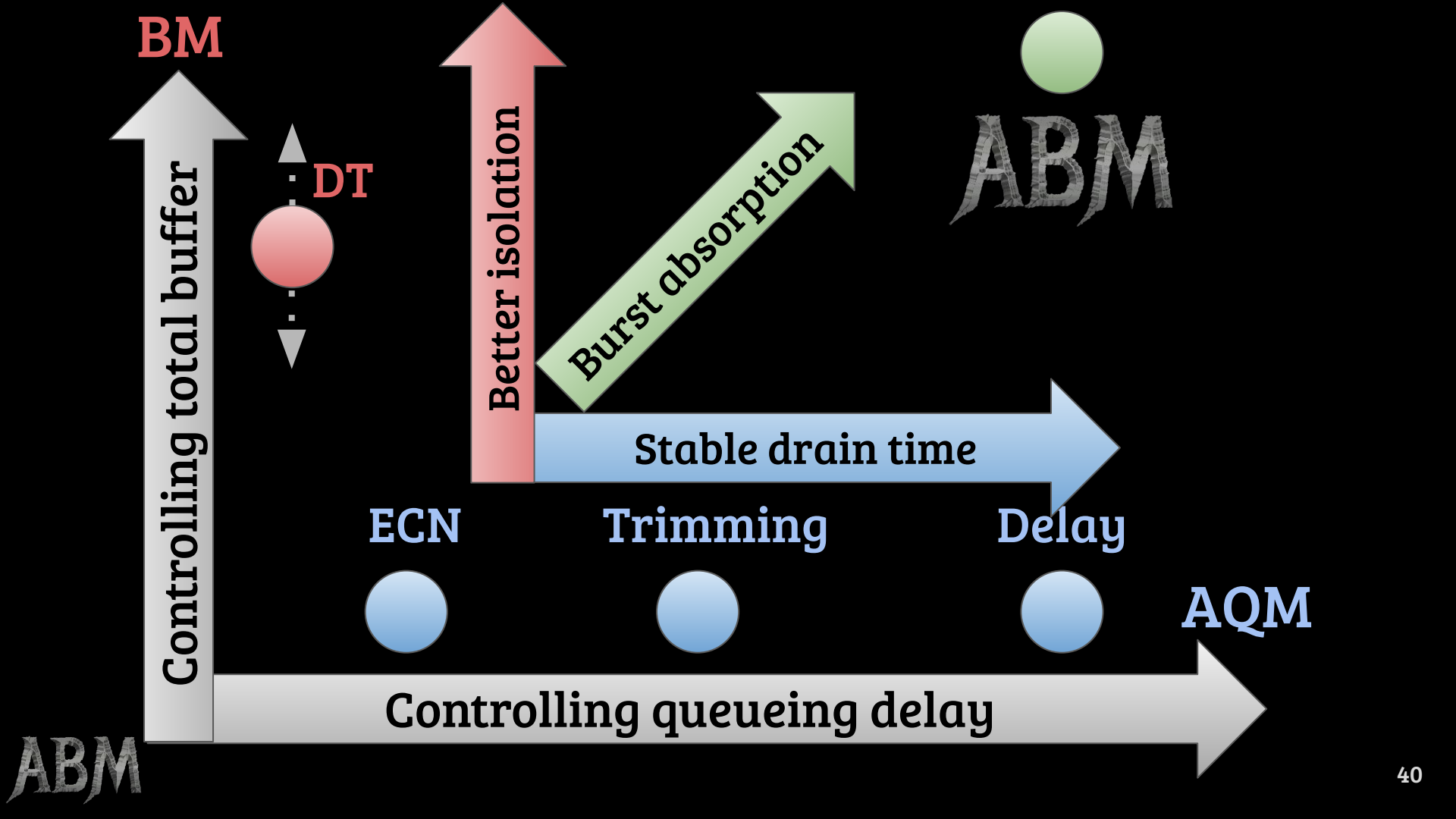
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Active **B**uffer **M**anagement

$$T_p^i(t) = \alpha_p \cdot \frac{1}{n_p} \cdot (B - Q(t)) \cdot \frac{\mu_p^i}{b}$$

Threshold per queue
port i, priority p

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Active **B**uffer **M**anagement

$$T_p^i(t) = \alpha_p \cdot \frac{1}{n_p} \cdot (B - Q(t)) \cdot \frac{\mu_p^i}{b}$$

Parameter

To be set for each priority

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Active **B**uffer **M**anagement

$$T_p^i(t) = \alpha_p \cdot \frac{1}{n_p} \cdot (B - Q(t)) \cdot \frac{\mu_p^i}{b}$$

congested queues of priority p

ABM

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Remaining shared buffer

ABM

Active **B**uffer **M**anagement

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Normalized dequeue rate

ABM

Active **B**uffer **M**anagement

$$T_p^i(t) = \underbrace{\alpha_p \cdot \frac{1}{n_p} \cdot (B - Q(t))}_{Buffer\ \ Management} \cdot \underbrace{\frac{\mu_p^i}{b}}_{AQM}$$

