Automated and Scalable QoS Control
- For Network Convergence

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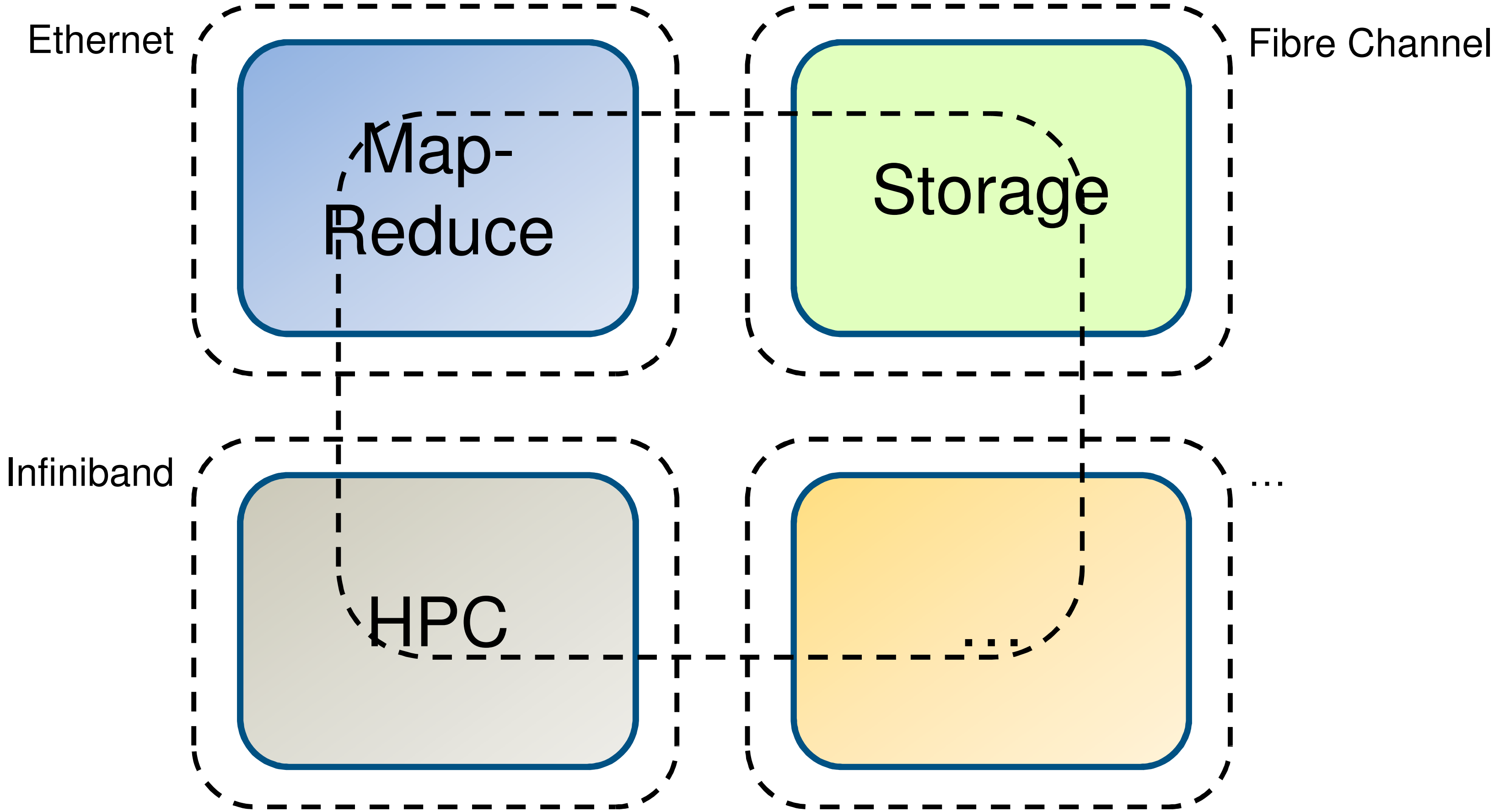
Motivation

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

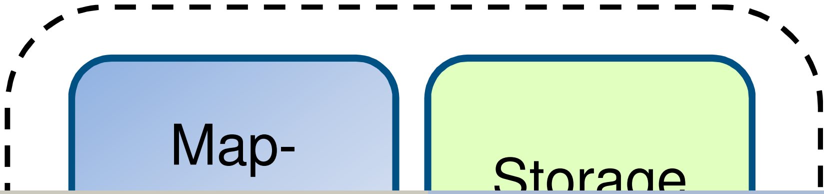
- Automated QoS control is needed

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)

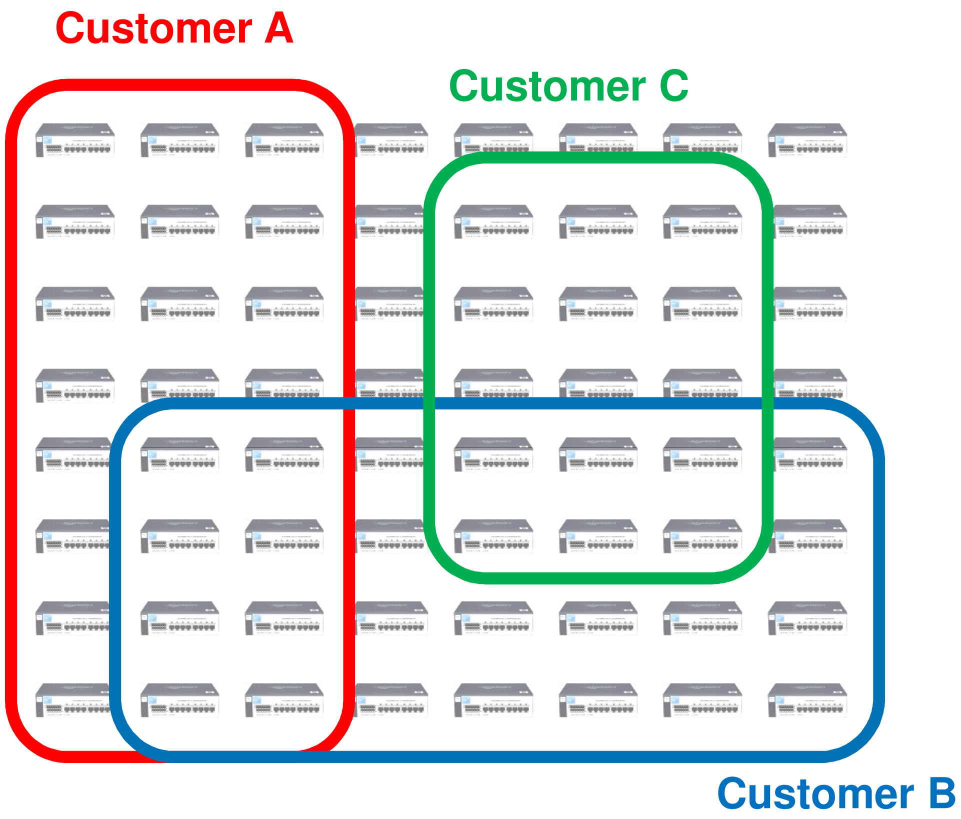
Data Center Ethernet (DCE)

Data Center Bridging (DCB)

Fibre Channel over Ethernet (FCoE)

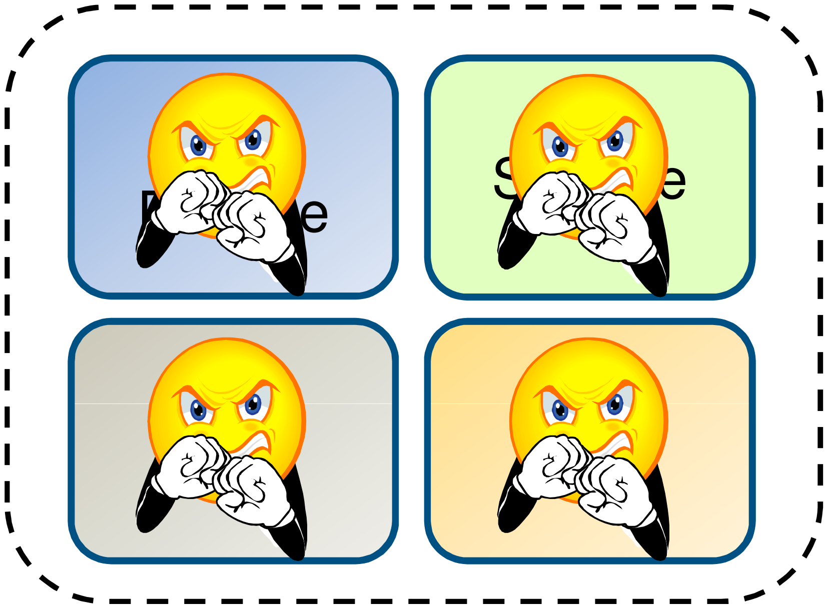
Fibre Channel over CEE (FCoCEE)

