Automated and Scalable QoS Control
- For Network Convergence

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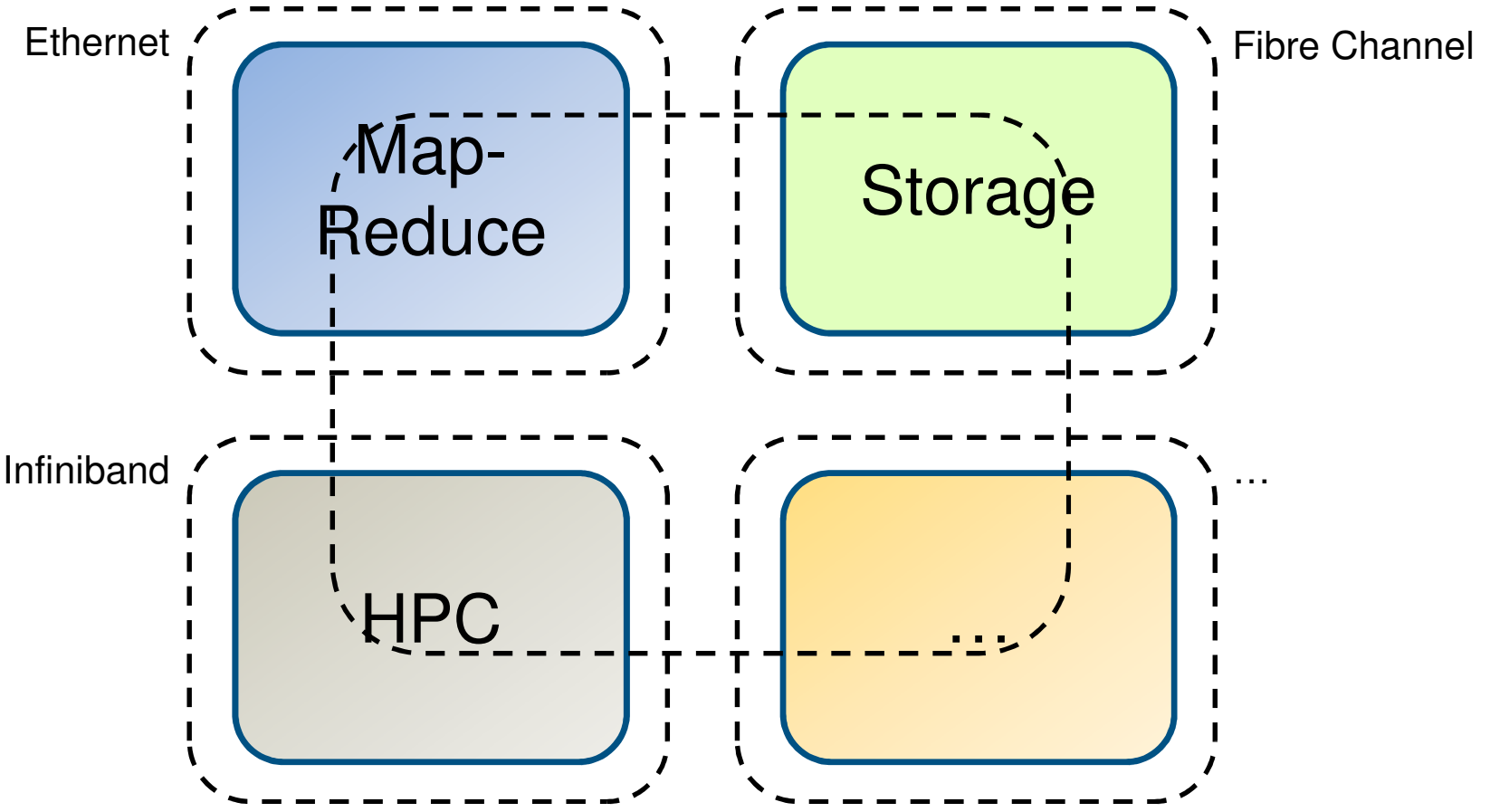
Motivation

- Why do we care about QoS control?
  - Network convergence
  - Multi-tenancy networks

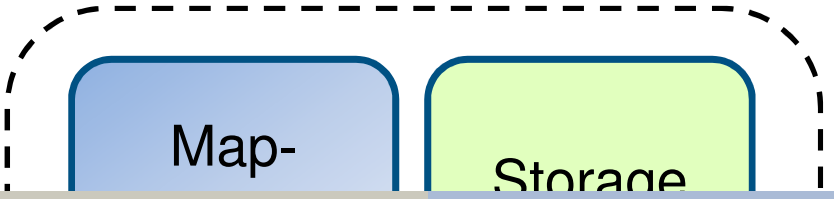
- Automated QoS control is needed

Network convergence



Different protocols, adapters, switches, and configuration

Network convergence



Fewer switches, ports, adapters, cables

Reduced power, equipment, cooling cost

Simpler topology

I/O consolidation

Unified resource management

Converged Enhanced Ethernet (CEE)

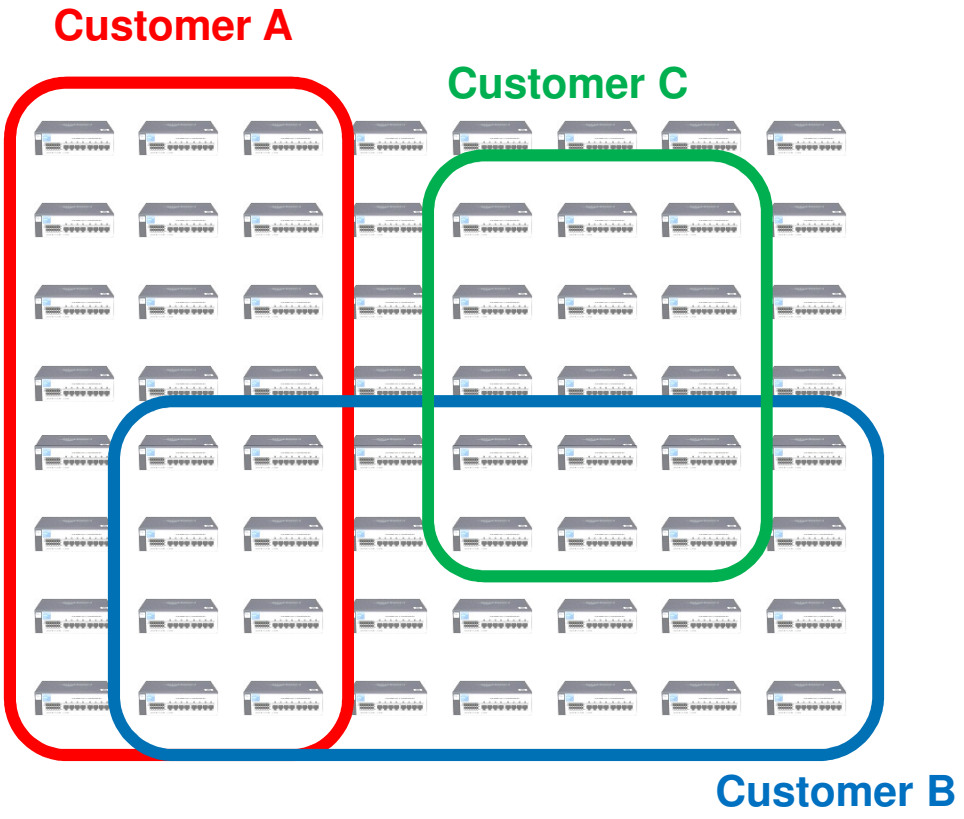
Data Center Ethernet (DCE)

Data Center Bridging (DCB)

Fibre Channel over Ethernet (FCoE)

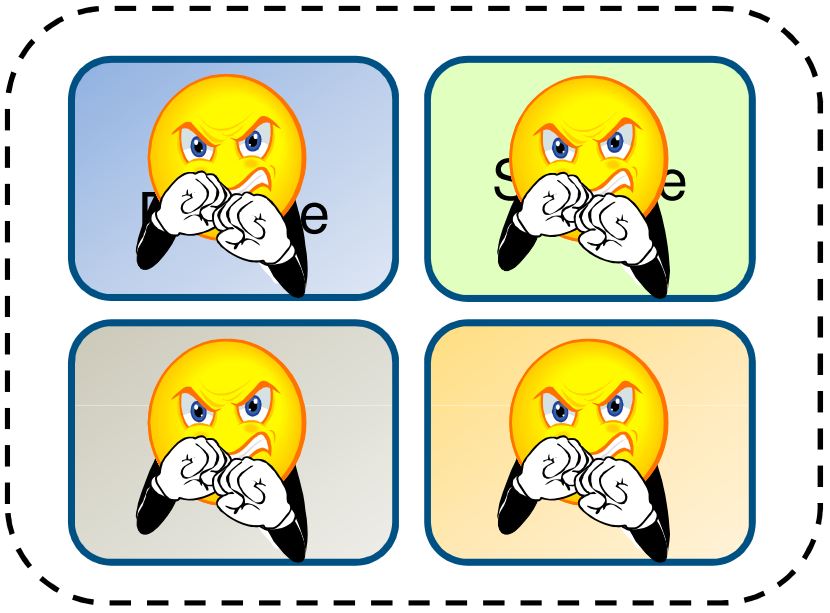
Fibre Channel over CEE (FCoCEE)

