Congestion Management – Congestion Isolation

Paul Congdon

Yolanda Yu

Kevin Shen

paul.congdon@tallac.com

yolanda.yu@huawei.com

kevin.shenli@huawei.com

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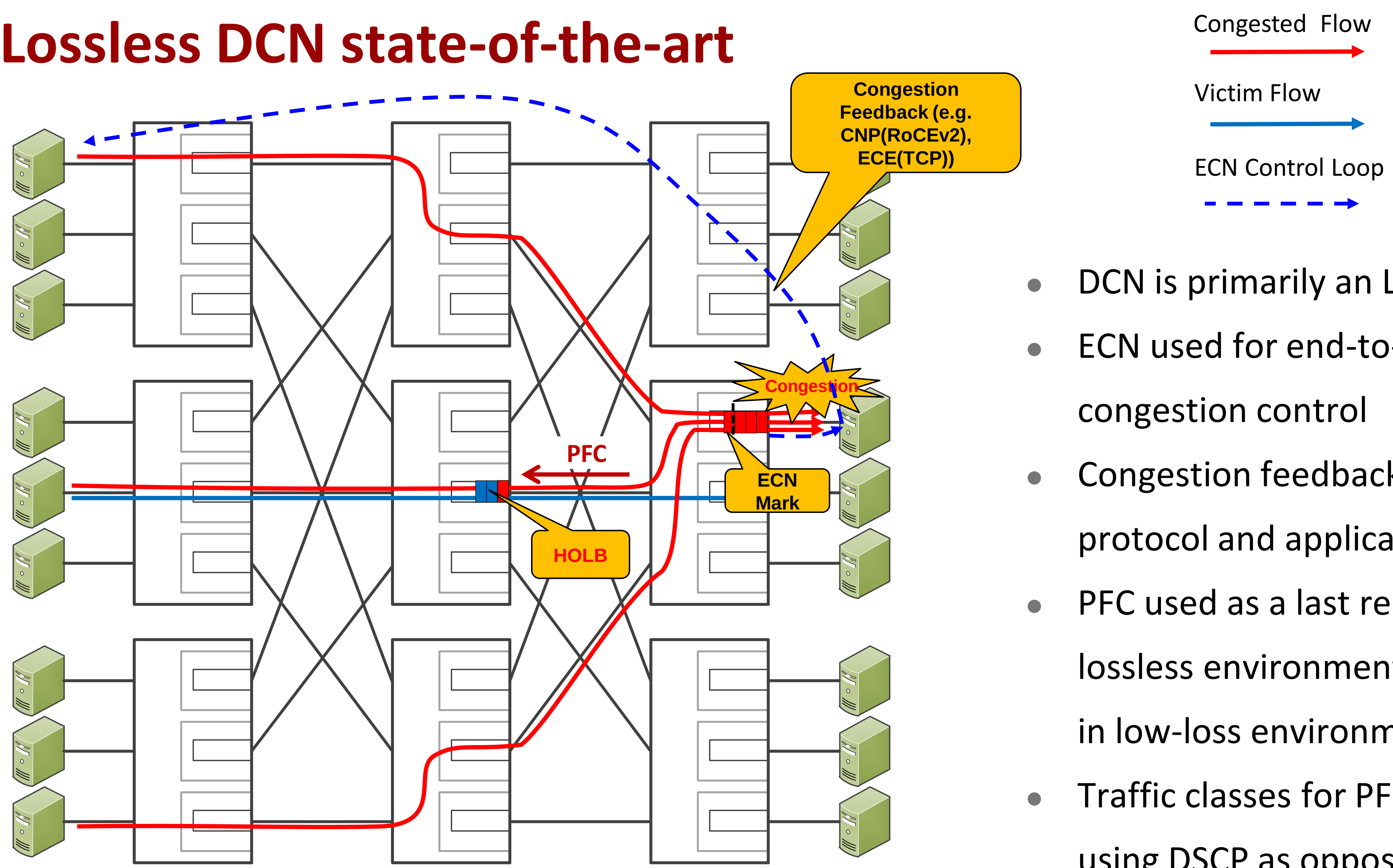
Agenda

- Low-Latency, Lossless, Large-Scale DCNs
- Challenges going forward
- Solution Goals
- Congestion Isolation Details
- Simulation Analysis
- Next Steps

The Case for Low-latency, Lossless, Large-Scale DCNs

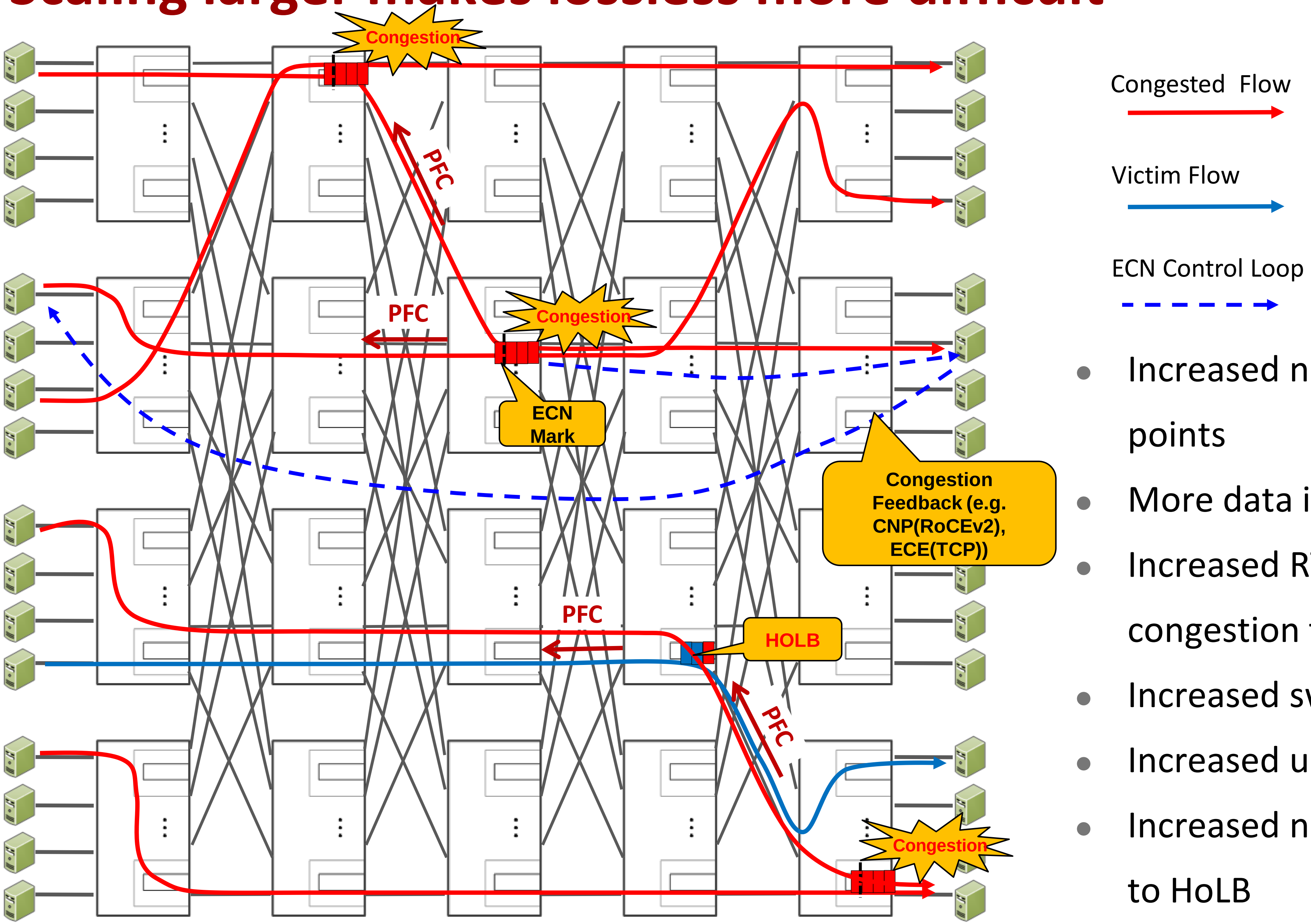
- More and more latency-sensitive applications are being deployed in data centers
  - Distributed Storage
  - AI / Deep Learning
  - Cloud HPC
  - High-Frequency Trading
- RDMA is operating at larger scales thanks to RoCEv2
  - Chuanxiong Guo, et. al., Microsoft, ”RDMA over Commodity Ethernet at Scale”, SIGCOMM 2016
  - Y Zhu, H Eran, et. al., Microsoft, Mellanox, “Congestion control for large-scale RDMA deployments”, SIGCOMM 2015
  - Radhika Mittal, et. al., UC Berkeley, Google, “TIMELY: RTT-based Congestion Control for the Datacenter”, SIGCOMM 2015
- The scale of Data Center Networks continues to grow
  - Larger, faster clusters are better than more smaller size clusters
  - Server growth continues at 25% - 30% putting pressure on cluster sizes and networking costs