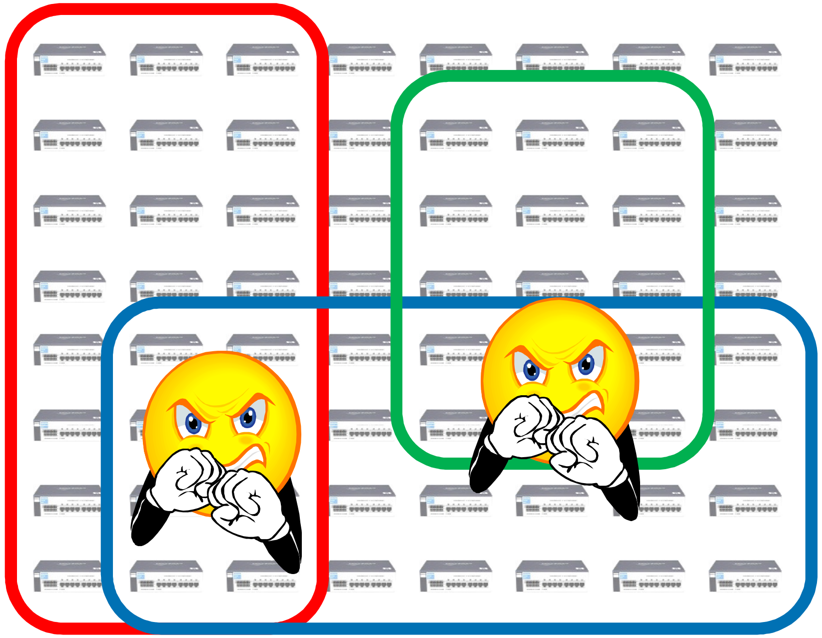
Multi-tenancy networks



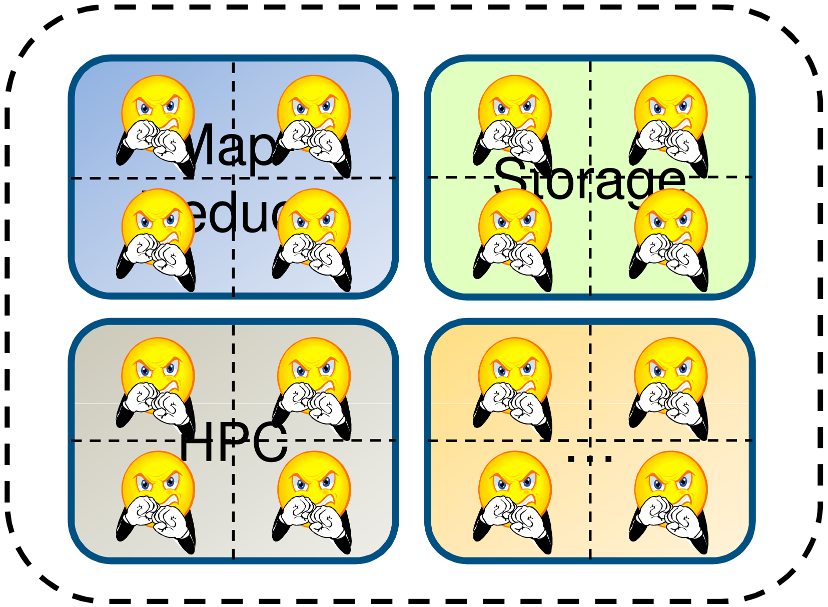
- Serve multiple customers with a single fabric
- Better utilization of network infrastructure