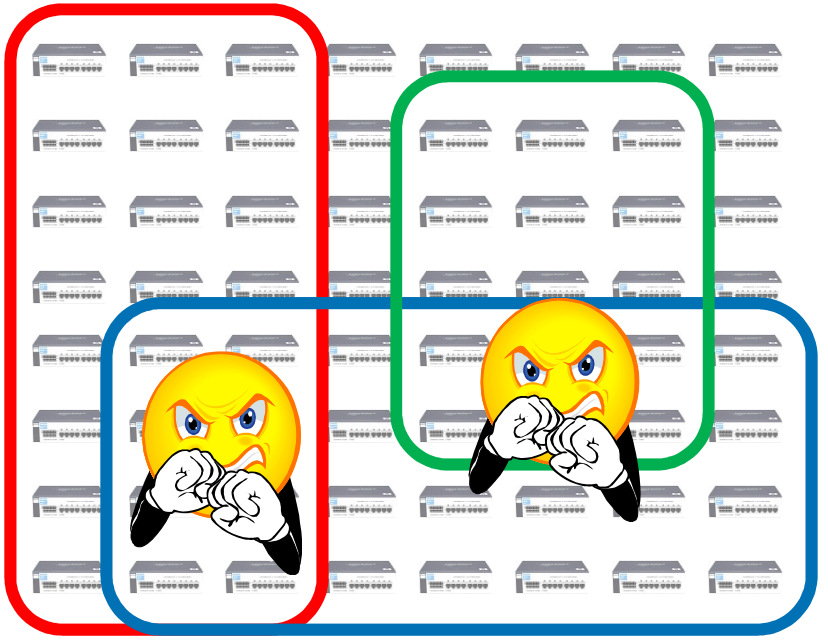
Multi-tenancy networks



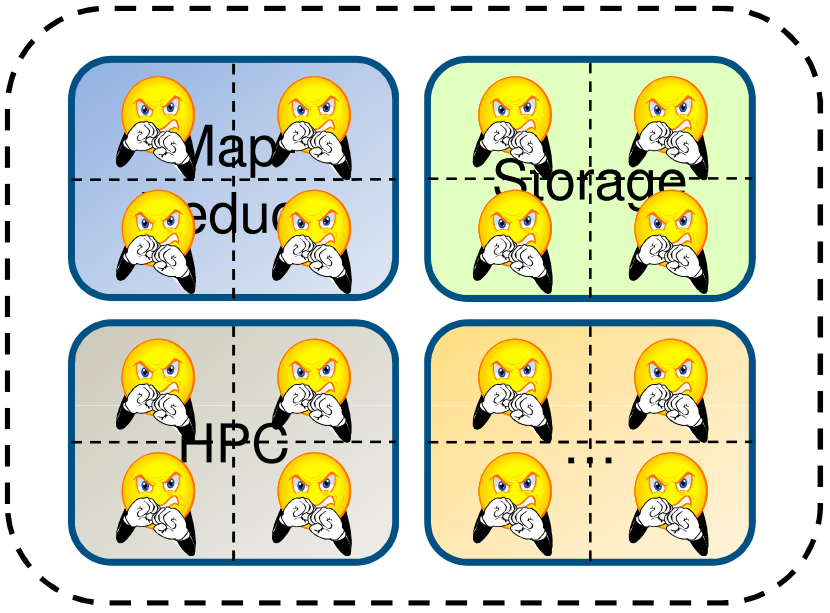
- Serve multiple customers with a single fabric
- Better utilization of network infrastructure