Lossless DCN state-of-the-art



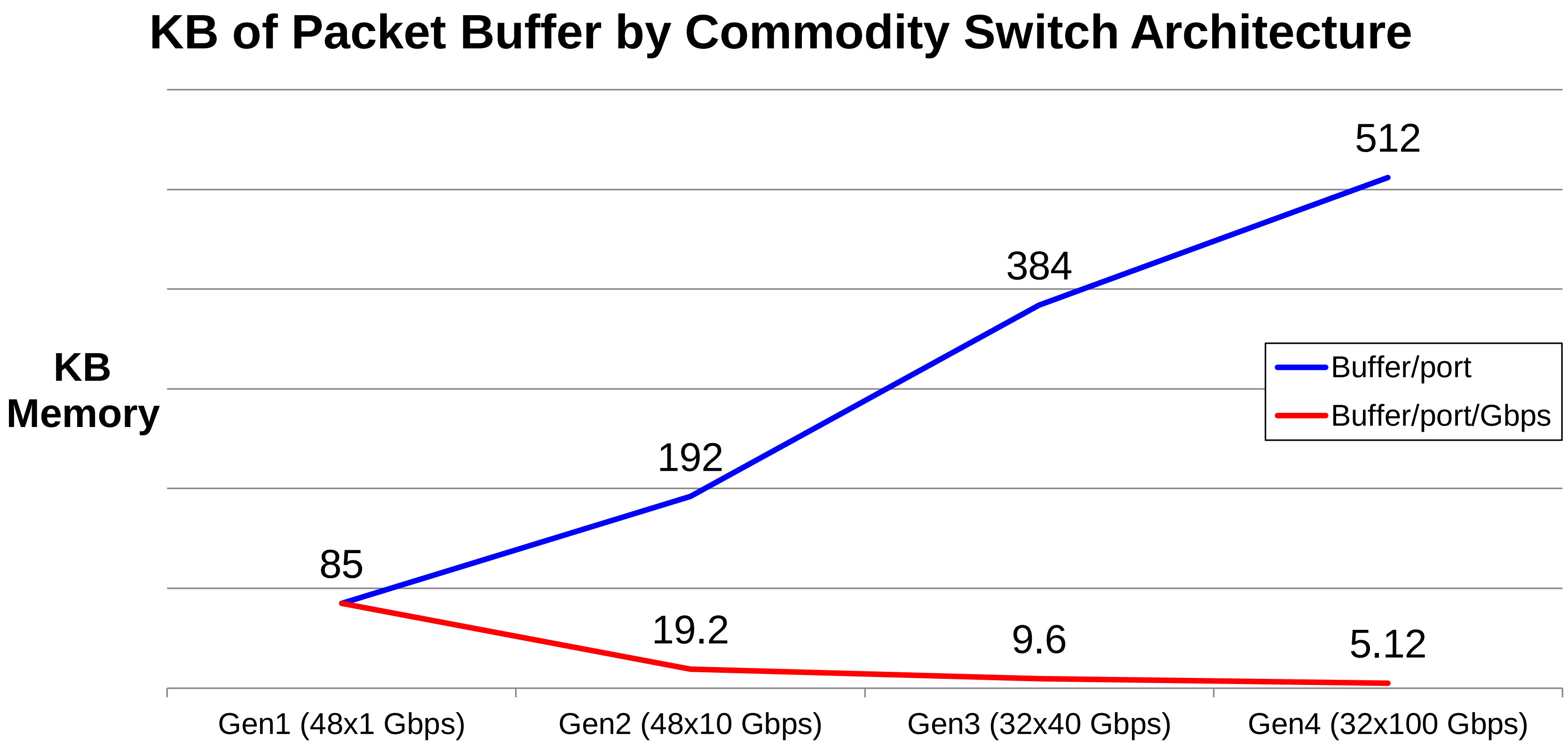
- DCN is primarily an L3 network
- ECN used for end-to-end congestion control
- Congestion feedback can be protocol and application specific
- PFC used as a last resort to ensure lossless environment, or not at all in low-loss environments.
- Traffic classes for PFC are mapped using DSCP as opposed to VLAN tags

Scaling larger makes lossless more difficult



- Increased number of congestion points
- More data in-flight
- Increased RTT and delay for congestion feedback
- Increased switch buffer requirements
- Increased use of PFC
- Increased number of victim flows due to HoLB

Switch buffer growth is not keeping up



Commodity Shallow Buffer Switches in DCNs are desirable:

- Low Latency
- Low Cost

However, packet loss can create performance issues:

- Source: Broadcom, "White Paper: Buffer Requirements for Datacenter Network Switches", DNFAMILY-WP1101, August 25, 2015

Source: "Congestion Control for High-speed Extremely Shallow-buffered Datacenter Networks". In Proceedings of APNet'17, Hong Kong, China, August 03-04, 2017, https://doi.org/10.1145/3106989.3107003

Concerns about over-using PFC

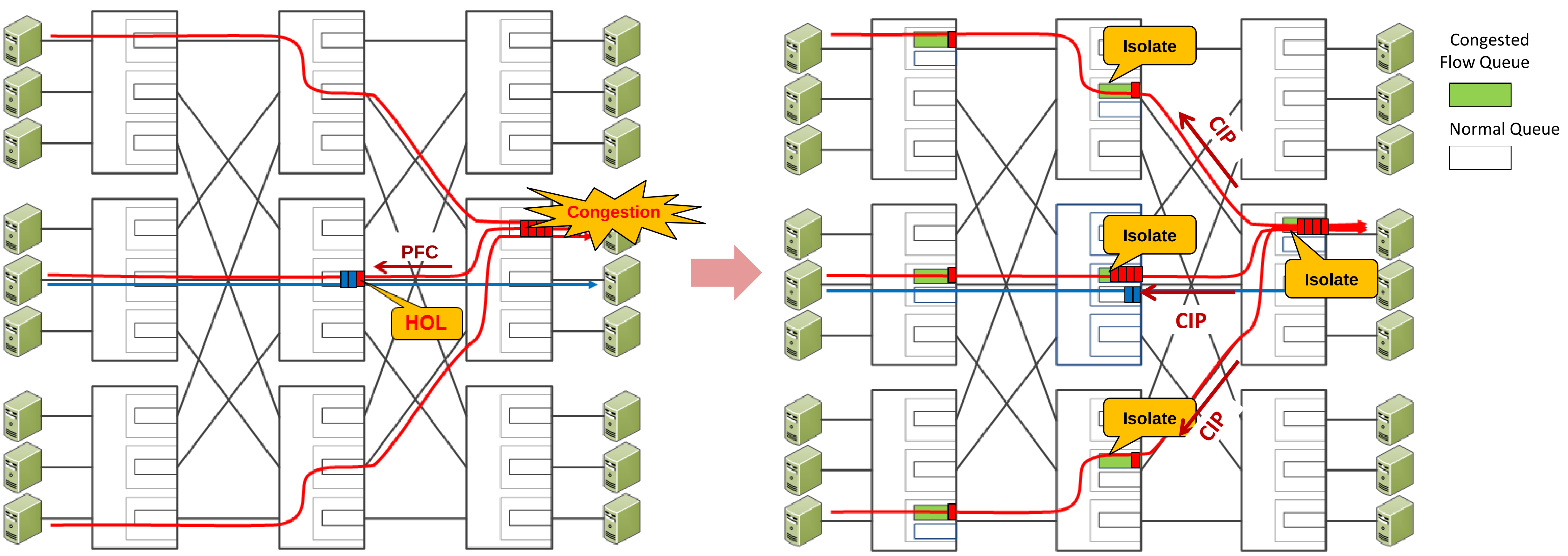
- HoL blocking
- Congestion spreading
- Buffer Bloat, increasing latency
- Increased jitter reducing throughput
- Deadlocks