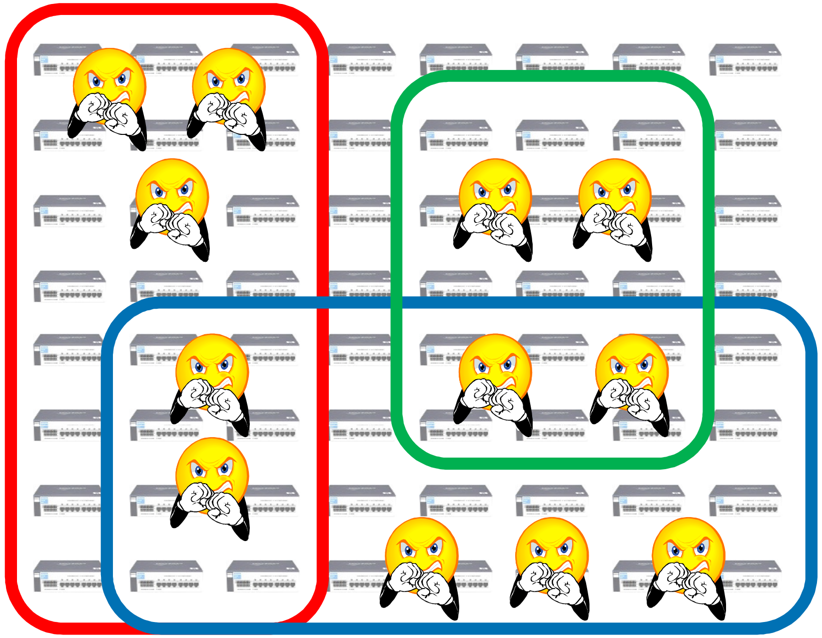
Performance isolation



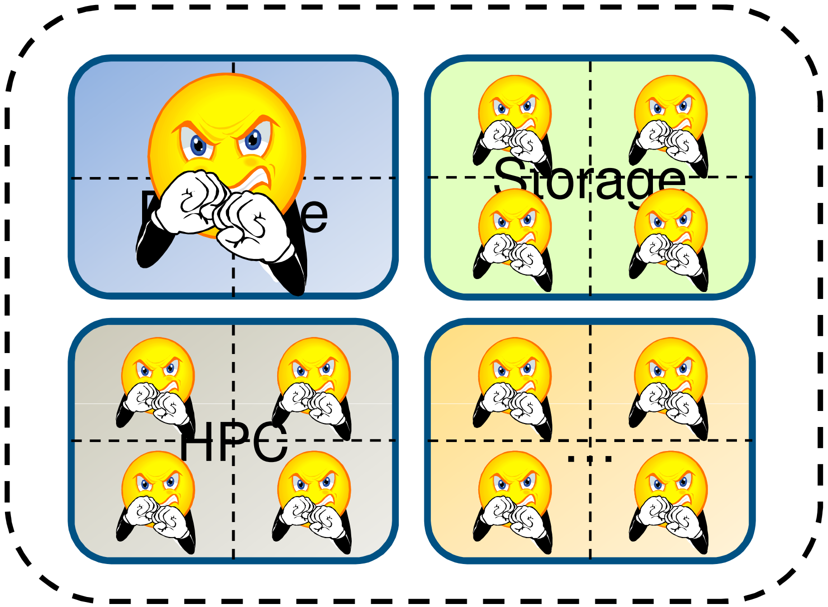


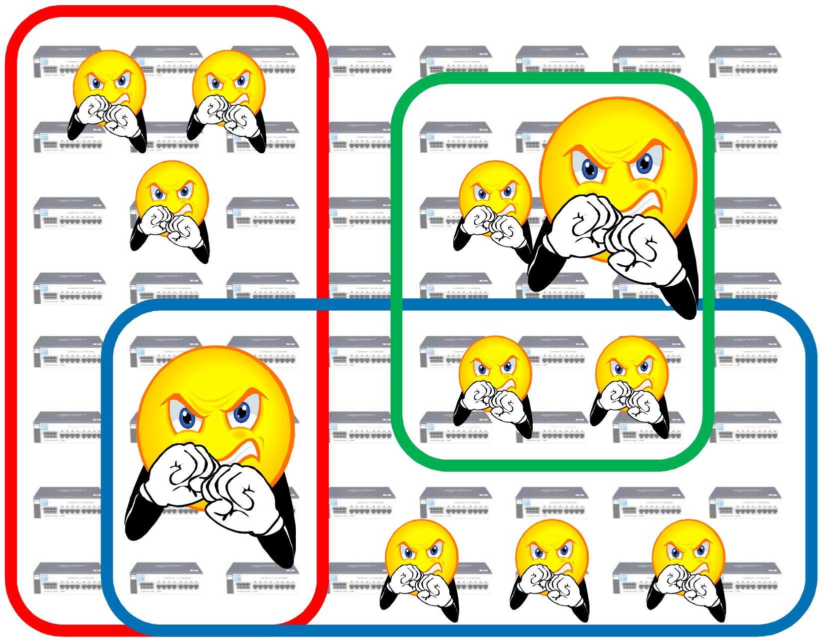
Performance isolation



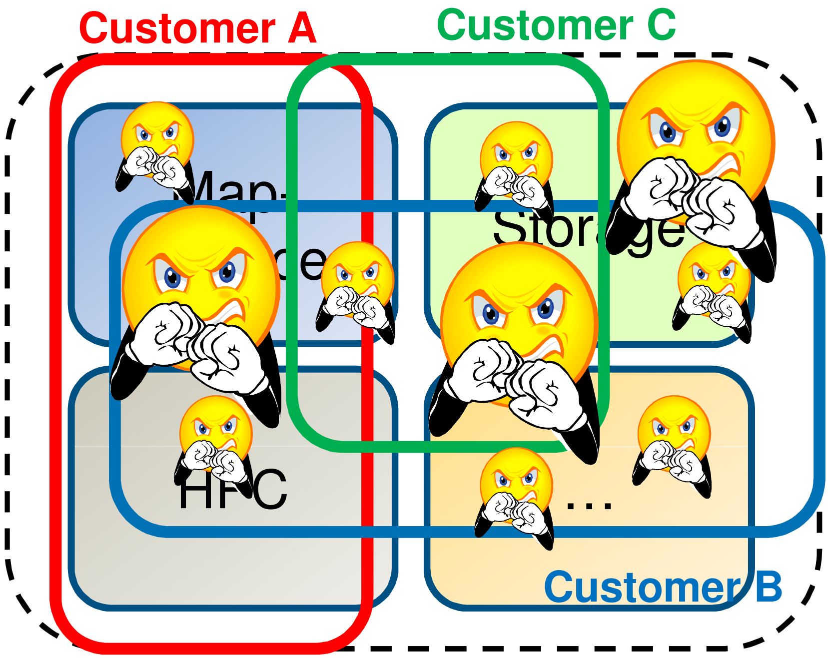


Performance isolation





Performance isolation



Virtualized Servers

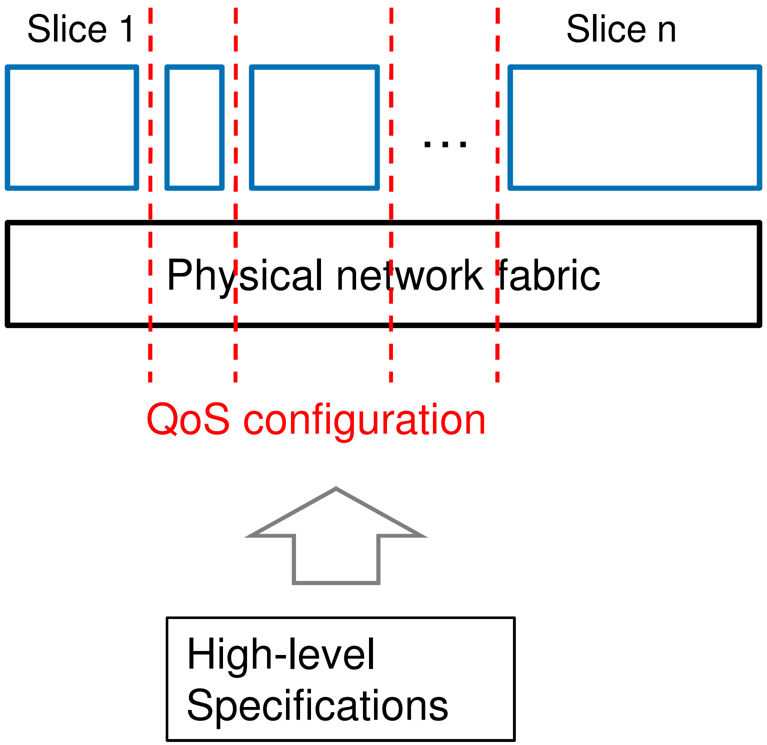
Variable Workloads

Bugs, malicious attack

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

Goal

- Enables performance isolation with QoS control