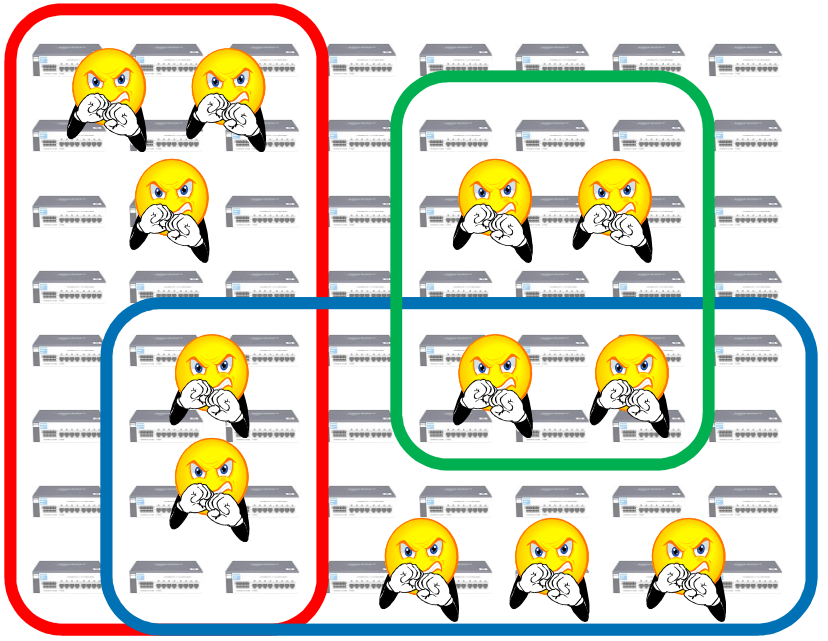
Performance isolation



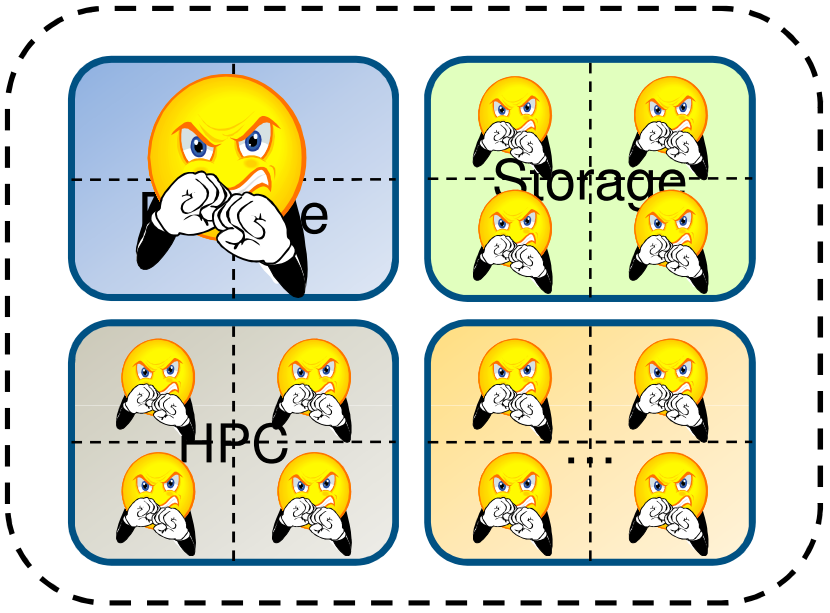


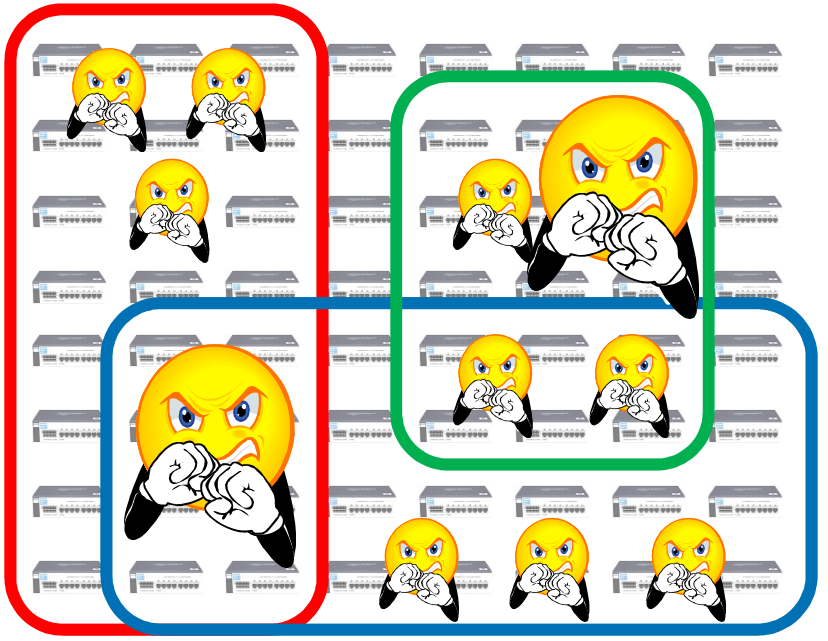
Performance isolation



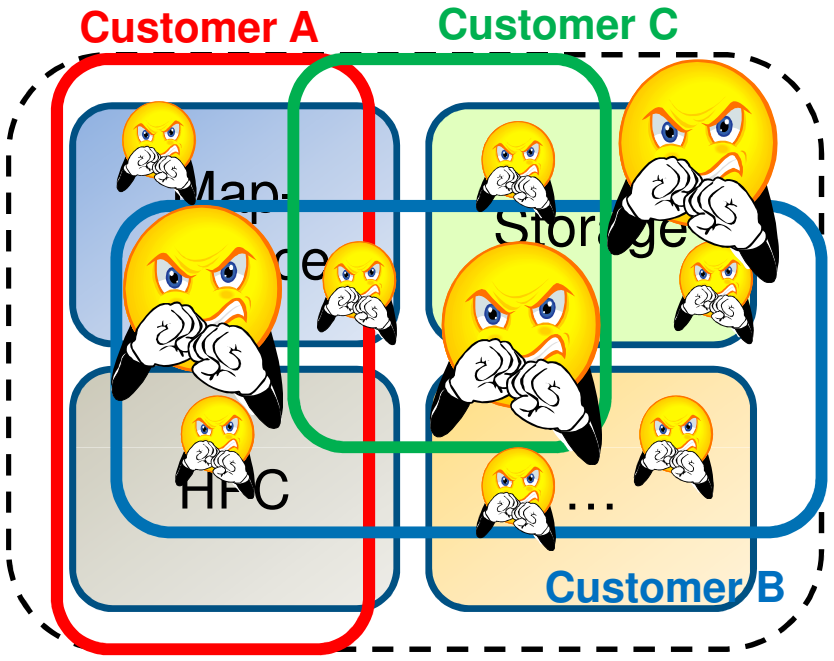


Performance isolation





Performance isolation



Virtualized Servers

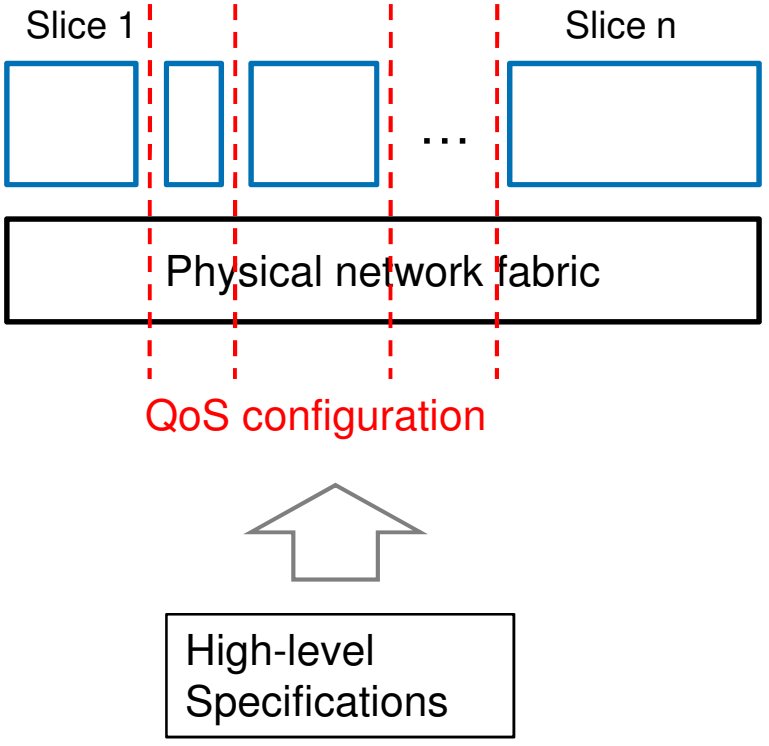
Variable Workloads

Bugs, malicious attack

- Need virtual network slices
- Need fine-grained performance isolation

Goal

- Enables performance isolation with QoS control



Good news

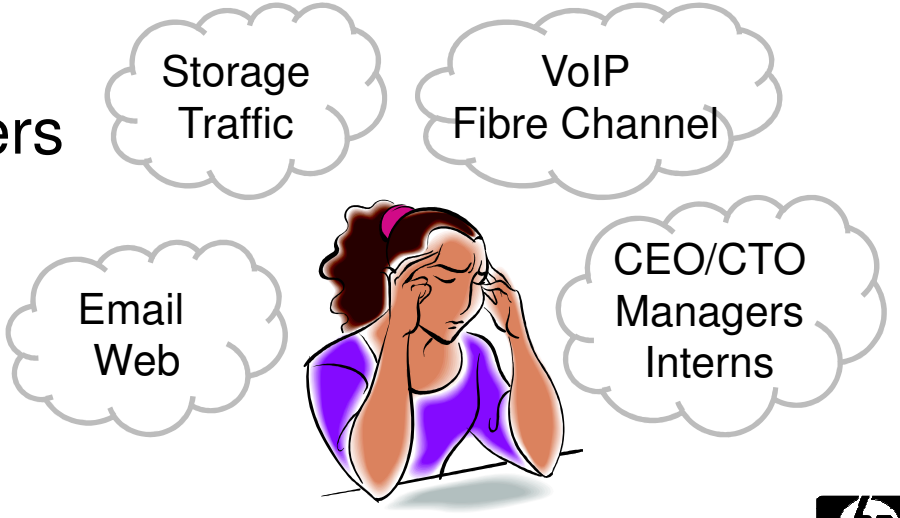
- Most commodity switches have QoS knobs
  - rate limiter
  - priority queues
  - schedulers

- Single network domain
  - datacenters, enterprise networks, …
  - free from Layer-8 issues (billing, collaborations, …)
  - fine-grained control becomes feasible

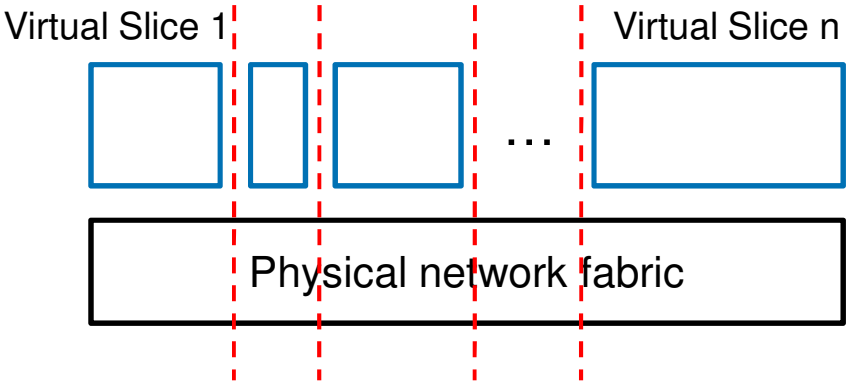
Challenges

- Coarse-grained QoS knobs
  - designed for distributed management
  - class-based
  - no e2e performance

- Manual configuration
  - no standards for classifiers
  - error-prone
  - static (not adaptive)