Goals

- Support larger, faster data centers (Low-Latency, High-Throughput)
- Support lossless transfers
- Improve performance of TCP and UDP based flows
- Reduce pressure on switch buffer growth
- Reduce the frequency of relying on PFC for a lossless environment

- Eliminate or significantly reduce HOLB caused by over-use of PFC

Isolate the congestion to mitigate HOLB



Congestion Isolation

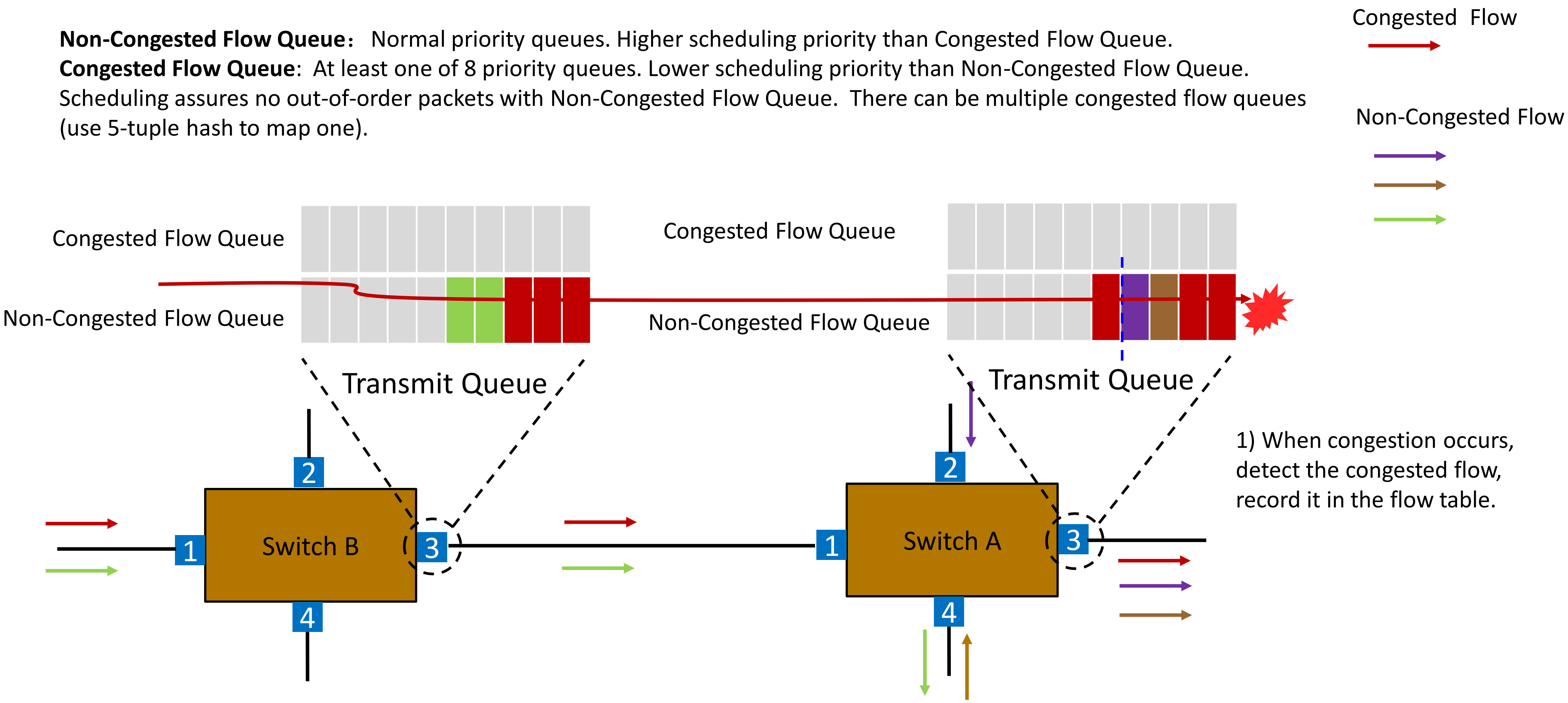
Definition: An approach to isolate flows causing congestion and signal upstream to isolate the same flows to avoid head-of-line blocking.

The approach involves:

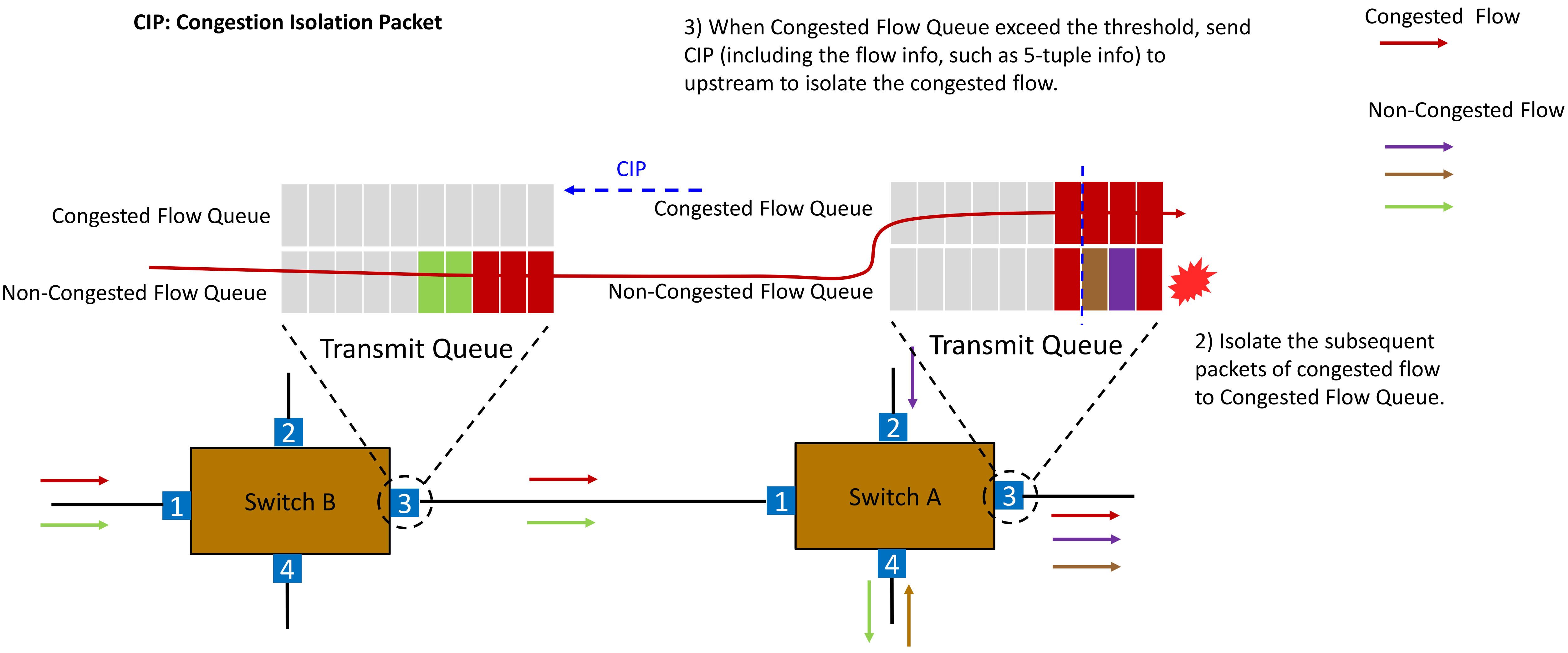
1. Identifying the flows creating congestion (e.g. perhaps already done for QCN and/or ECN)
2. Using implementation specific approaches to dynamically adjust the traffic class of offending flows without packet re-ordering (e.g. DVL – Dynamic Virtual Lanes)
3. Signaling upstream indications via a Congestion Isolation Packet (CIP)

Congestion Isolation with Dynamic Virtual Lanes

Non-Congested Flow Queue: Normal priority queues. Higher scheduling priority than Congested Flow Queue.
Congested Flow Queue: At least one of 8 priority queues. Lower scheduling priority than Non-Congested Flow Queue. Scheduling assures no out-of-order packets with Non-Congested Flow Queue. There can be multiple congested flow queues (use 5-tuple hash to map one).