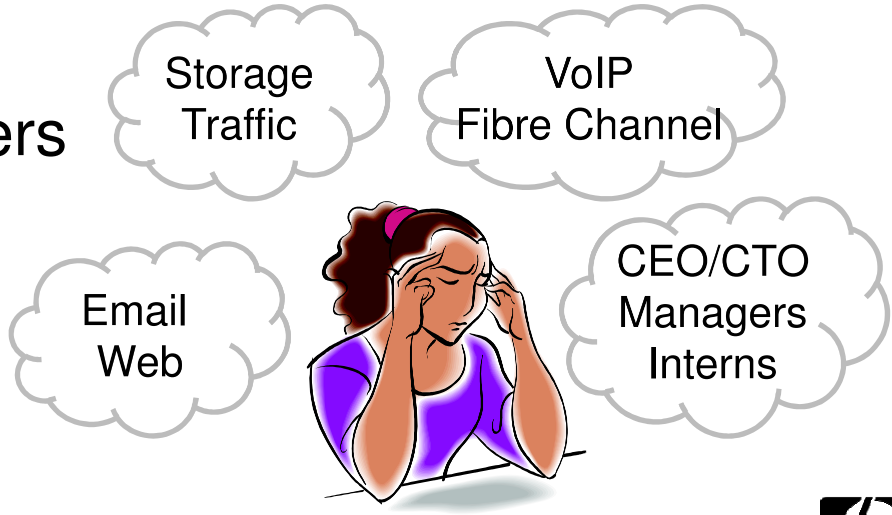
Good news

- 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

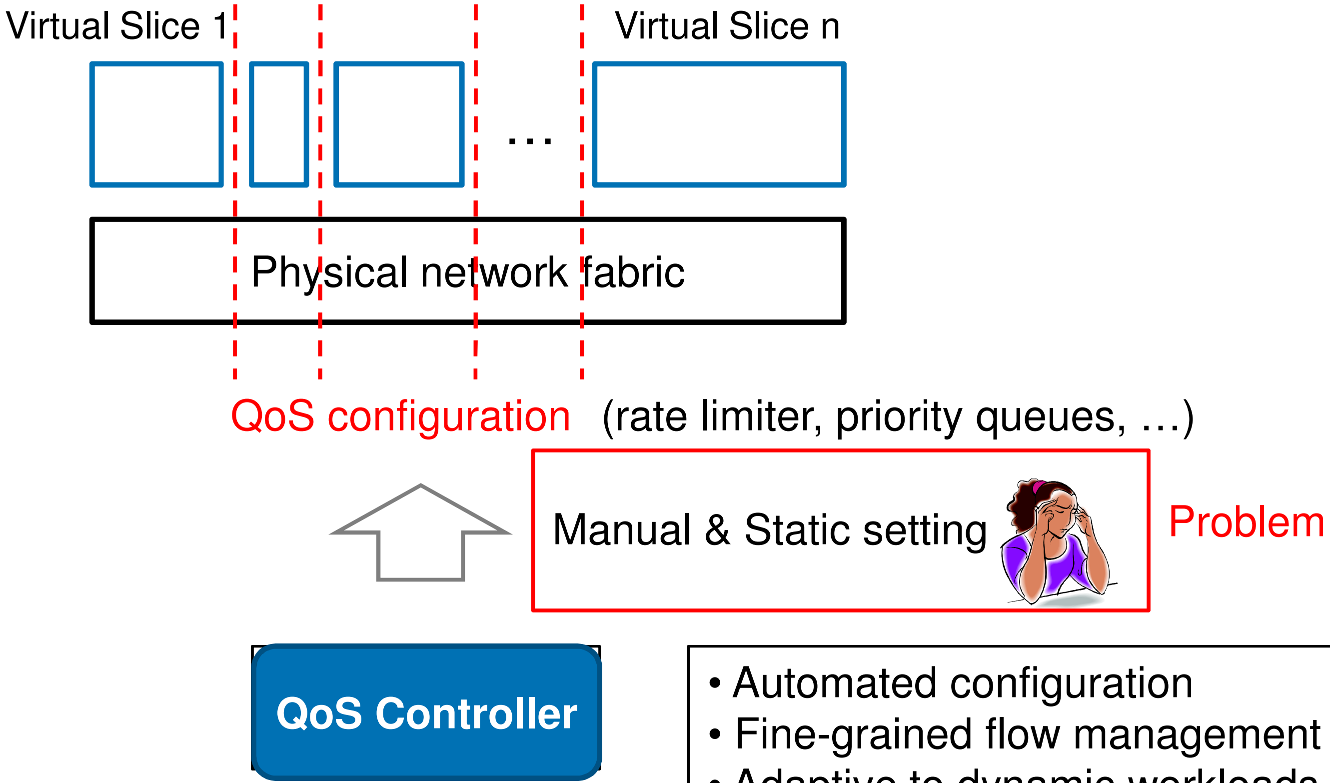
Challenges

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

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

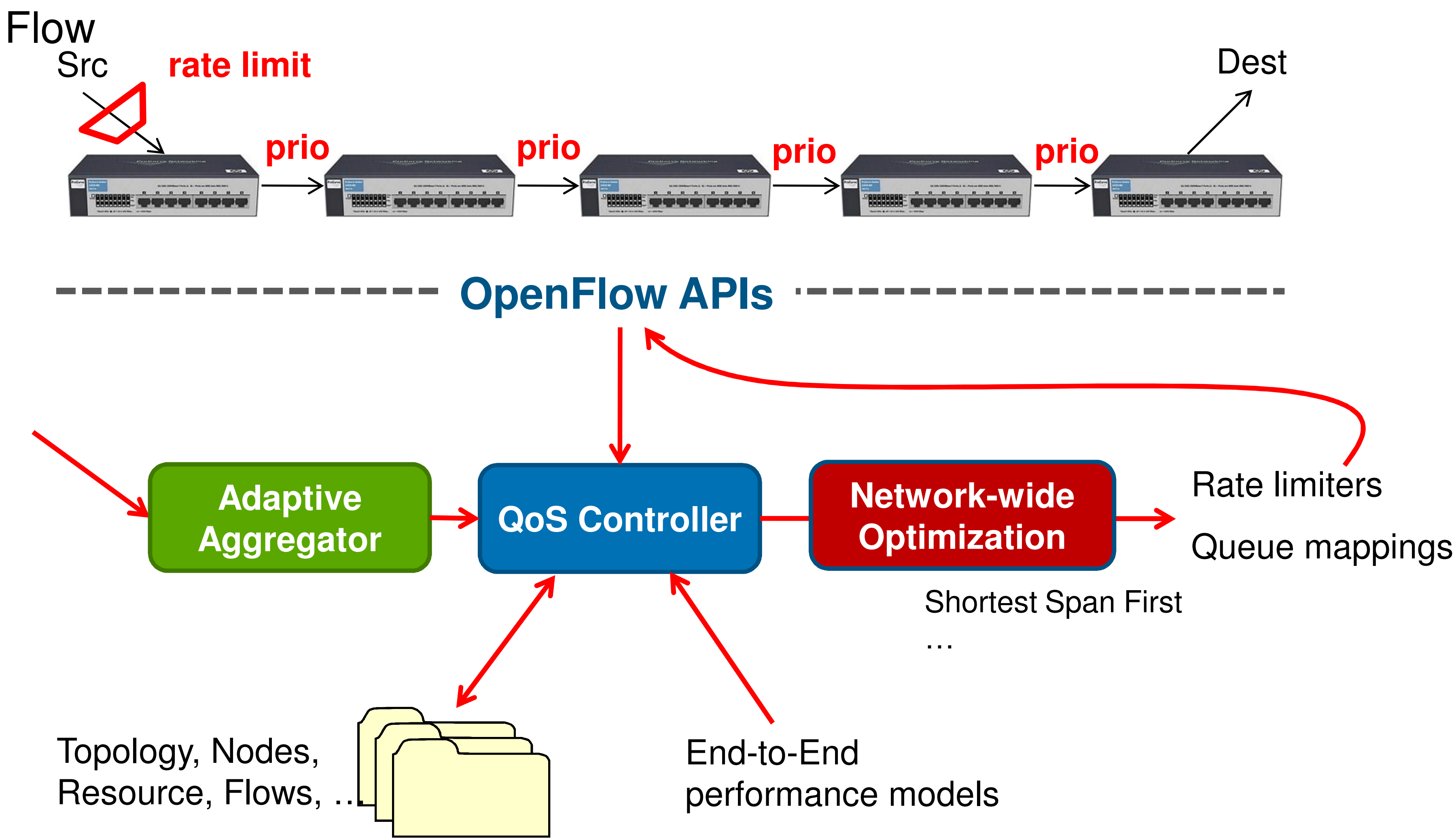


Our Solution: OpenFlow QoS Controller

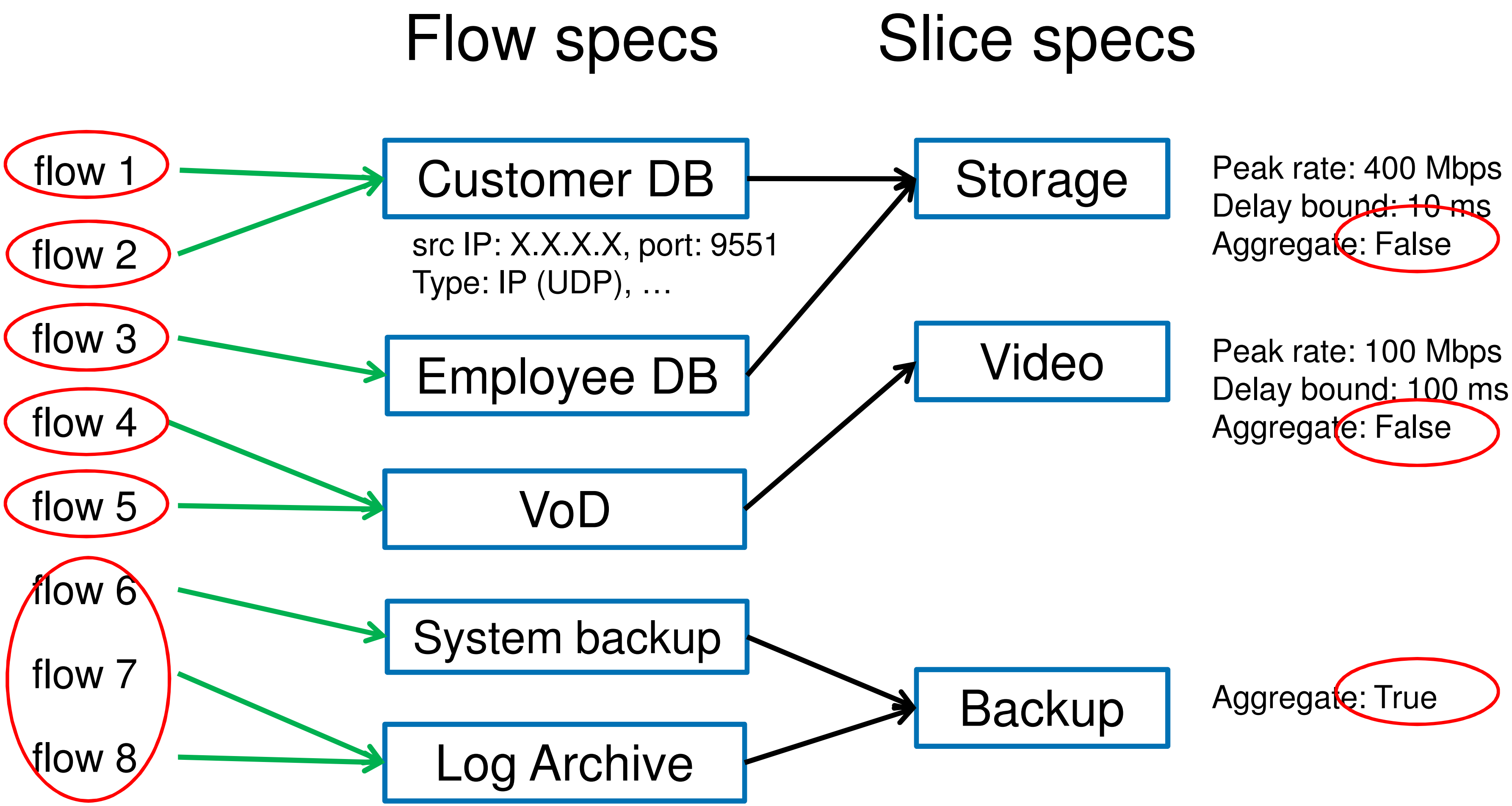


- Automated configuration
- Fine-grained flow management
- Adaptive to dynamic workloads