Our Solution: OpenFlow QoS Controller



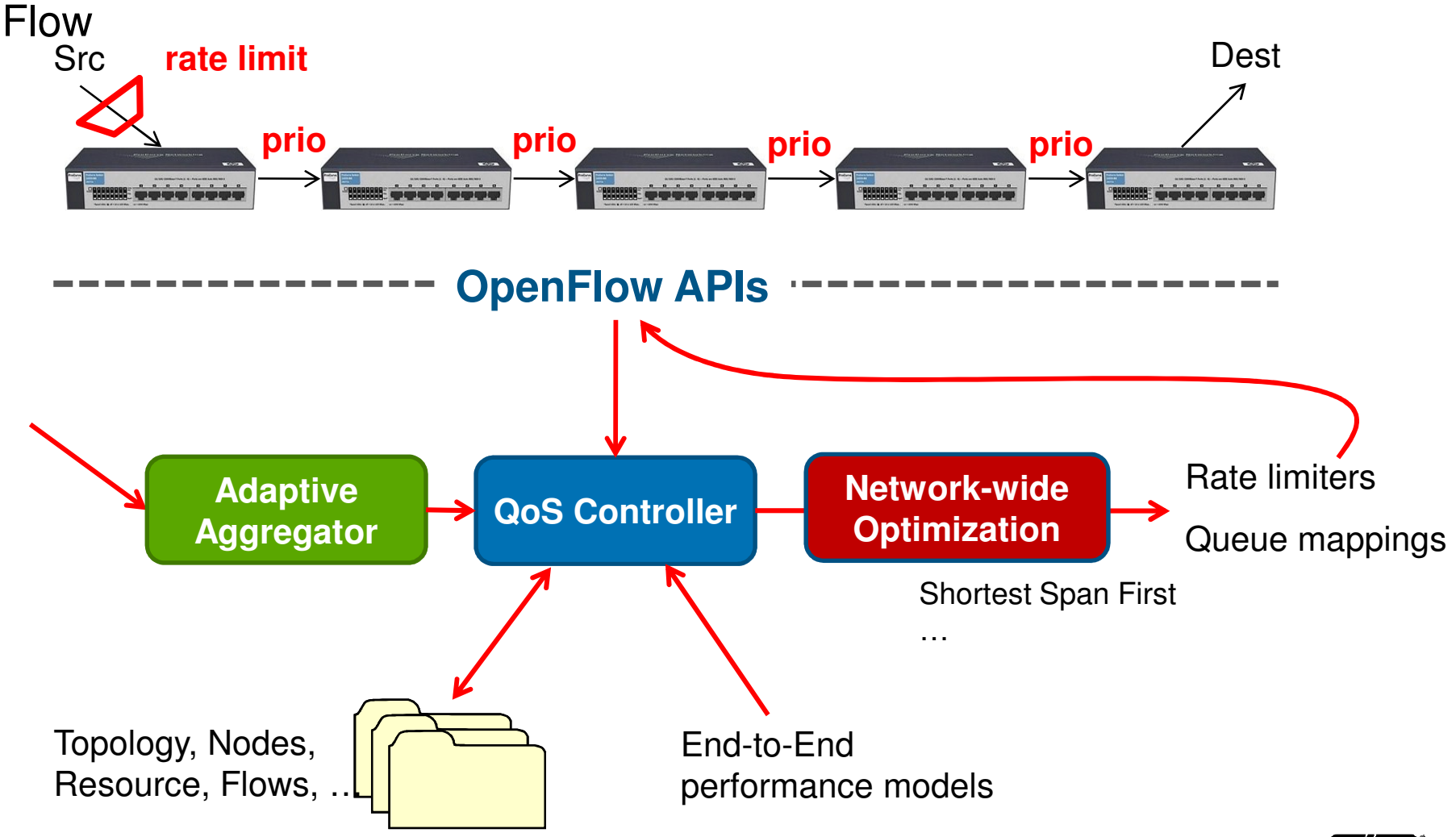
QoS configuration (rate limiter, priority queues, …)

Manual & Static setting  Problem

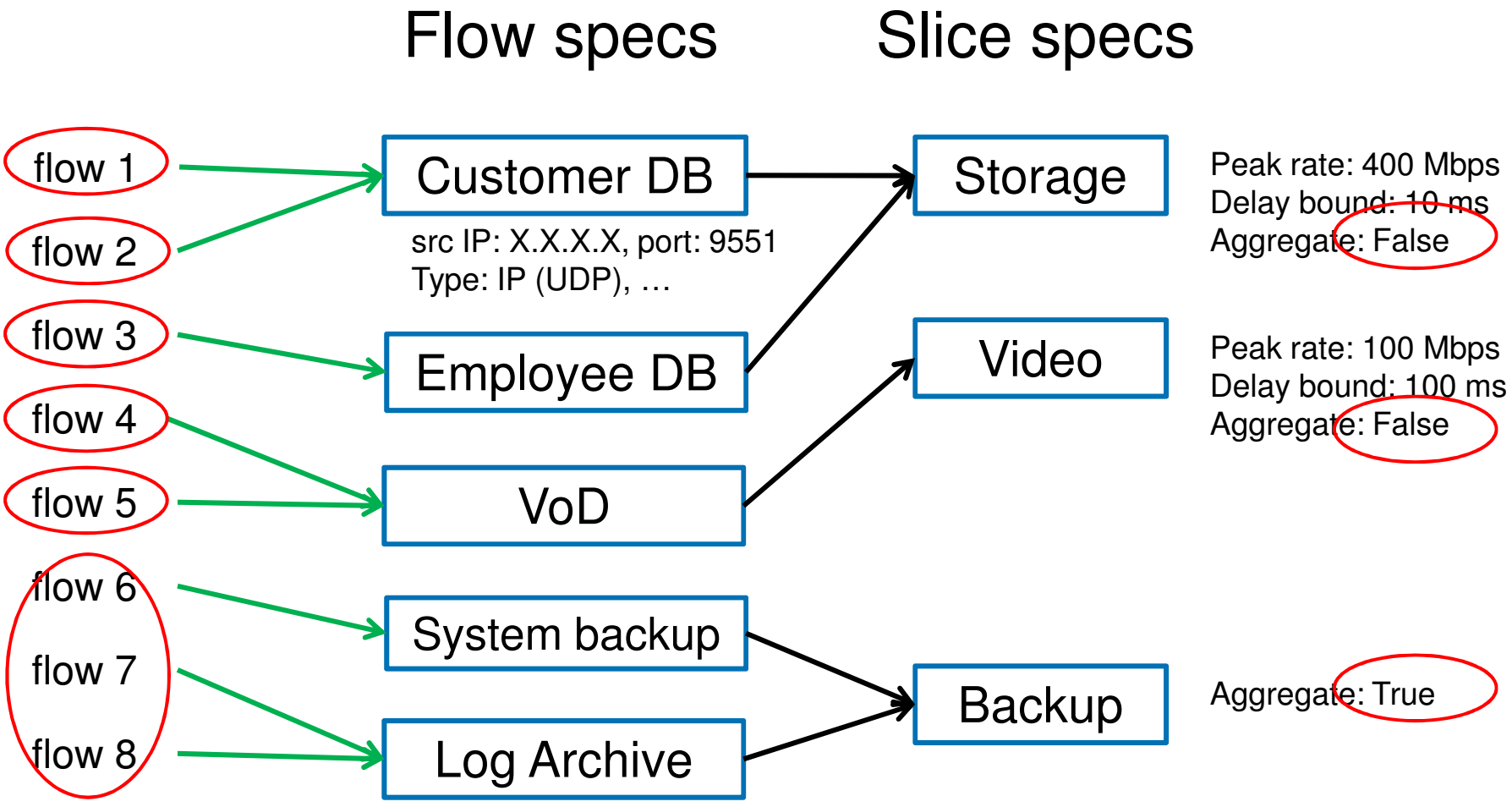
QoS Controller

- Automated configuration
- Fine-grained flow management
- Adaptive to dynamic workloads