Congestion Isolation with Dynamic Virtual Lanes



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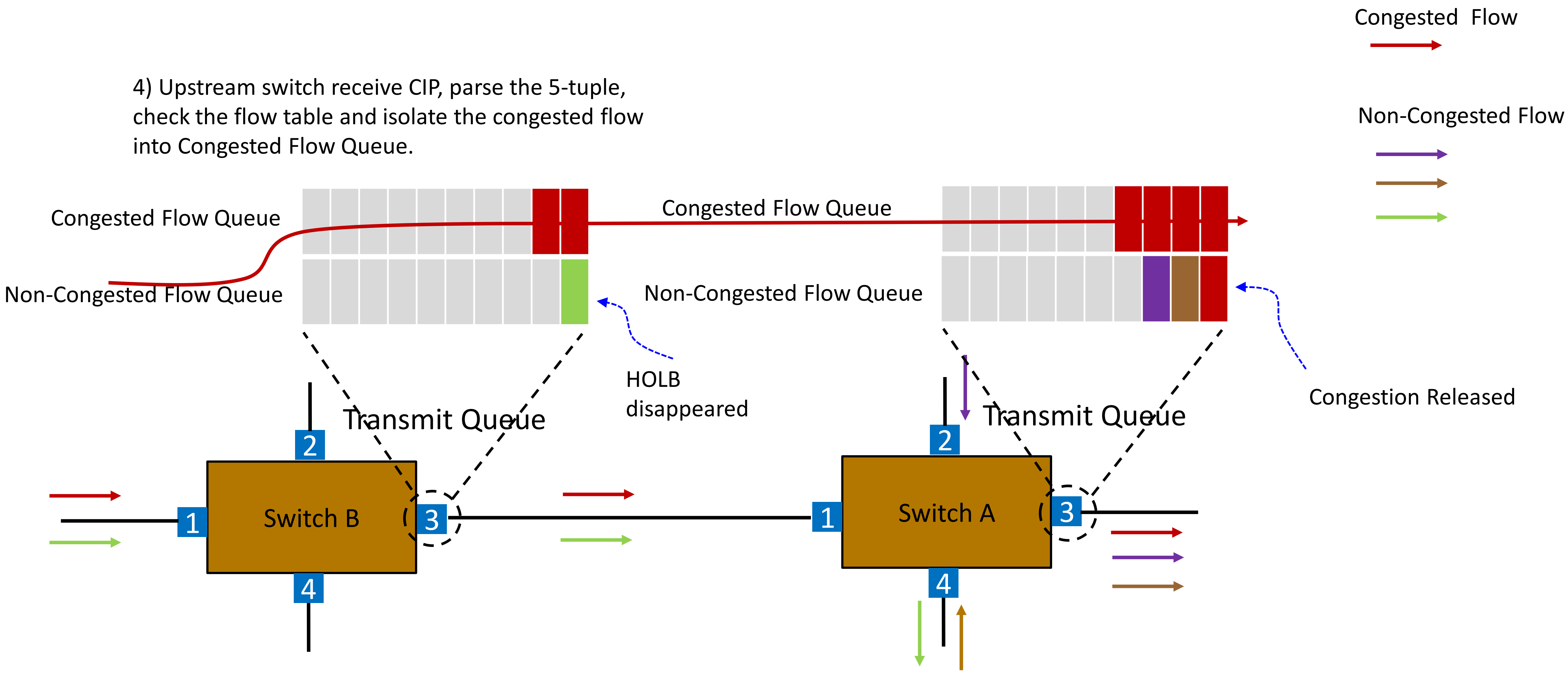
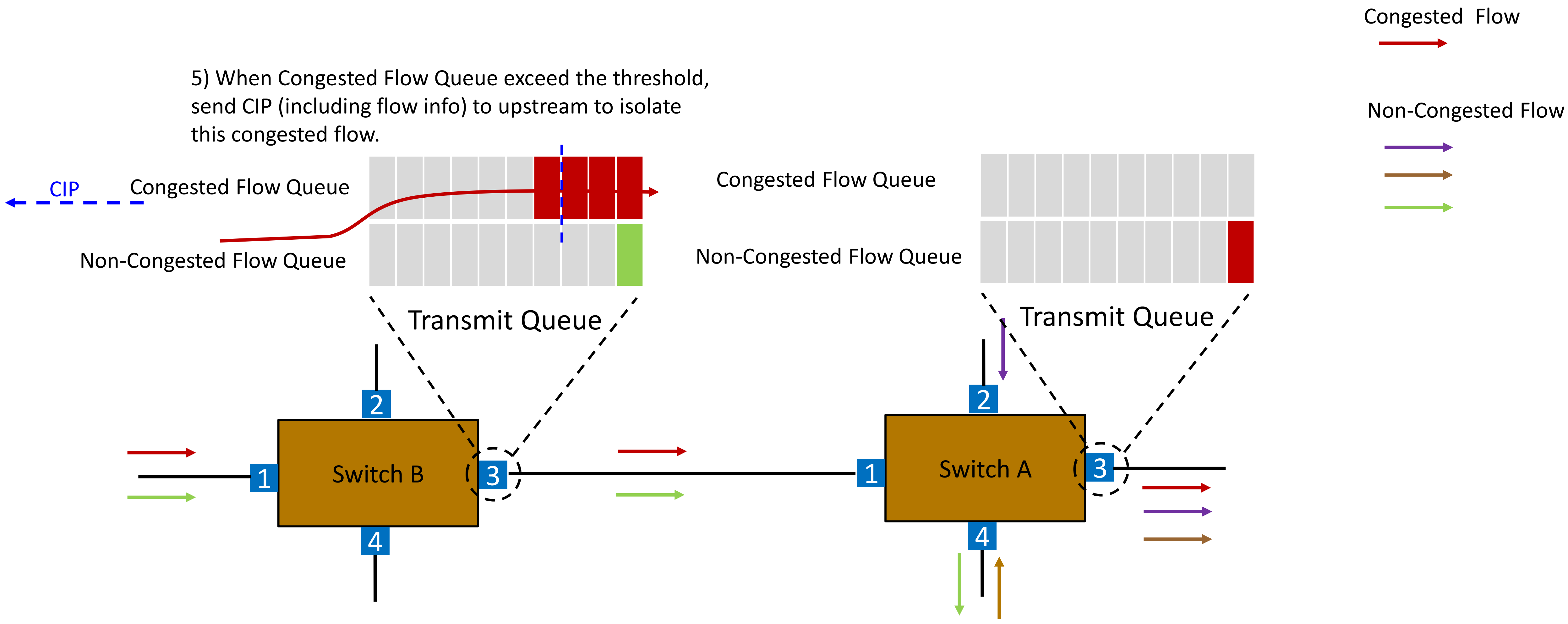
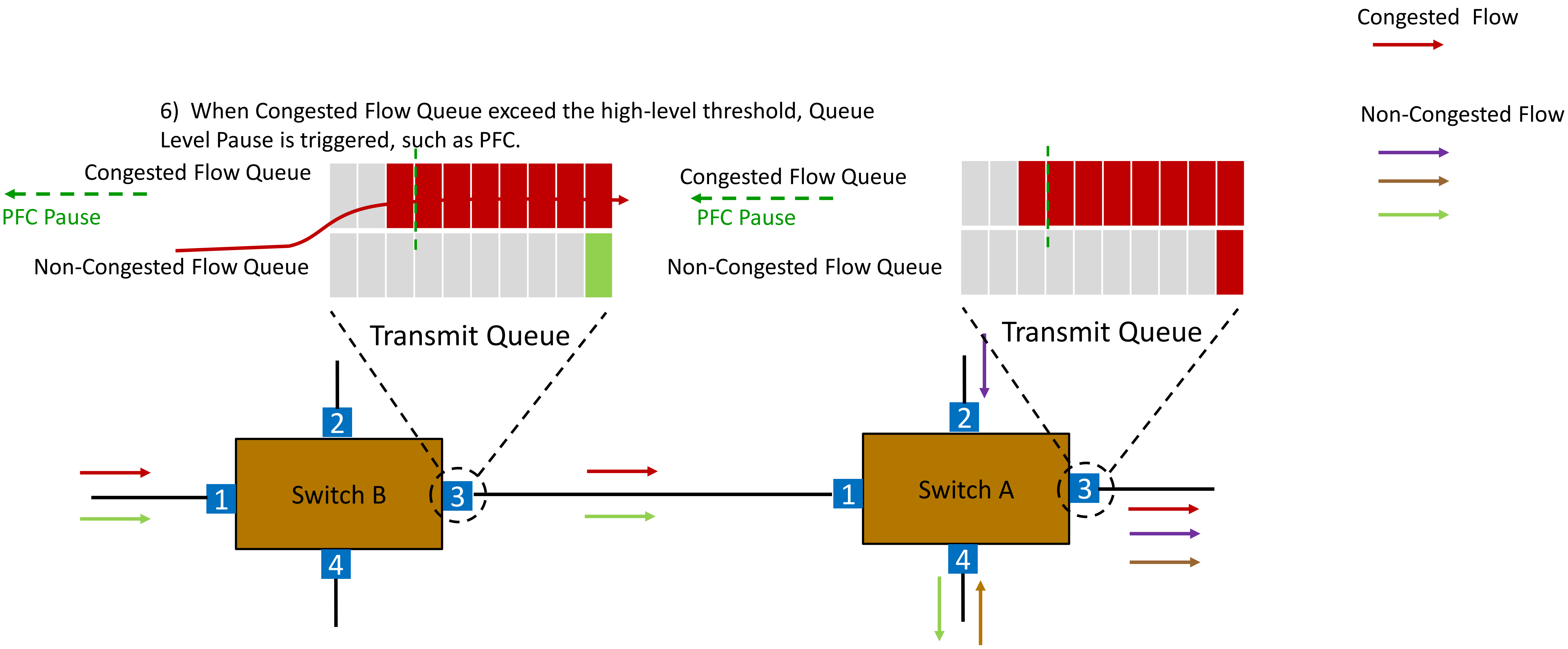