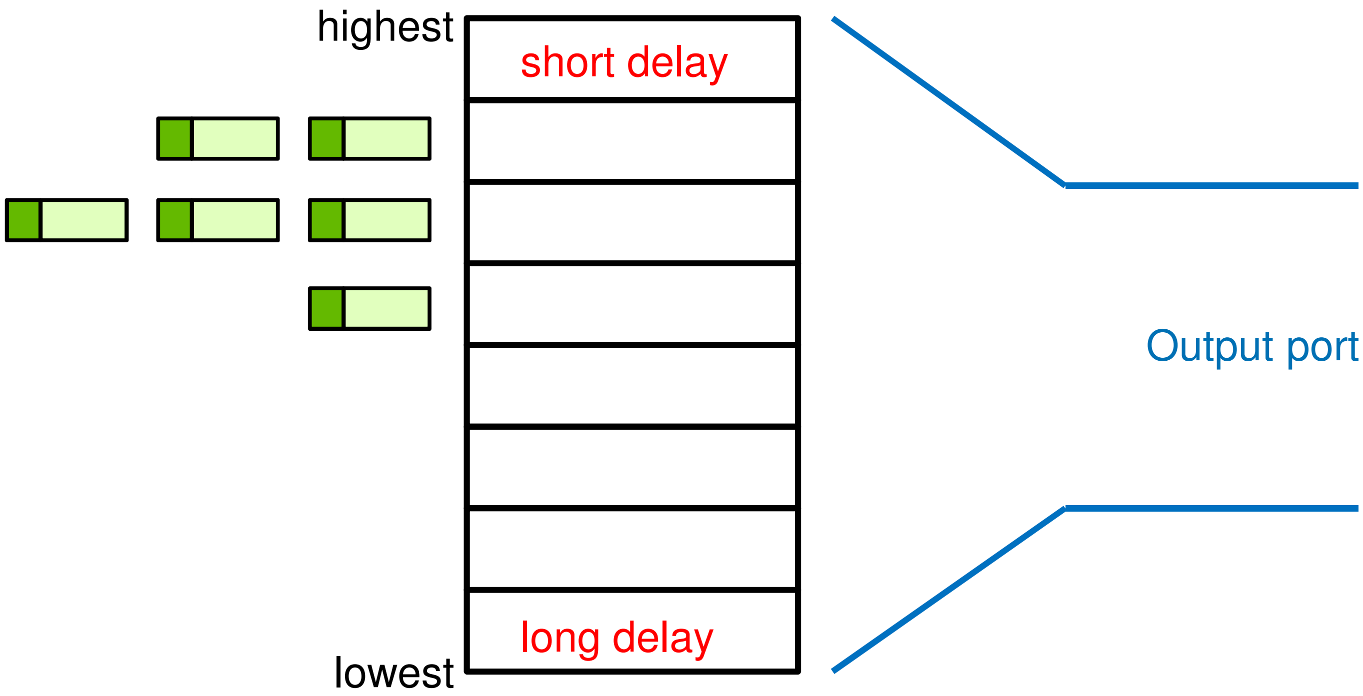
Overview of OpenFlow QoS controller



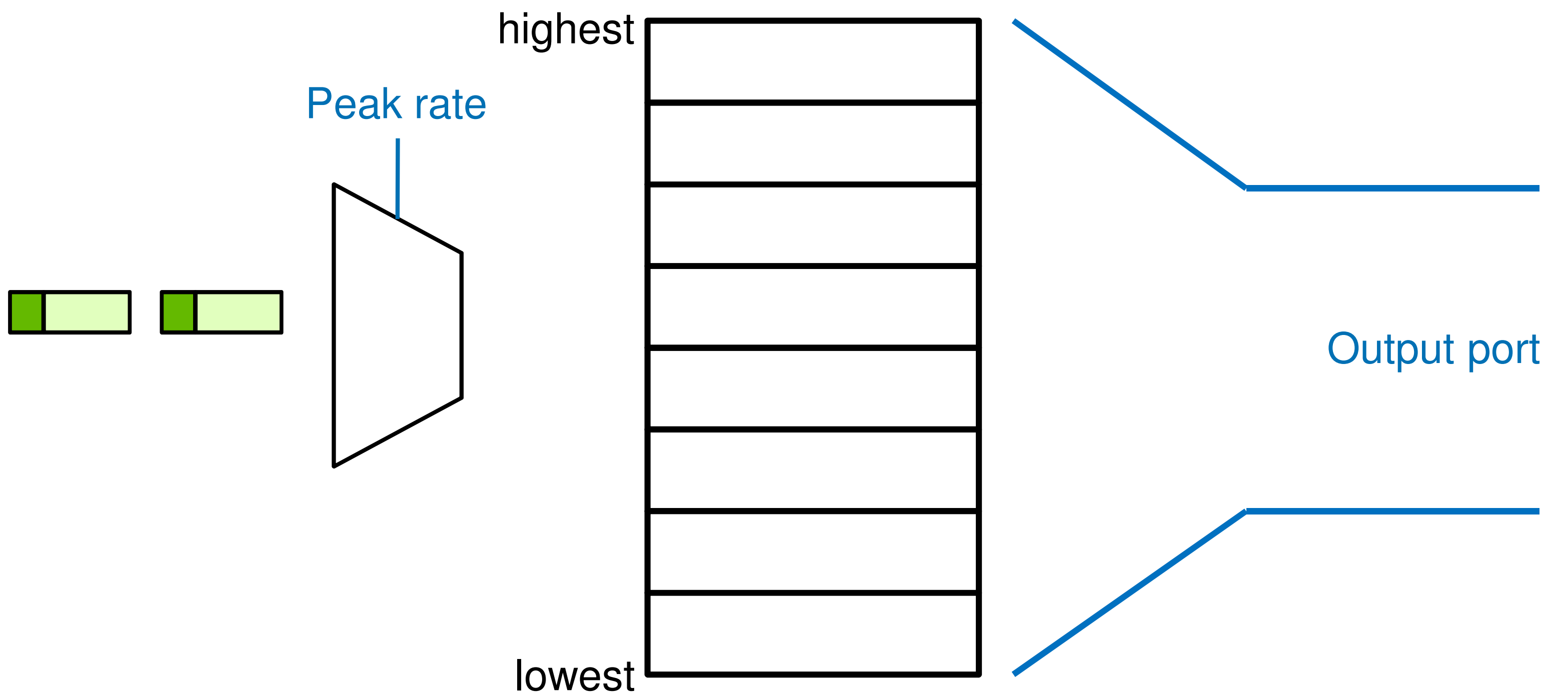
Adaptive aggregation



Available QoS Knobs (Priority queue)

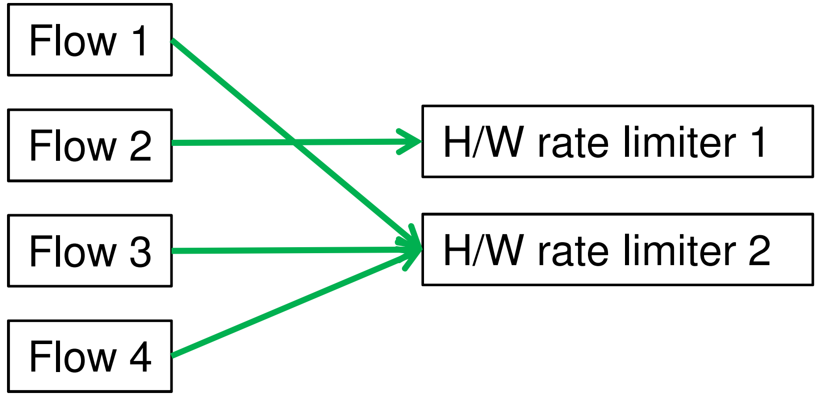


Available QoS Knobs (Rate limiter)