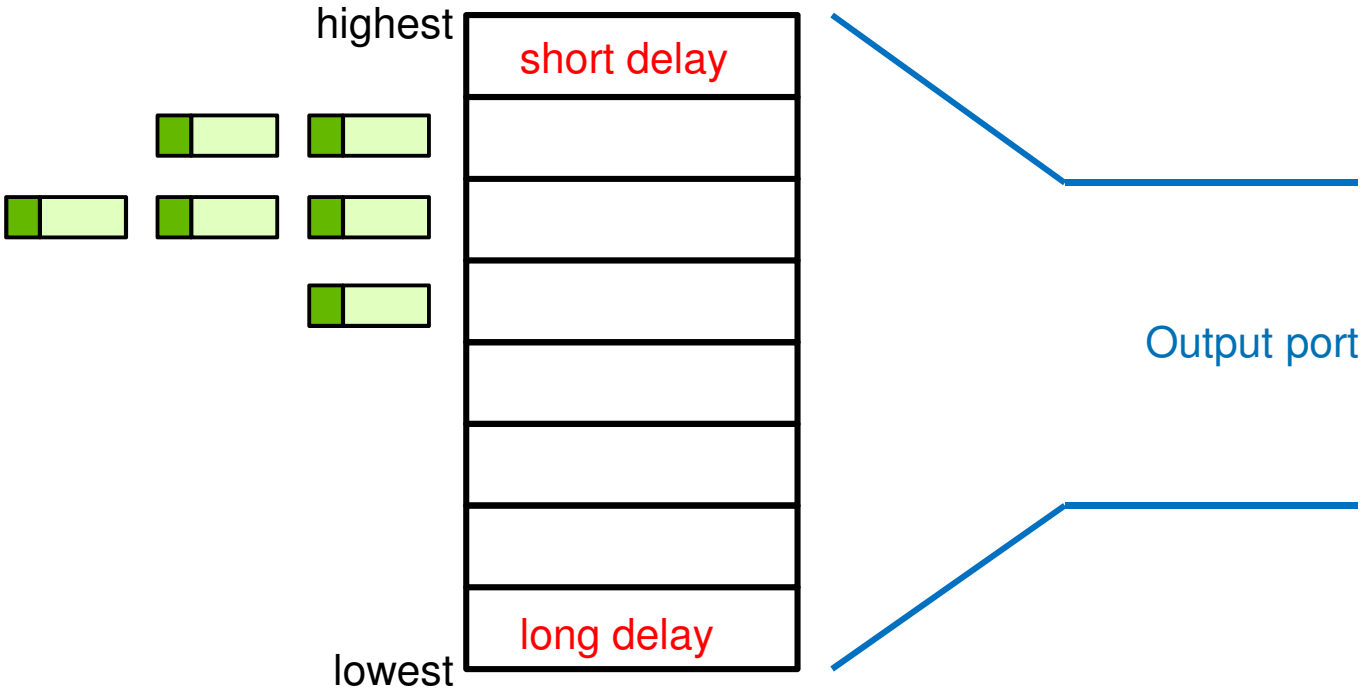
Overview of OpenFlow QoS controller



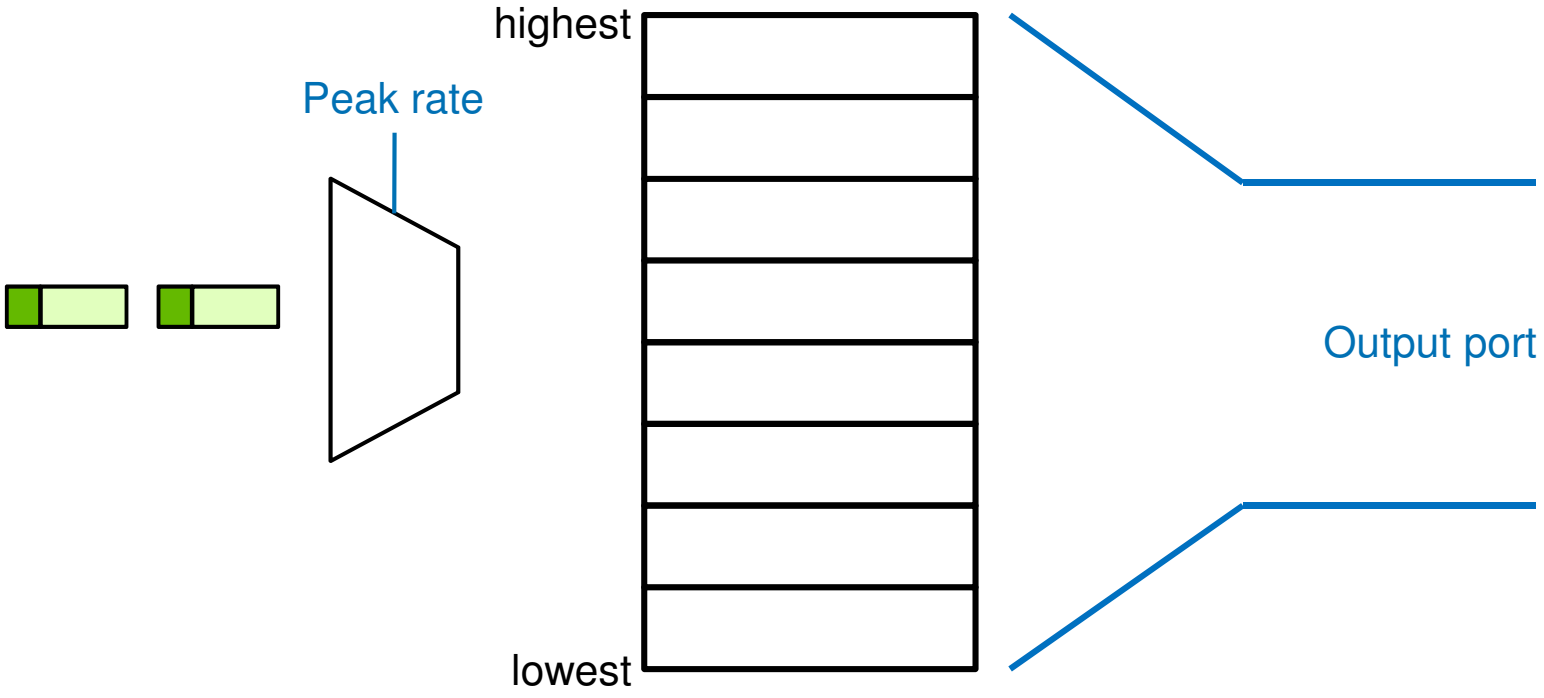
Adaptive aggregation



Available QoS Knobs (Priority queue)

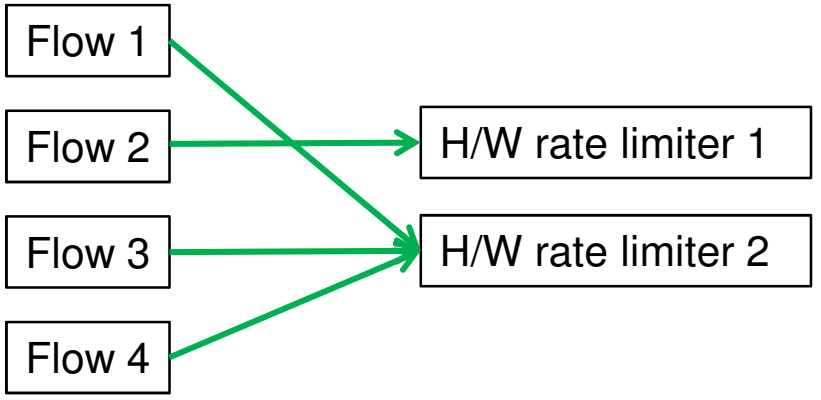


Available QoS Knobs (Rate limiter)

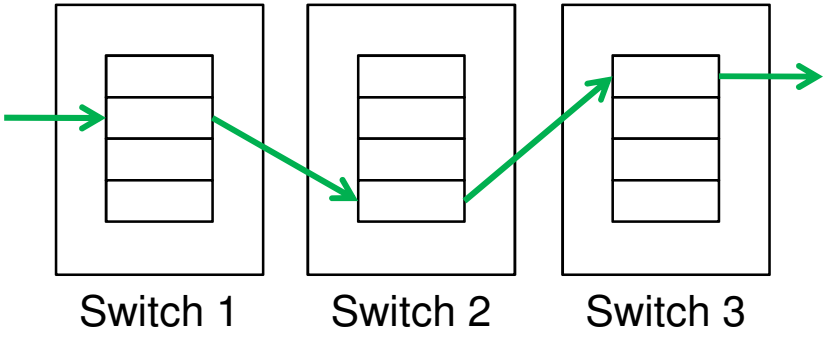


OpenFlow QoS APIs

Rate limiter



Priority queue mapping



- Extension of OpenFlow specification
- Expose QoS capability in switches

OpenFlow QoS APIs

- With OpenFlow flow control
  - fine-grained control of flows
  - automated flow management

- With OpenFlow QoS APIs
  - uniform control of QoS knobs
  - configure QoS for individual (or aggregate) flows

Admission Control

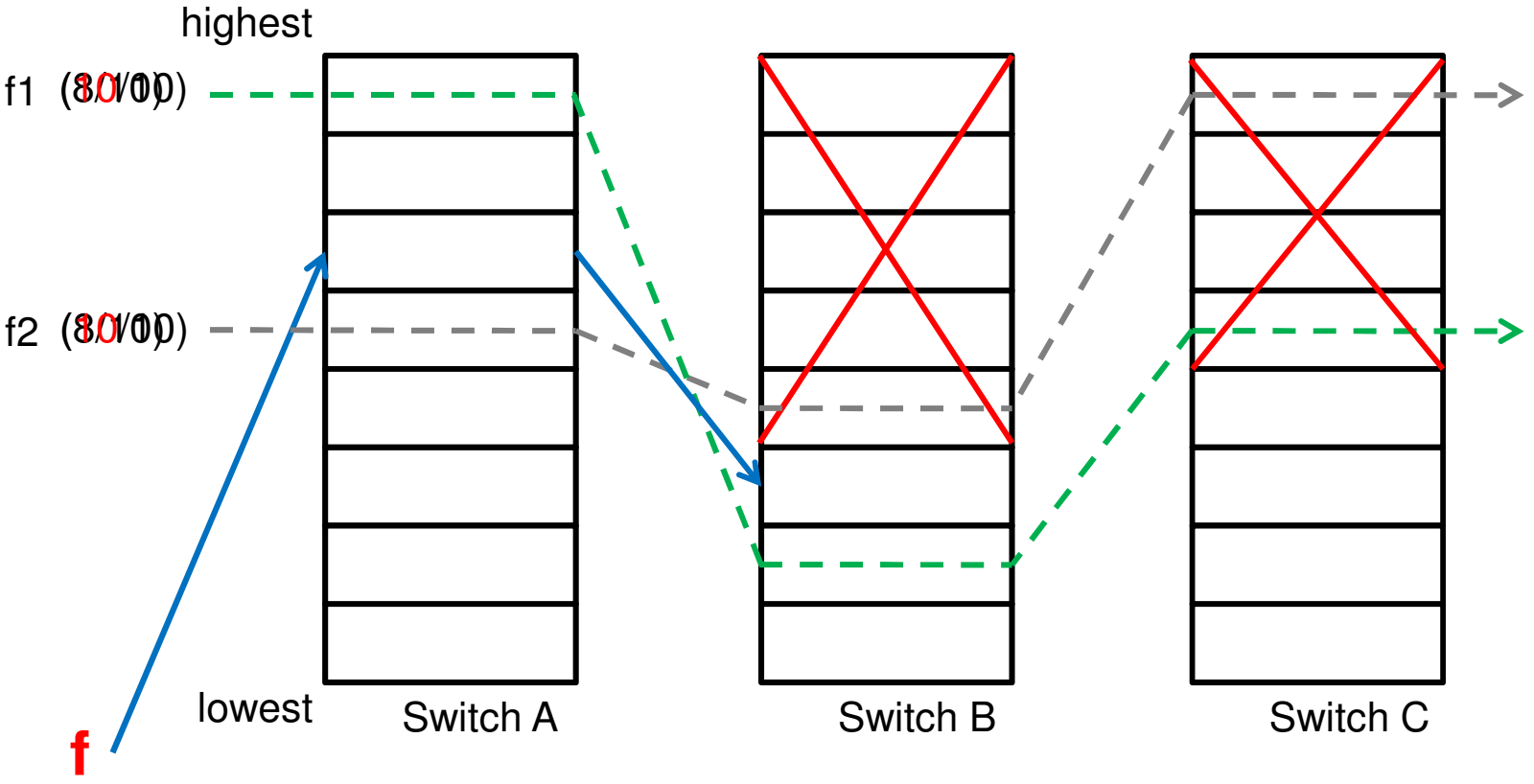
- Input
  - new flow arrival event
  - performance requirements (peak rate, e2e delay)
  - database for the current network state
  - end-to-end performance model