Congestion Isolation with Dynamic Virtual Lanes



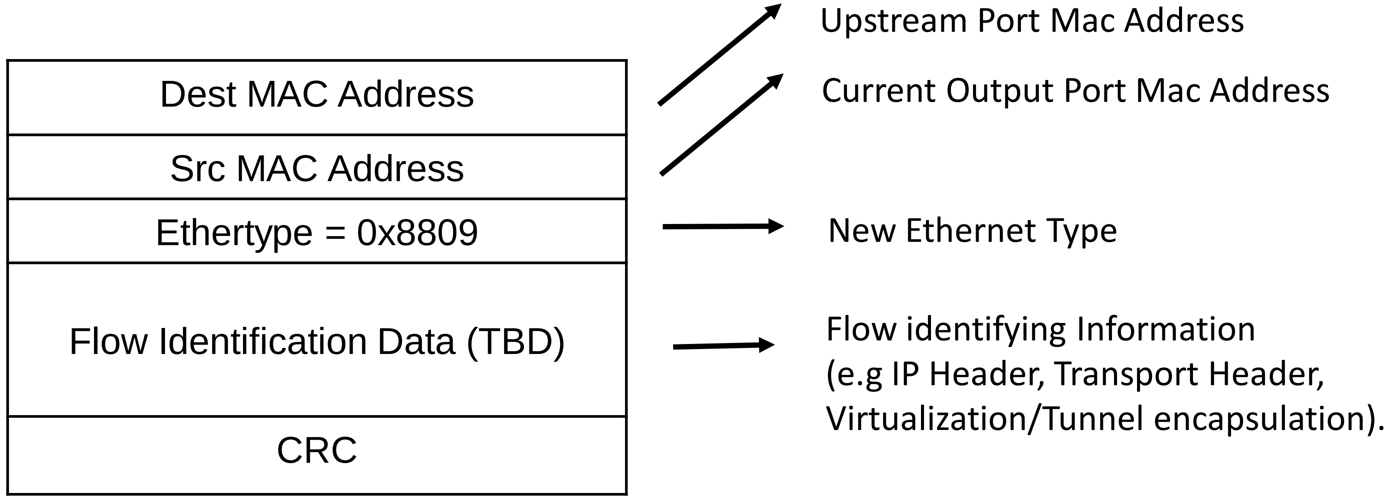
Congestion Isolation with Dynamic Virtual Lanes



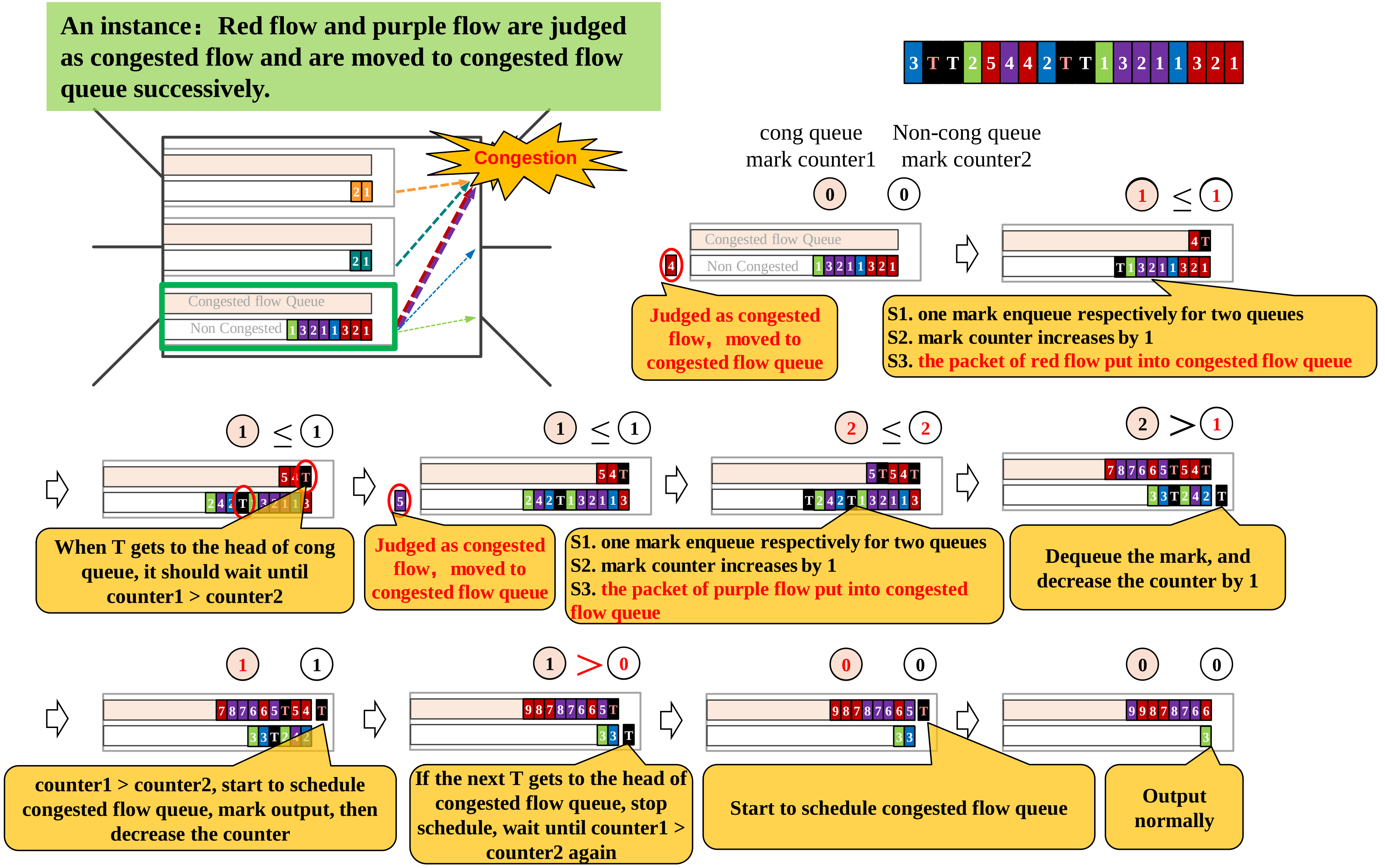
Congestion Isolation Packet

- Objectives/Requirements:
  - Provide upstream neighbor with an indication that a flow has been isolate
  - Provide upstream neighbor with flow identification information
  - No adverse effects of single packet loss
  - Low overhead