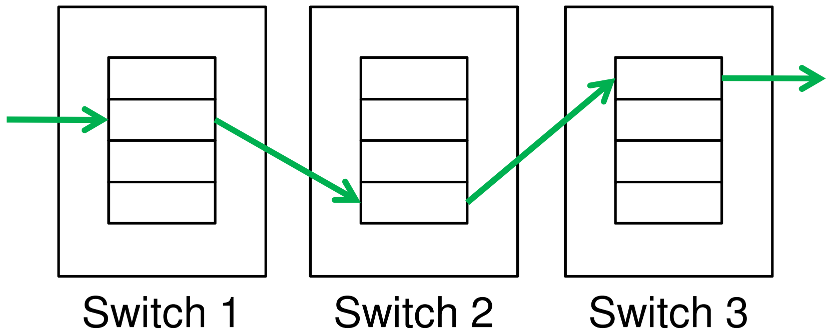


OpenFlow QoS APIs

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

invent

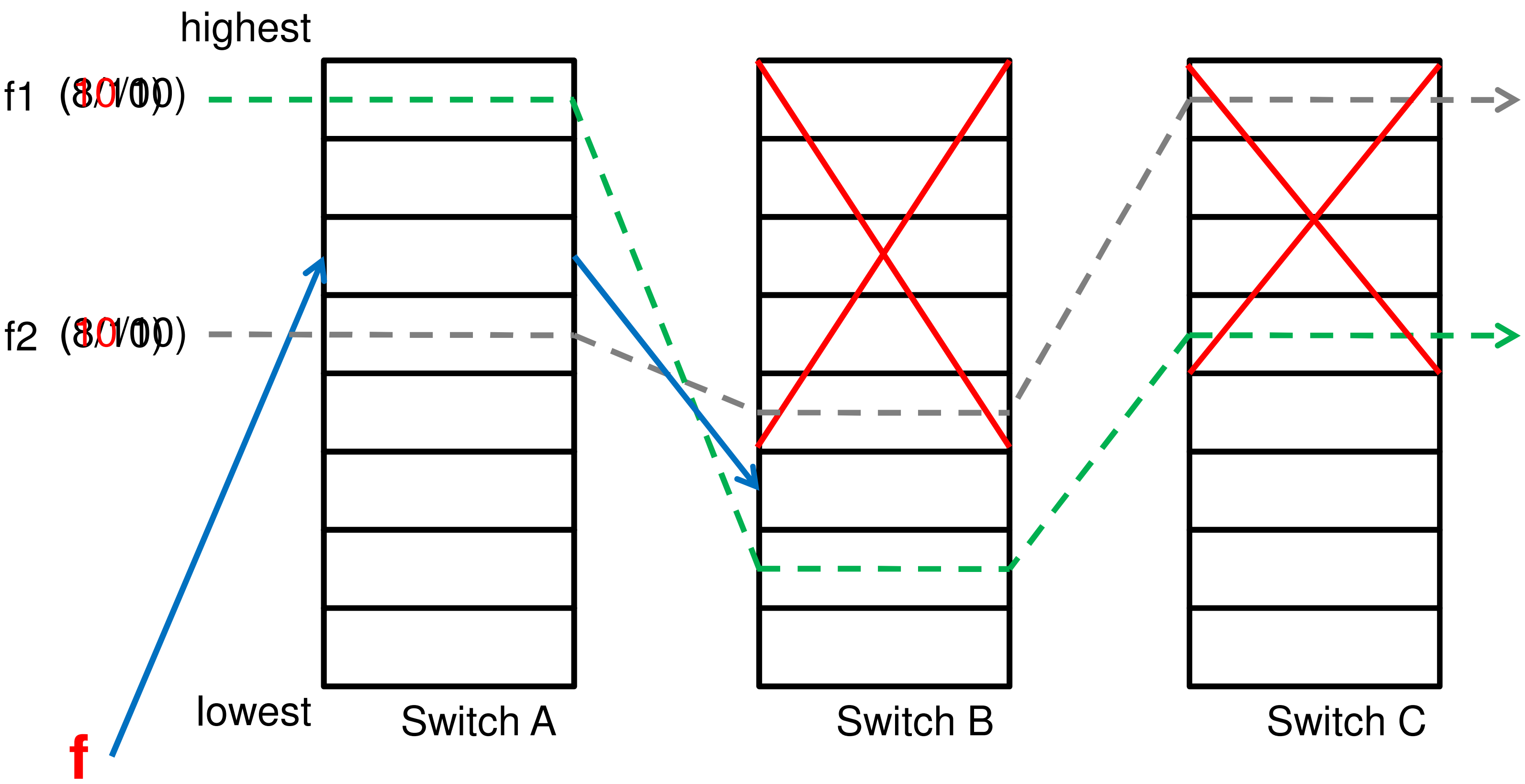
Admission Control

- 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



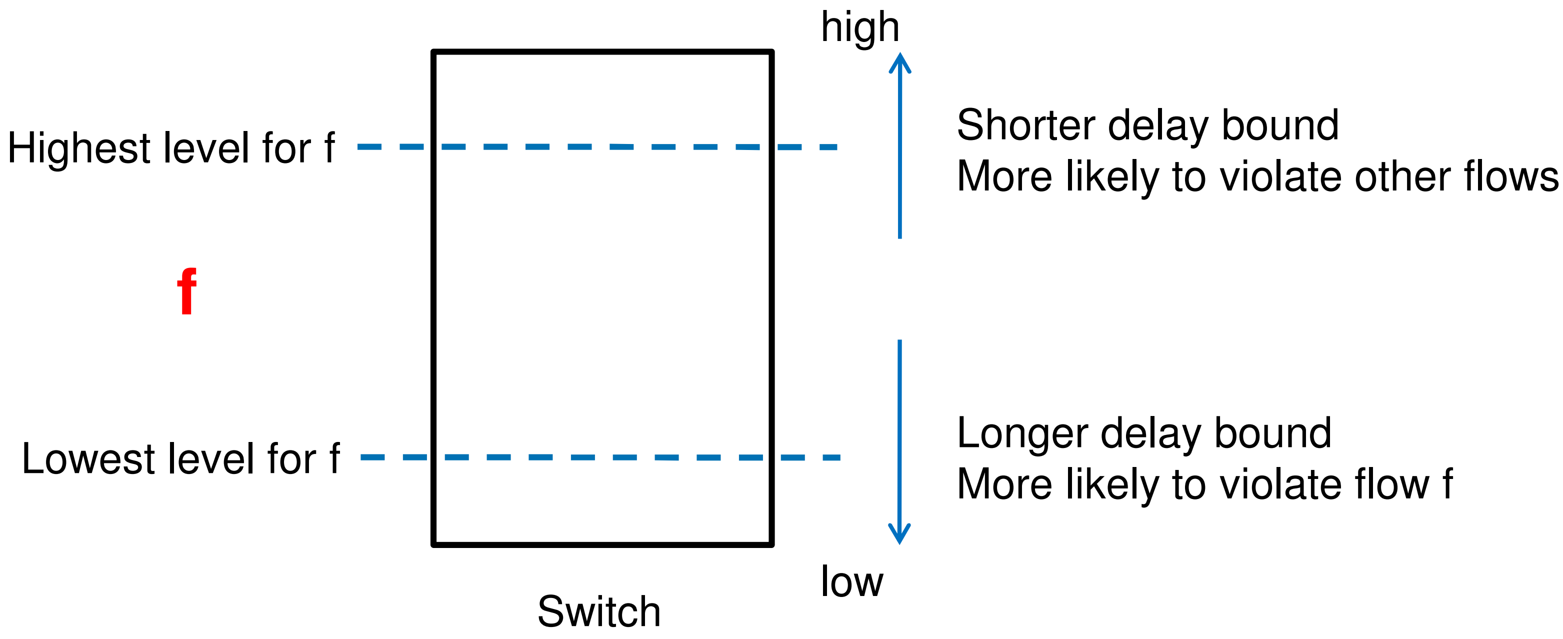
We should consider interactions between

- flows in a switch
- flows in multiple switches

Admission control heuristic

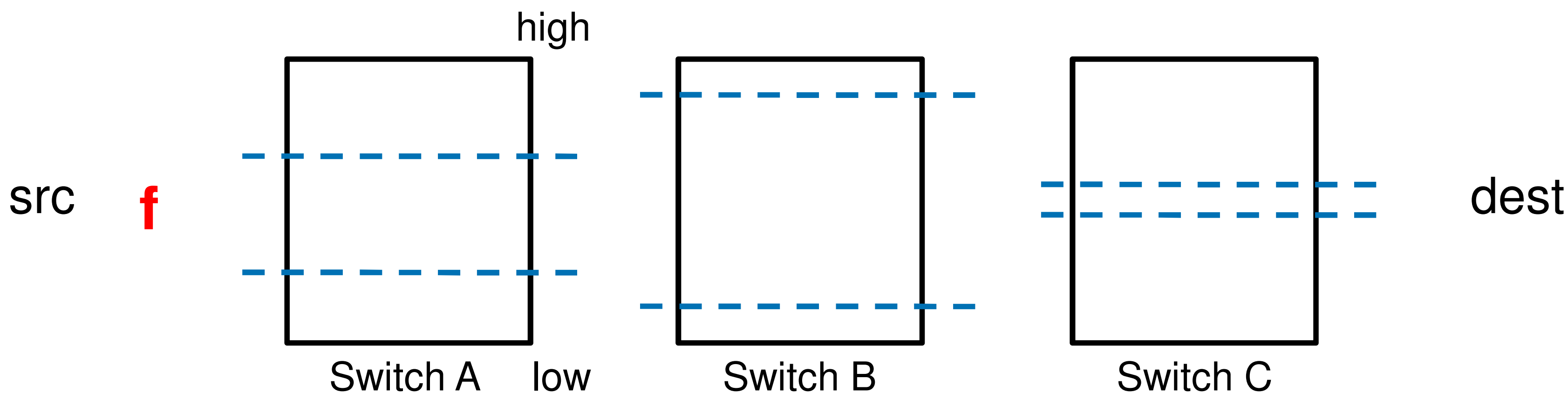
- Goal
  - increase the ratio of admitted flows
  - lower the complexities in queue allocation
- Shortest Span First (SSF)
- Basic ideas
  - estimate affordable options for a flow