- Output
  - admission control result (accept/reject)
  - priority queue assignment, rate limiter settings
  - path selection

Admission Control

- Two conditions should be satisfied
  - satisfy *f* 's performance requirement
  - not violate existing flows in the networks

Difficulties in queue assignment



We should consider interactions between

- flows in a switch
- flows in multiple switches

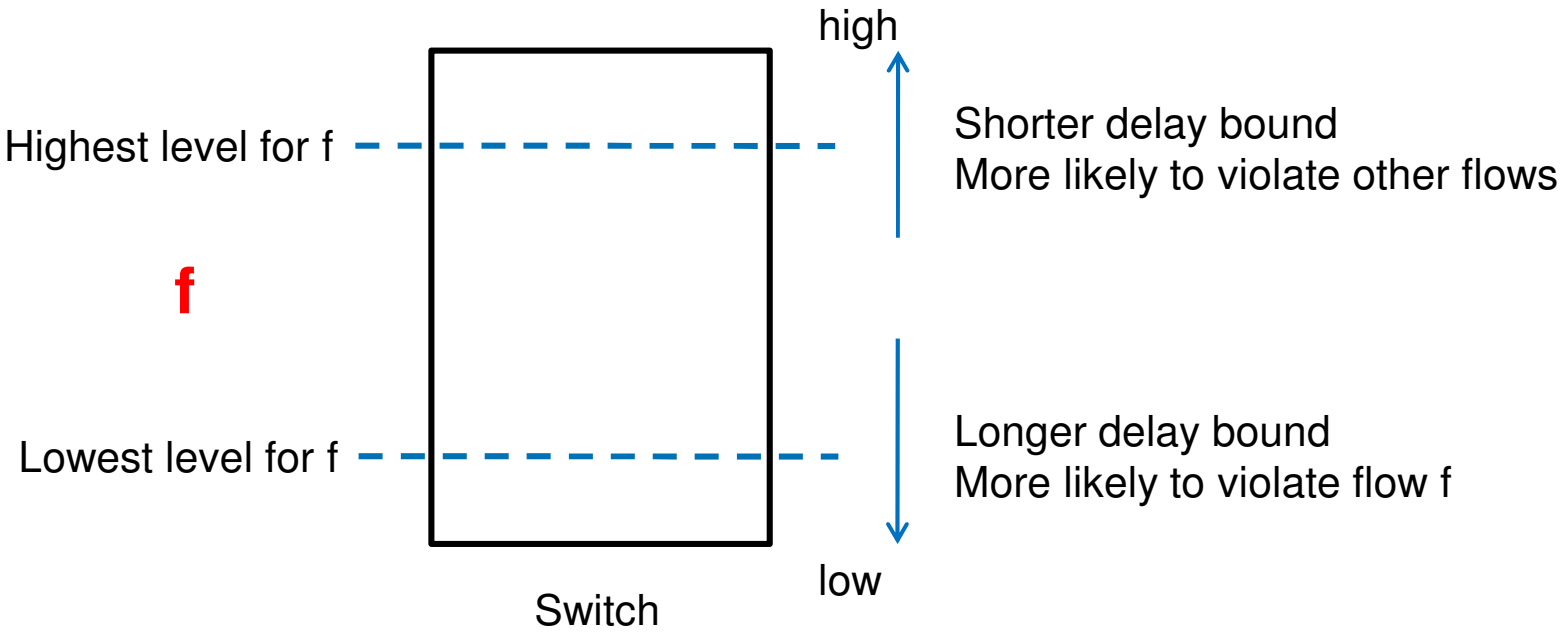
Admission control heuristic

- Goal
  - increase the ratio of admitted flows
  - lower the complexities in queue allocation

- Shortest Span First (SSF)

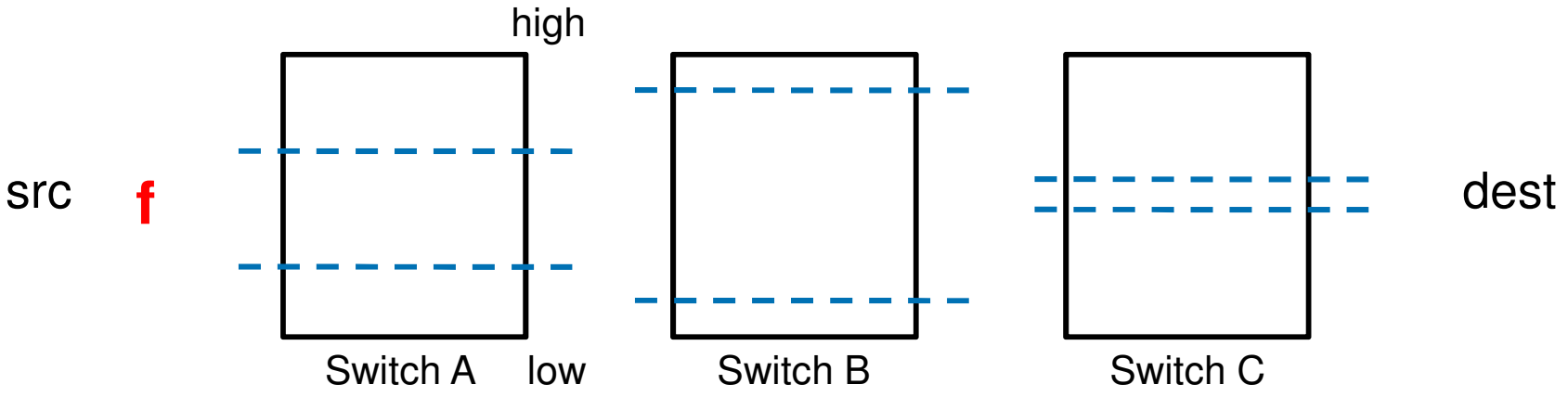
- Basic ideas
  - estimate affordable options for a flow
  - try first switches more likely to reject flow

Highest level & Lowest level



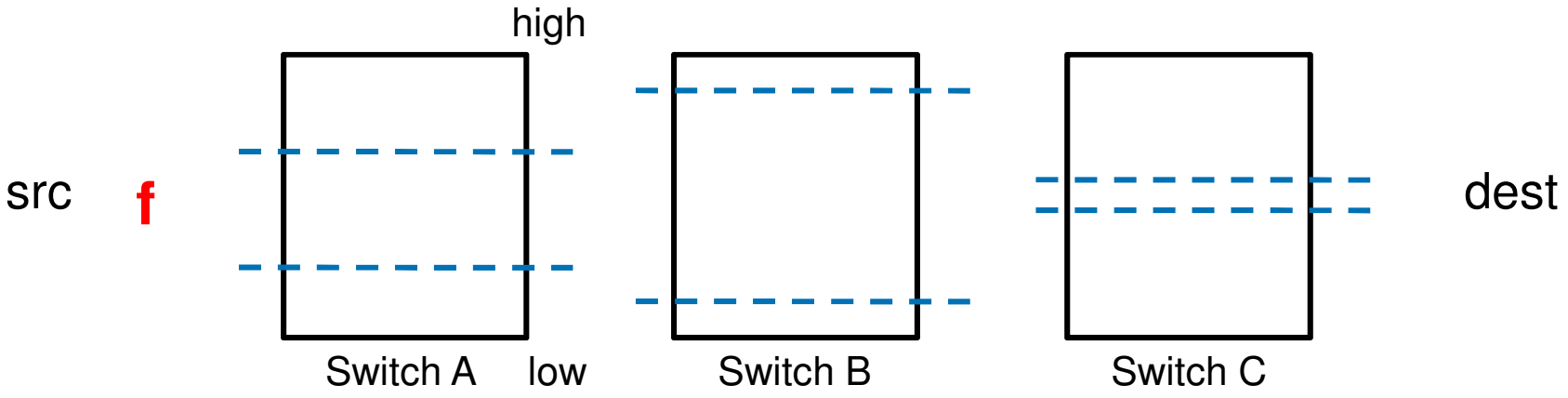
- Highest level: not violate existing flows
- Lowest level: not violate the new flow
- Span: available options for **f**