Properties of ABM

- Upper bounds the buffer allocated to a priority
  (Prevents monopoly)

$$B_p^{max} \leq \frac{B \cdot \alpha_p}{1+\alpha_p}$$

Depends only on the parameter set *for the corresponding priority*

Properties of ABM

- Lower bounds the buffer allocated to a priority **(Minimum buffer guarantee)**

$$B_p^{min} \geq \frac{B \cdot \alpha_p}{1 + \sum_{p \in \mathcal{P}} \alpha_p}$$

***Depends only on the parameter set** for all priorities*

Properties of ABM

- Upper bounds the drain time for each priority
  (Bounded queuing delays)

$$\Gamma \leq \frac{B \cdot \alpha_p}{(1+\alpha_p) \cdot b}$$

Depends only on the parameter set *for the corresponding priority and the port bandwidth*

Evaluation

- NS3 simulations
- Leaf-Spine topology (4:1 oversubscription)
- 9.6KB buffer-per-port-per-Gbps for all switches
  - Similar to Broadcom TridentII switch
- Websearch + incast workload

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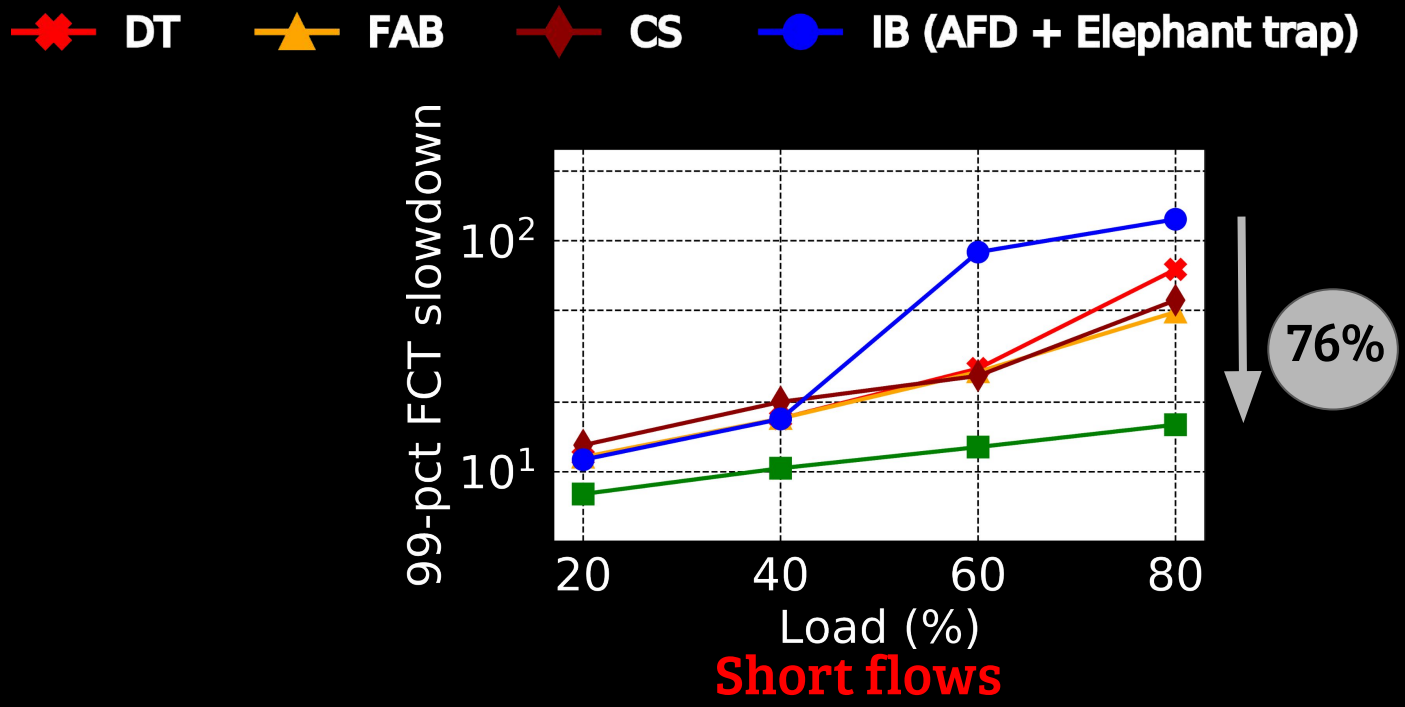
ABM Improves Short Flows FCTs