  - try first switches more likely to reject flow

Highest level & Lowest level



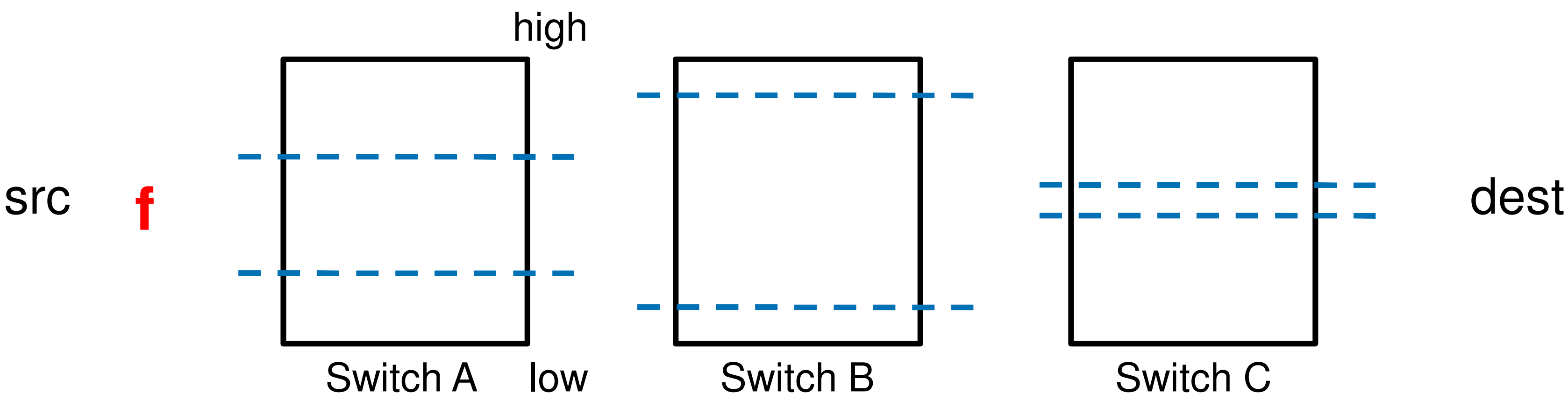
- Highest level: not violate existing flows
- Lowest level: not violate the new flow
- Span: available options for **f**

Shortest Span First (SSF)



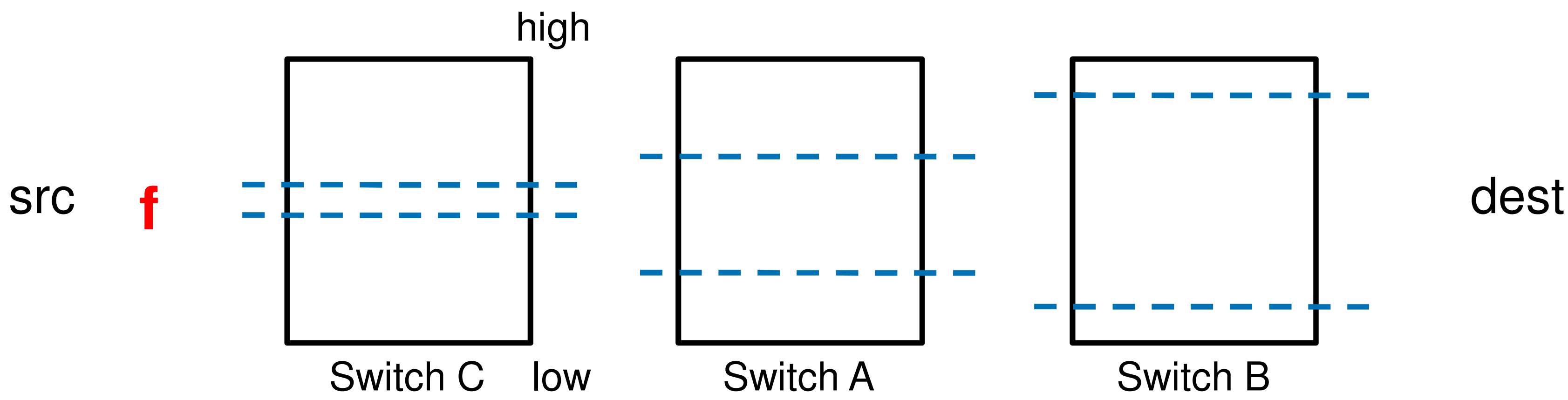
- Step 1: compute highest & lowest levels independently

Shortest Span First (SSF)



- Step 2: sort switches in order of the span

Shortest Span First (SSF)



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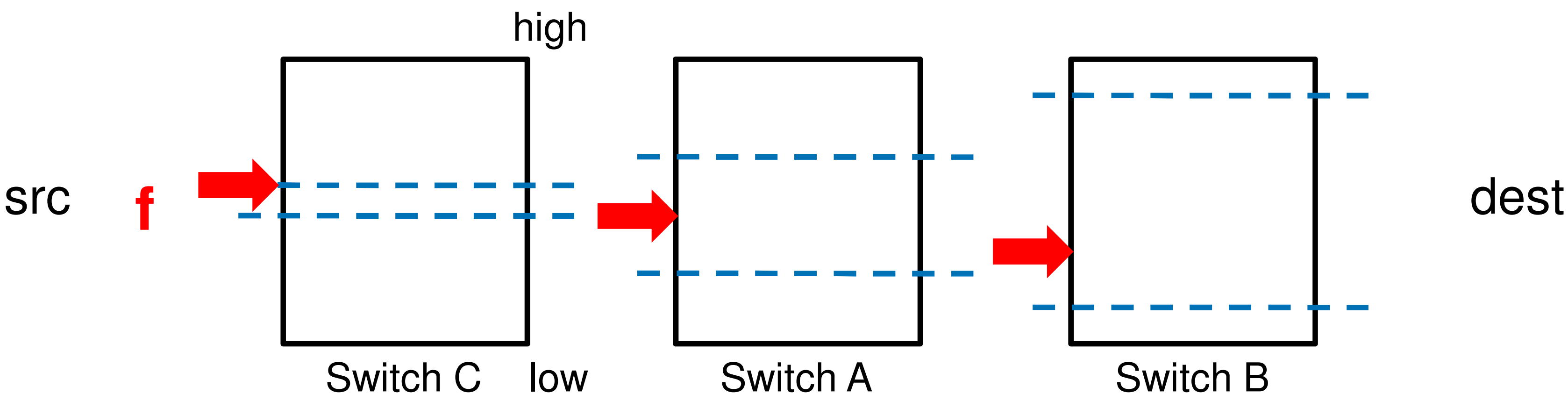
Shortest Span First (SSF)