Shortest Span First (SSF)



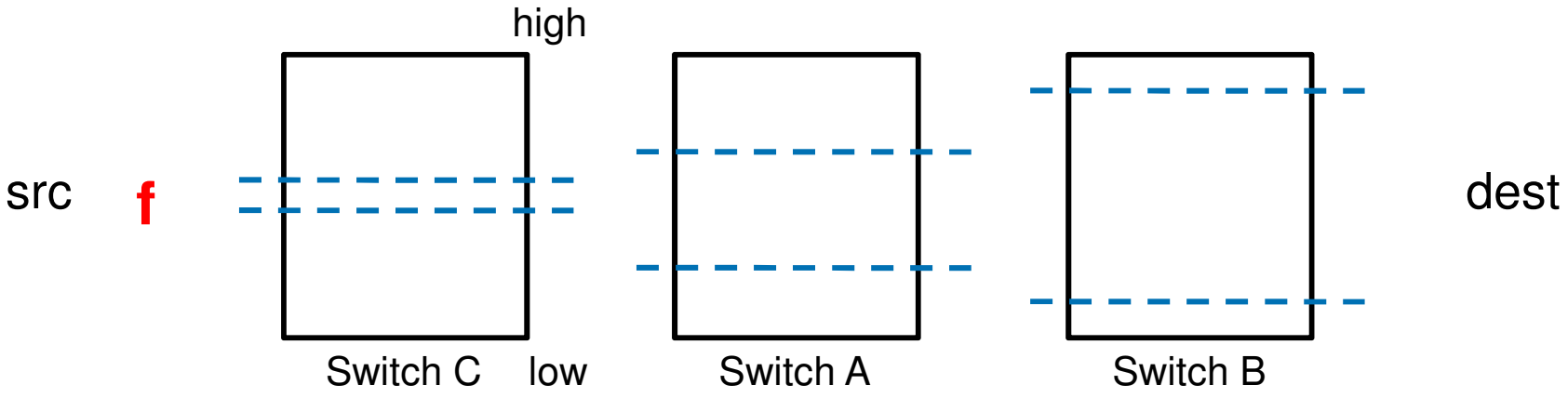
- Step 1: compute highest & lowest levels independently

Shortest Span First (SSF)



- Step 2: sort switches in order of the span

Shortest Span First (SSF)



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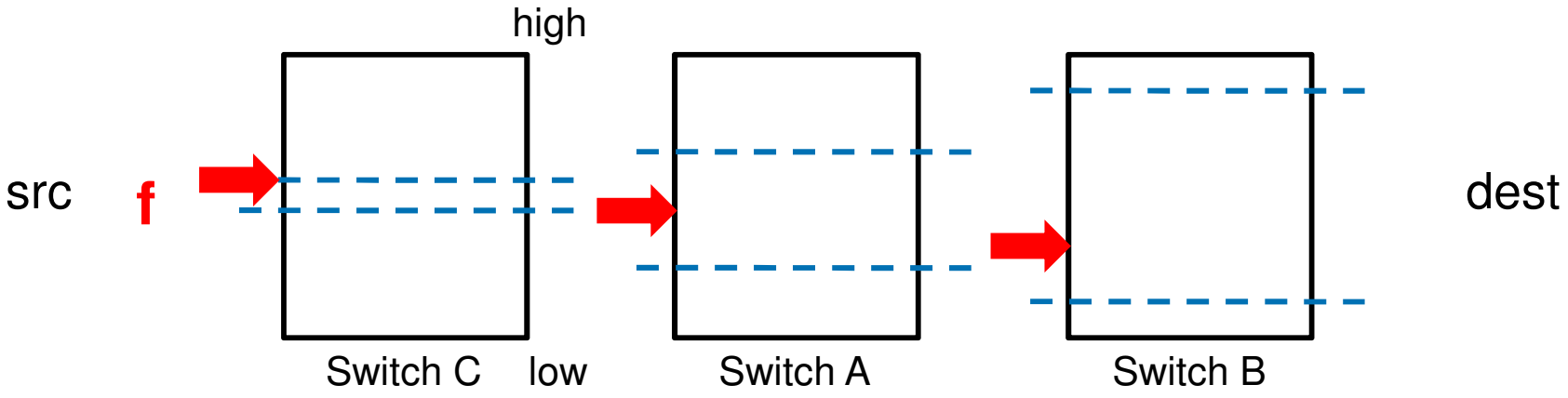
Shortest Span First (SSF)

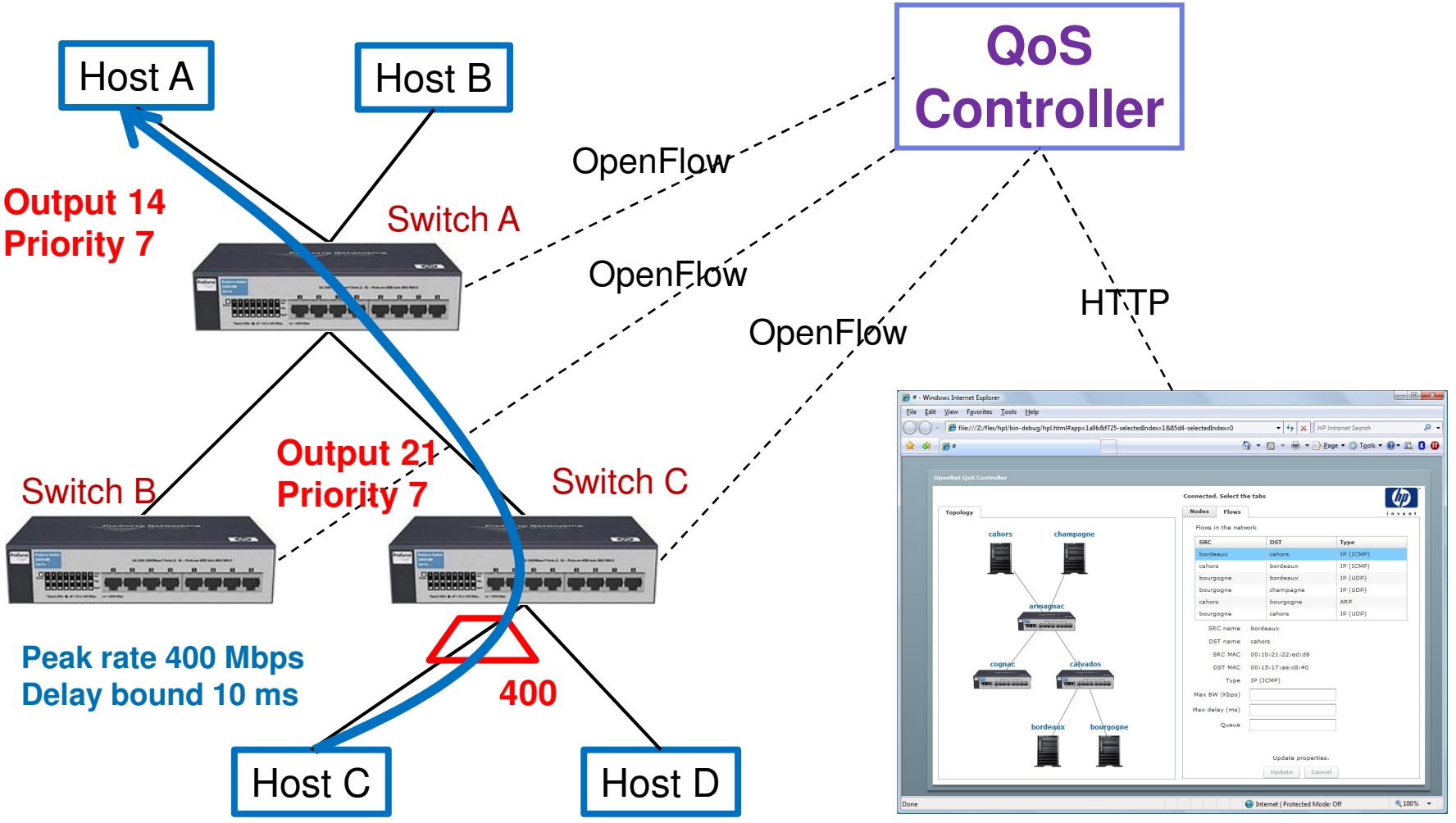


- Step 3: try highest level at each hop
  - try first a switch more likely to reject flow

Implementataion

- QoS APIs implemented on
  - hardware switch (HP ProCurve 5406zl)
  - software switch (Open vSwitch)
- QoS Controller implemented on top of NOX
  - open-source OpenFlow controller
  - http://noxrepo.org
- QoS Controller web interface