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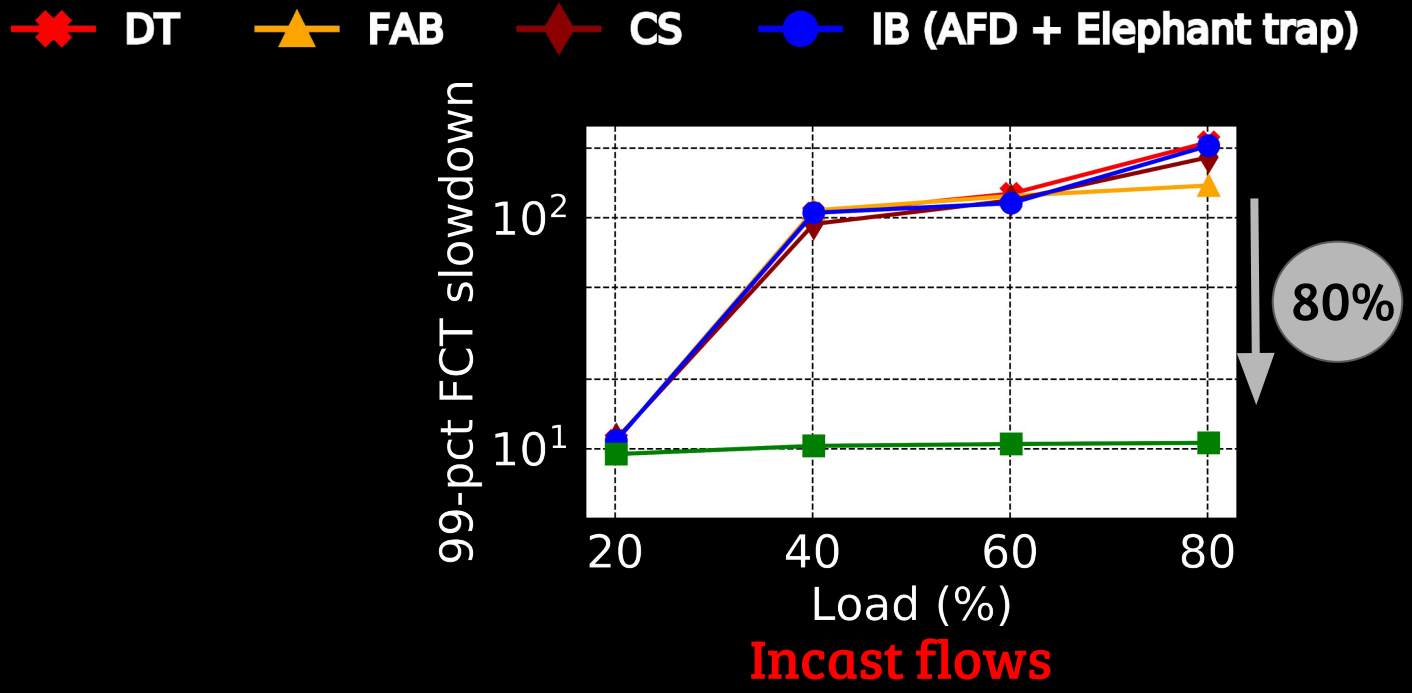
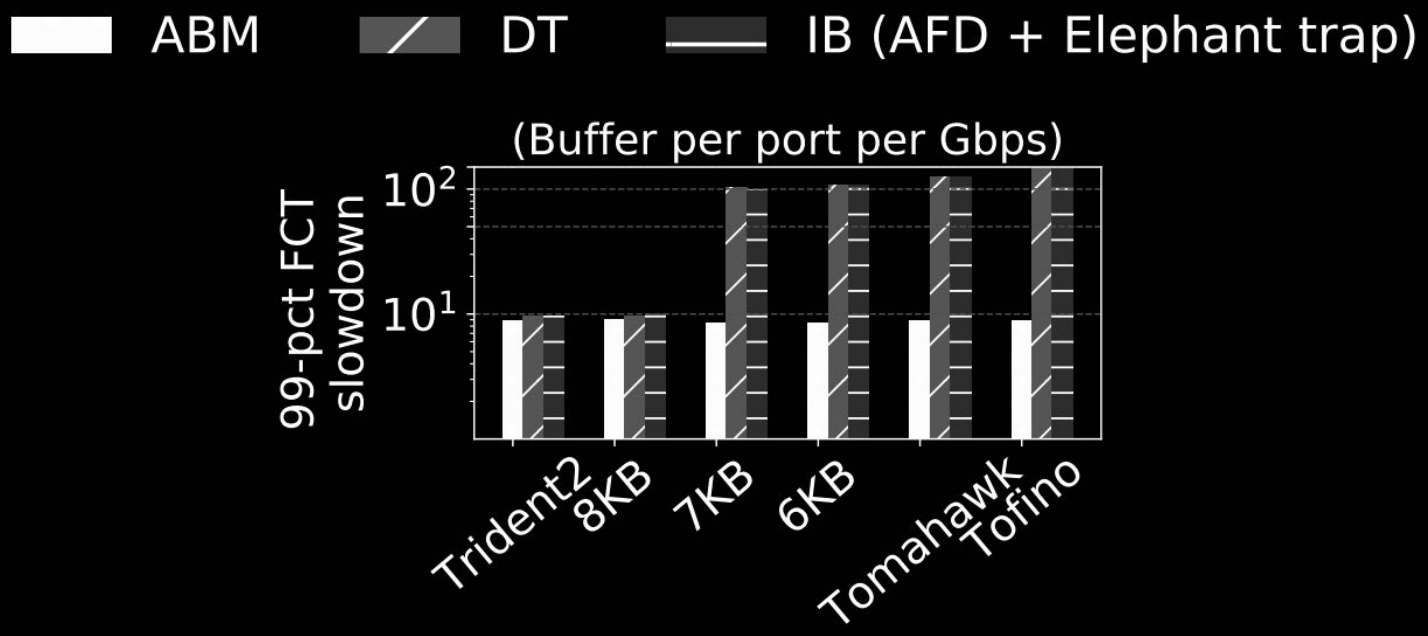