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

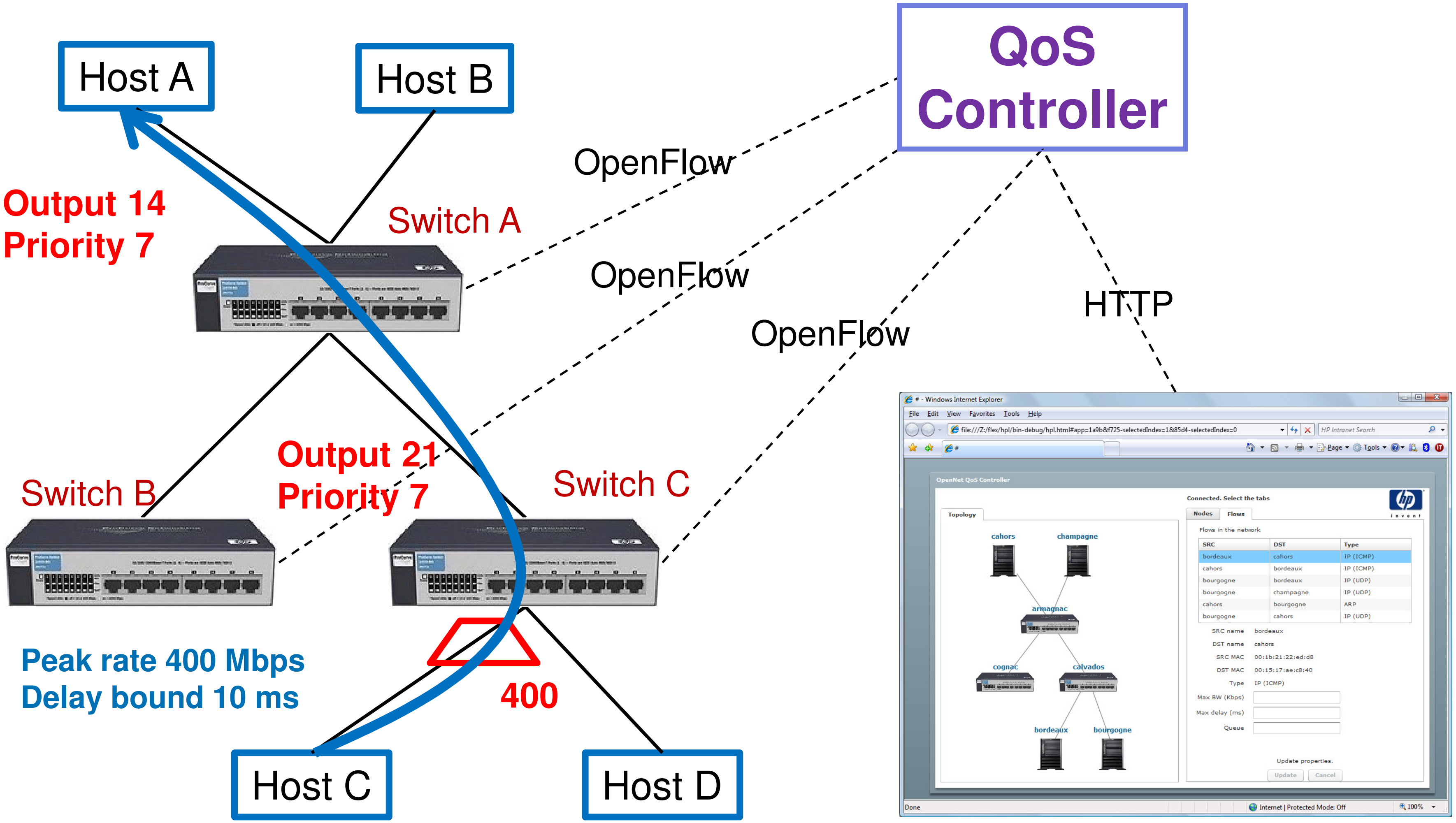
Implementataion

- 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

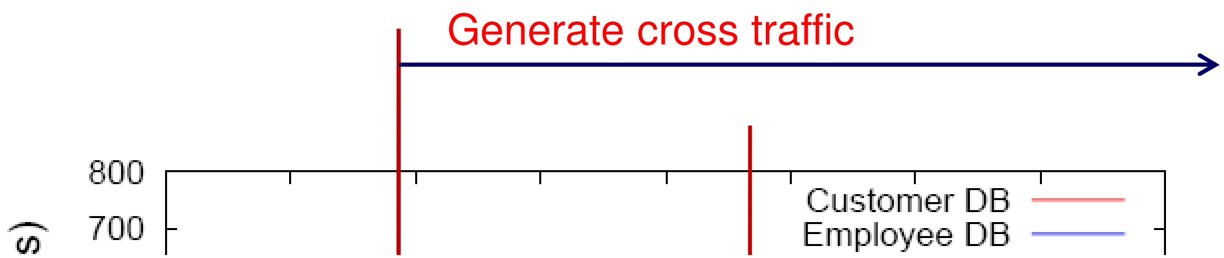


Host A
Host B
QoS Controller
OpenFlow
Output 14
Priority 7
Switch A
OpenFlow
HTTP
OpenFlow
Output 21
Priority 7
Switch B
Switch C
Peak rate 400 Mbps
Delay bound 10 ms
400
Host C
Host D

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

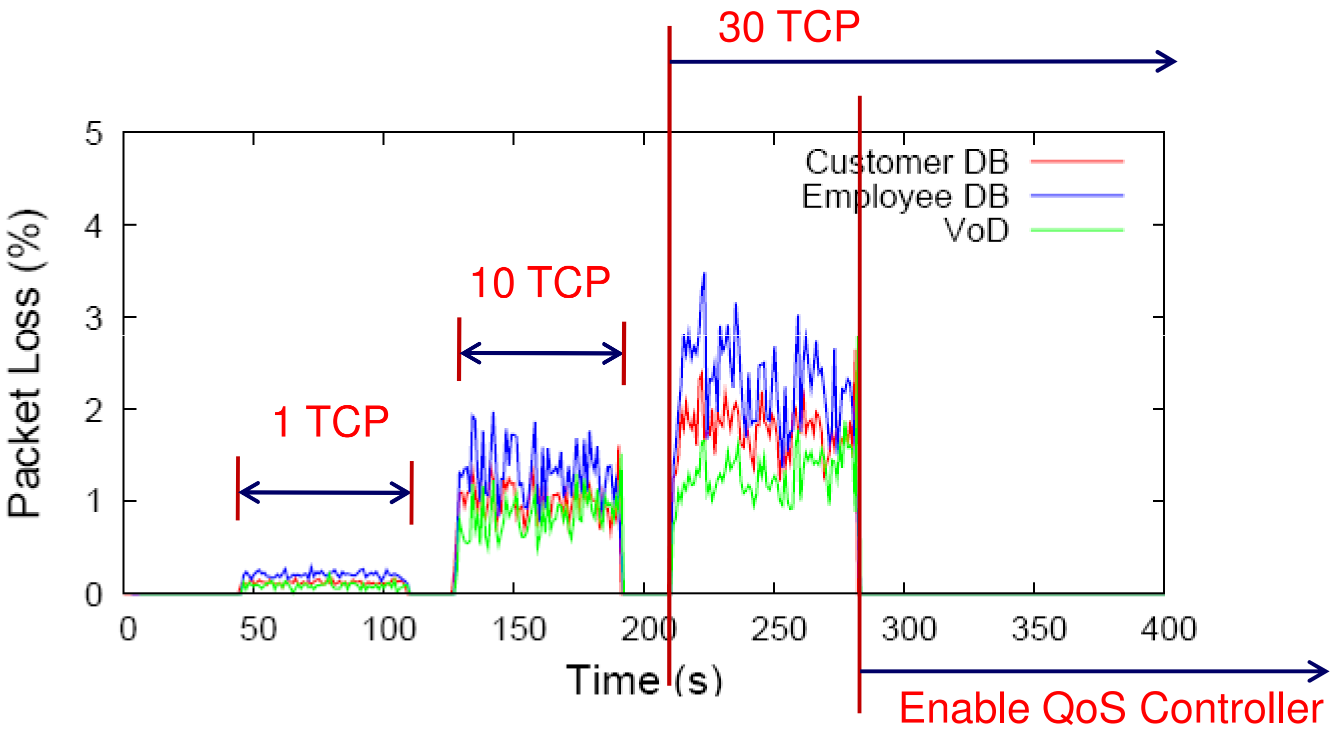
Throughput with UDP cross traffic



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

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