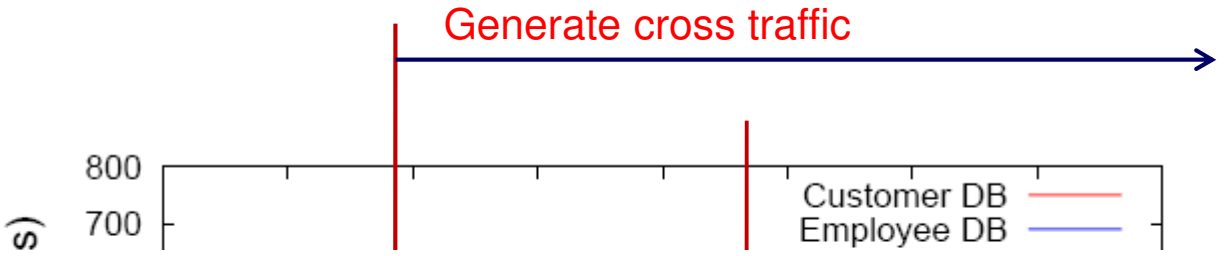
Prototype


Host A
Host B
QoS Controller
OpenFlow
Output 14
Priority 7
Switch A
OpenFlow
HTTP
OpenFlow
Output 21
Priority 7
Switch B
Switch C
Peak rate 400 Mbps
Delay bound 10 ms
400
Host C
Host D

Evaluation

- Traffic generation
  - generate 3 guaranteed flows from emulated services (UDP)
  - generate cross traffic (UDP, TCP)
- Disable/Enable QoS controller
- Measured throughput and packet loss in testbeds

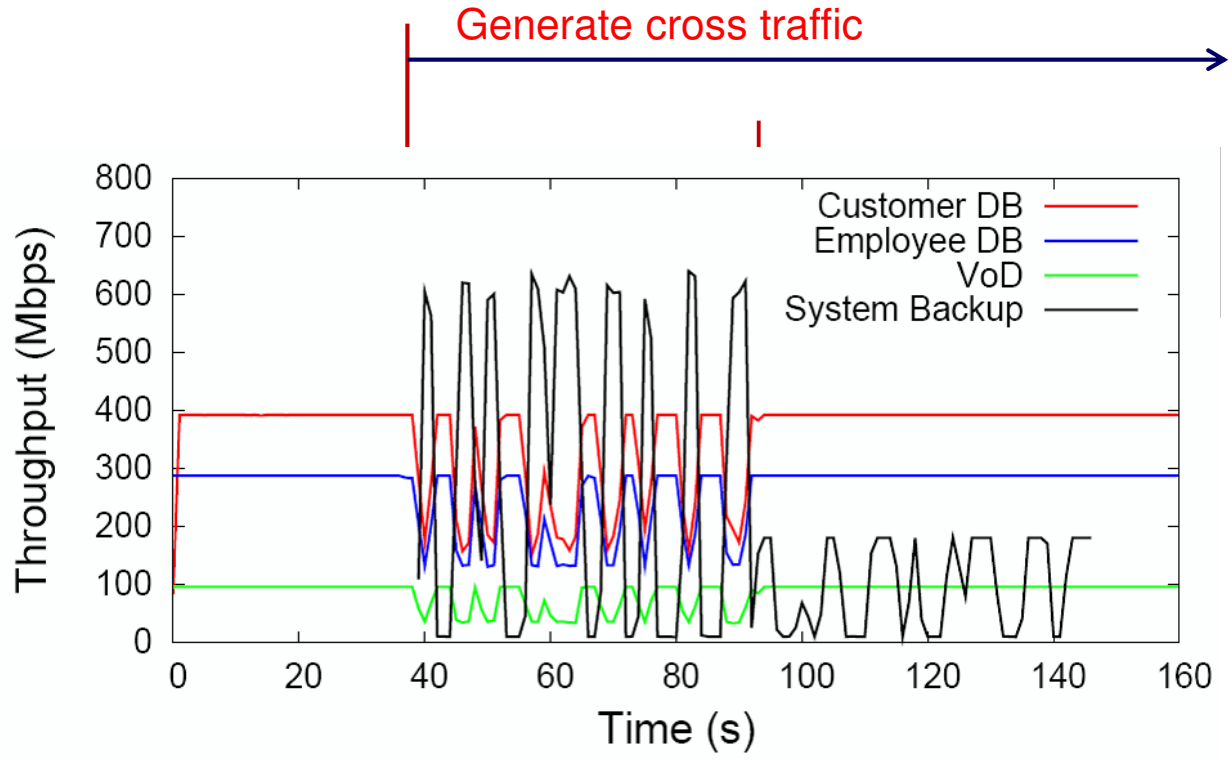
Throughput with UDP cross traffic



Flow name	Route (queue assignment)
Customer DB	H3 – S3(8) – S1(8) – H1
Employee DB	H4 – S3(8) – S1(8) – H2
VoD	H3 – S3(7) – S1(7) – H1
System Backup	H4 – S3(1) – S1(1) – H2

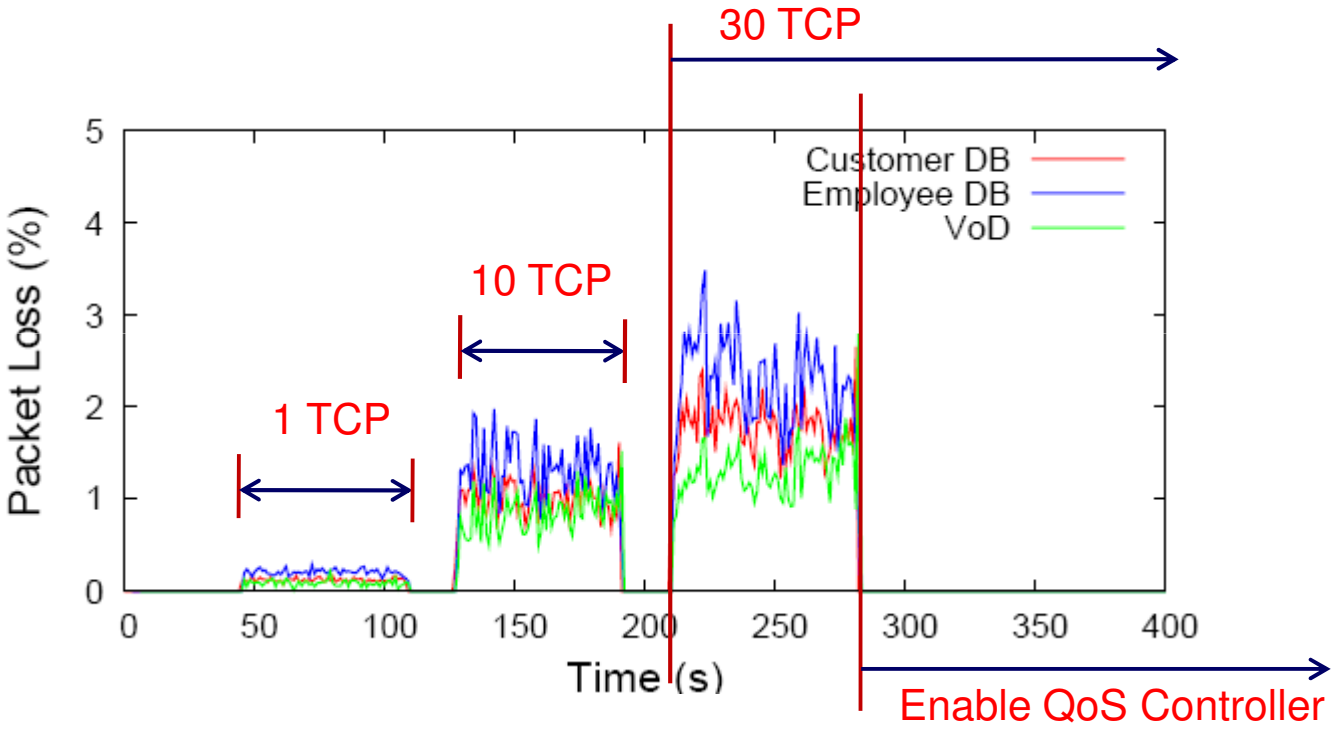
QoS controller protects guaranteed flows in congestion

Throughput with UDP cross traffic



QoS controller protects guaranteed flows in congestion

Packet loss with TCP cross traffic



QoS control is needed even when most traffic in network is TCP

Future works

- Evaluations
  - effectiveness of admission control heuristics (ratio of admitted flows)
  - compare with offline optimal assignment
  - simulations on a variety of datacenter networks (e.g., Hierarchical, FatTree, …)
- Deployment
  - extend deployment to large networks
  - test with mixture of services

Conclusion

- Single integrated network fabric is desirable
- We need fine-grained automated QoS control
- Contributions
  - Design & Implement OpenFlow QoS APIs
  - QoS controller: automated QoS control for network slicing

Thank you