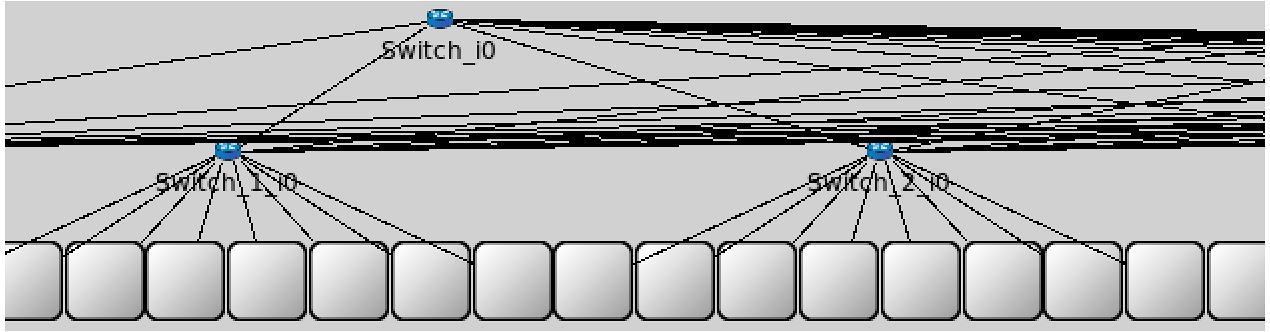
Format of Congestion Isolation Packet

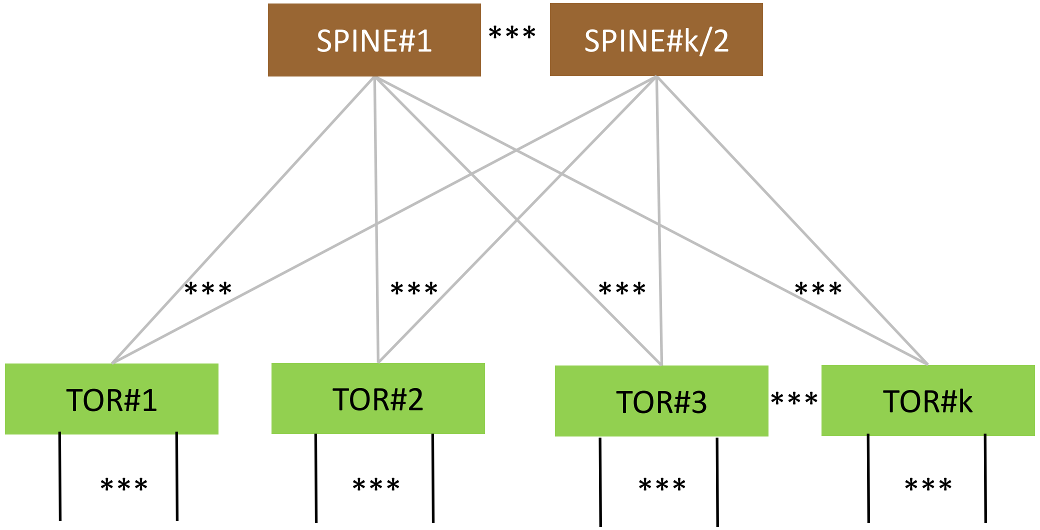


Handling the potential out-of-order problem



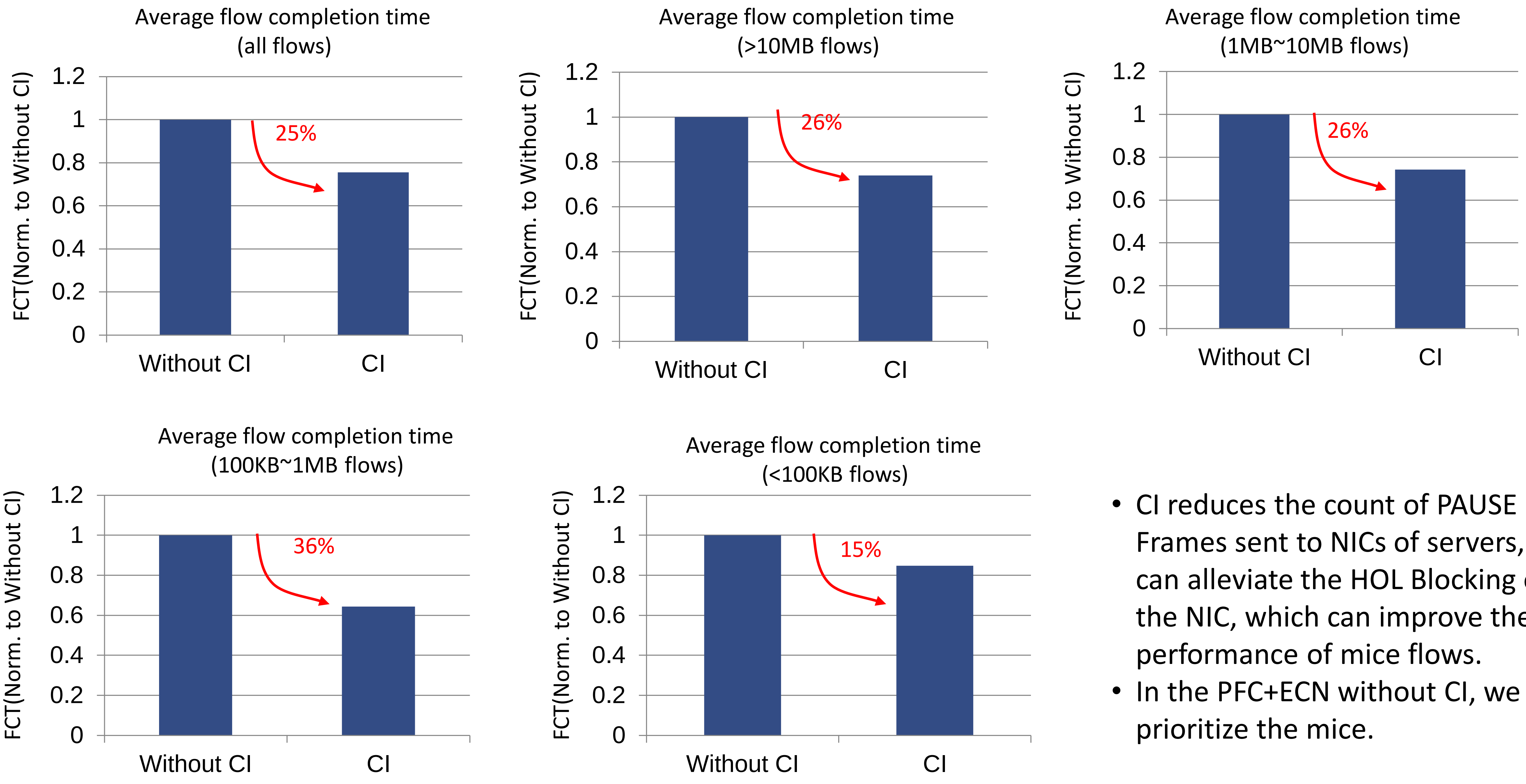
Simulation Set-up





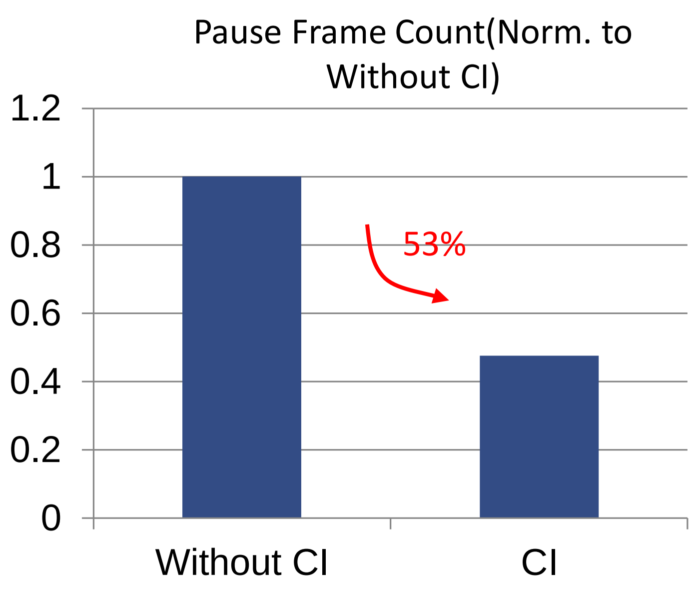
- OMNET++ Platform
- 2 Tier CLOS： 100G interface with 200ns of link latency 200ns(about 40m)
- Scale： 128 ~ 1152 servers, 24 ~ 72 switches
- Traffic Patterns:
  - Several regional all to all with some persistent incast
  - Flow size distribution is from 5 different real data center applications:
    - Enterprise IT, WebServer, Hadoop, Data Mining, Cache-Follower
- Compared Solutions:
  - PFC+ECN with CI: Congestion Isolation is implemented along with PFC+ECN
  - PFC+ECN without CI: Just PFC+ECN
  - All solutions include small flow prioritization mechanism