Evaluation under Shallow Buffers and Advanced CC



DCTCP

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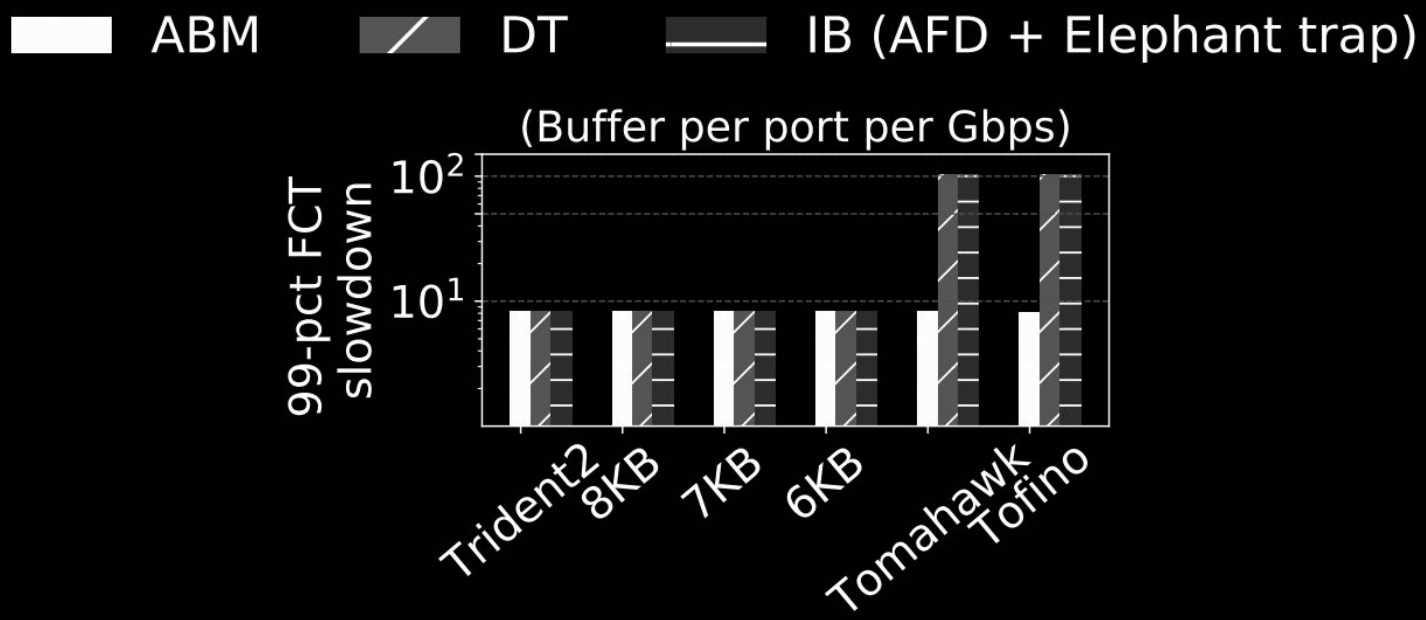

PowerTCP

Conclusion

- Existing approach of hierarchical buffer sharing is fundamentally limited to a single dimension
- ABM offers both isolation and stable drain time; and improves burst absorption
- ABM significantly improves the performance of incast flows
- ABM works well even under shallow buffers

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https://github.com/inet-tub/ns3-datacenter

Thank you

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ABM