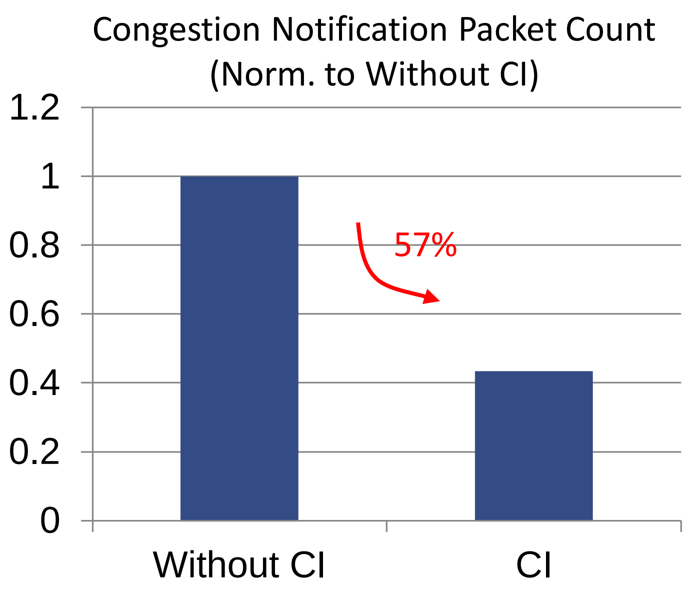
PFC+ECN with CI VS. PFC+ECN without CI

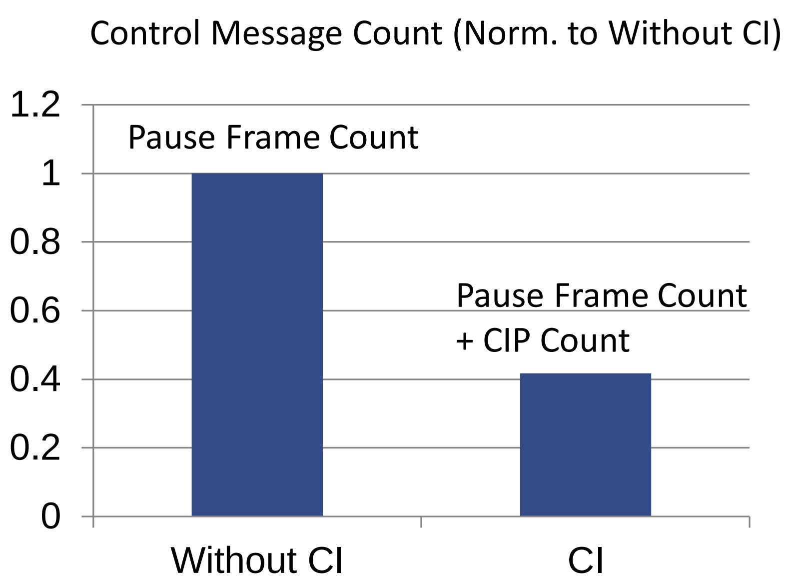


- CI reduces the count of PAUSE Frames sent to NICs of servers, so it can alleviate the HOL Blocking of the NIC, which can improve the performance of mice flows.
- In the PFC+ECN without CI, we also prioritize the mice.

Why PFC+ECN with CI outperforms PFC+ECN without CI





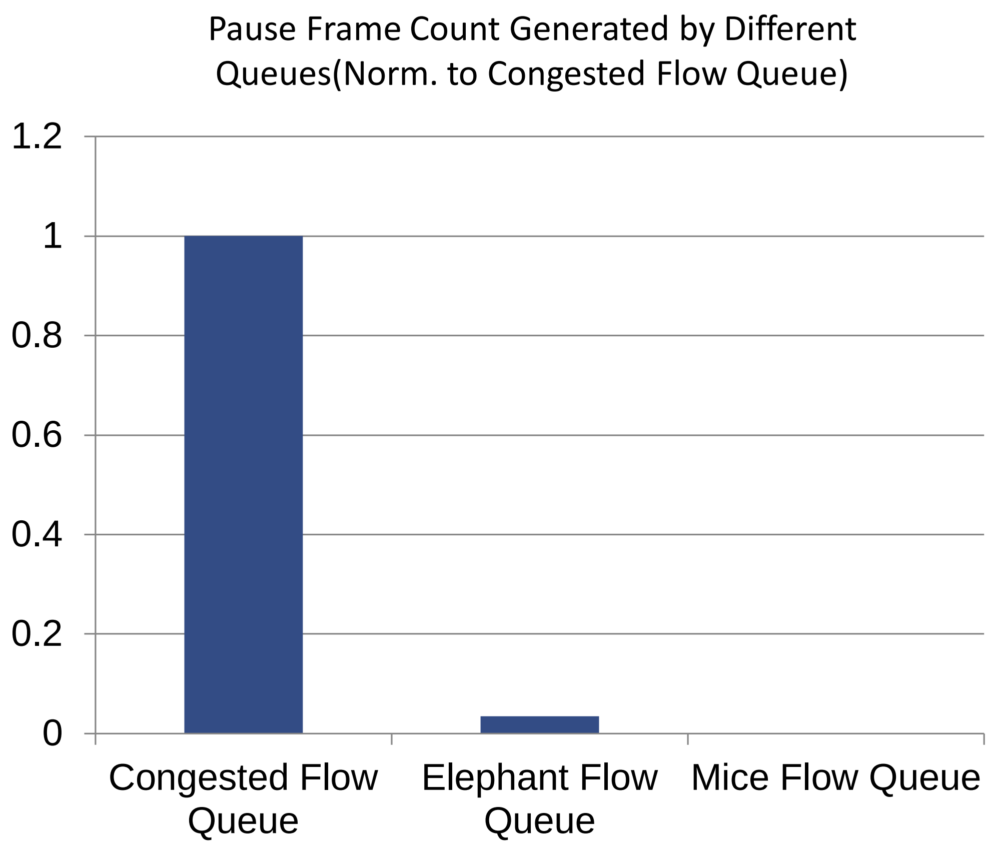


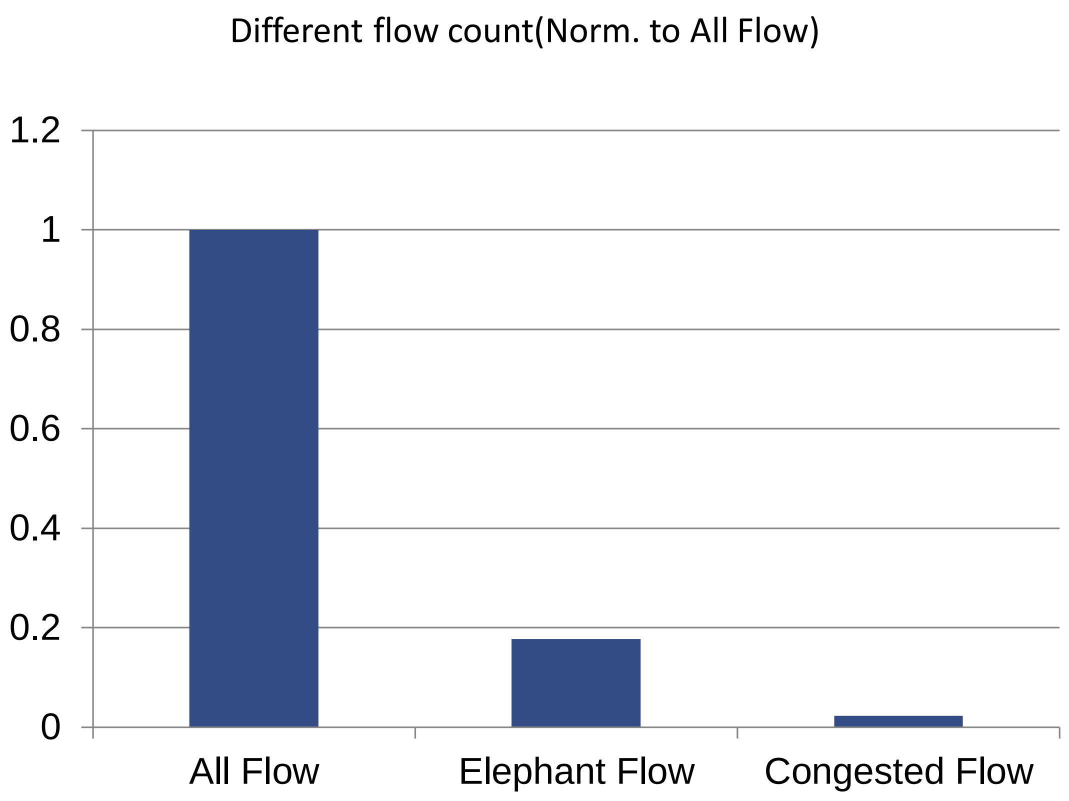
- CI reduces the pause frame count by 53%.

- CI reduces the CNP count by 57%.

- The count of new control message generated by CI is much less than the count it reduces the count of Pause frames.
- It has the same order-of-magnitude with large flow count.

Why PFC+ECN with CI outperforms PFC+ECN without CI

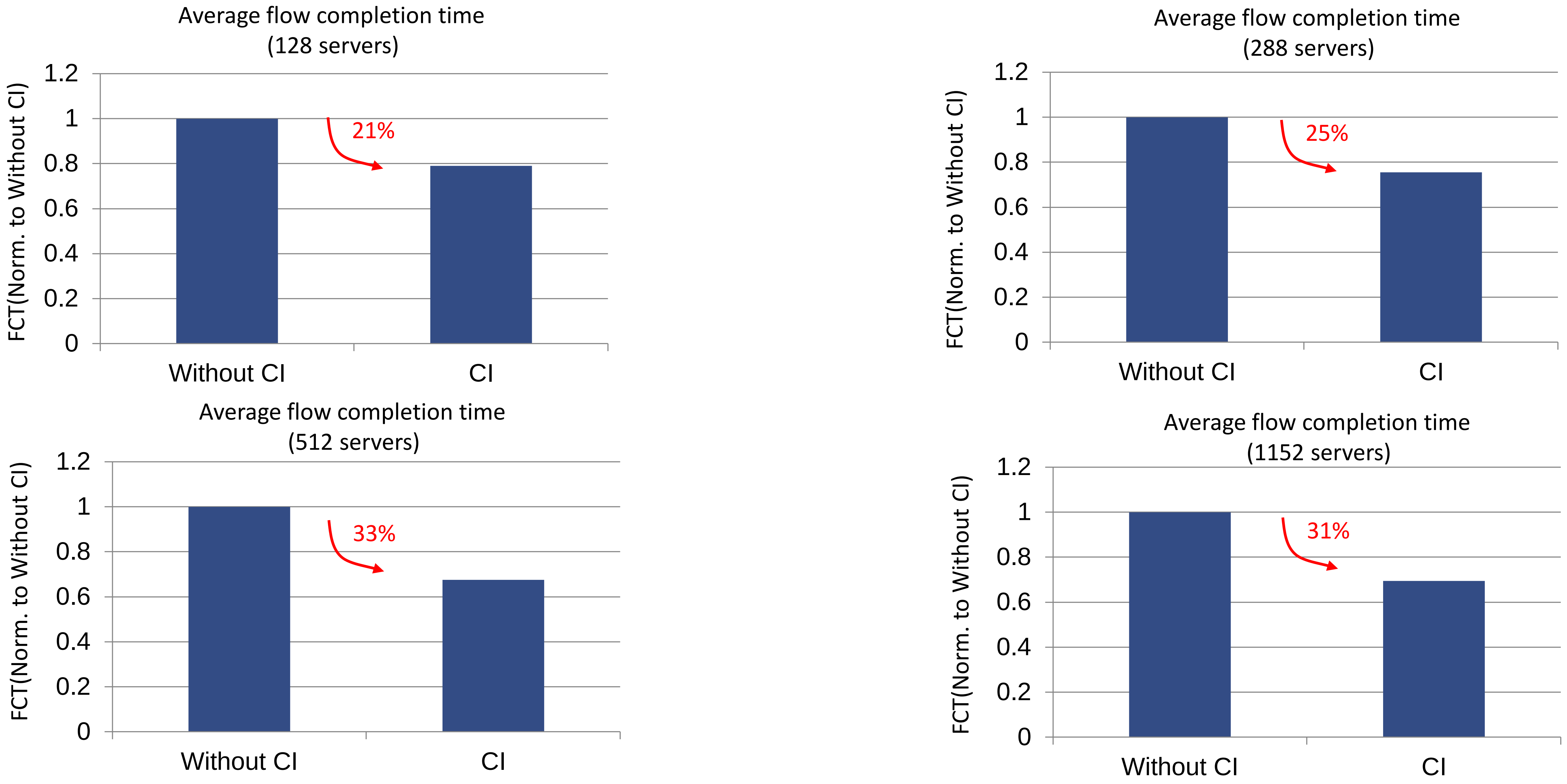




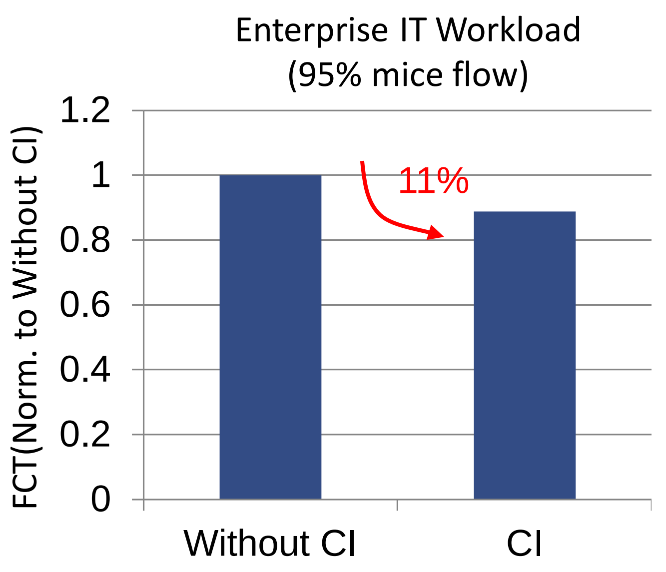
- 96.6% of the pause frames are generated by congested flow queues

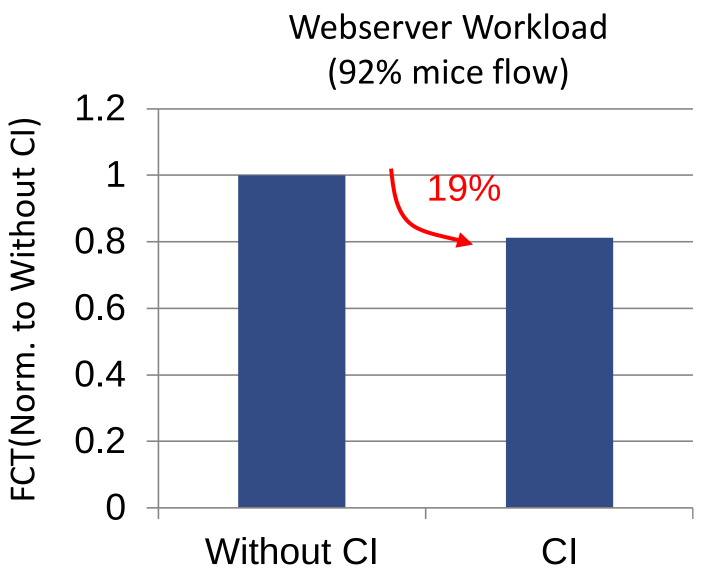
- The count of isolated flows is quite small. In our simulation with 22188 flows and 1152 server nodes. The proportion is 2% for total flows , and 12% for large flows.
- So the HOLB only occurs among the congested flows

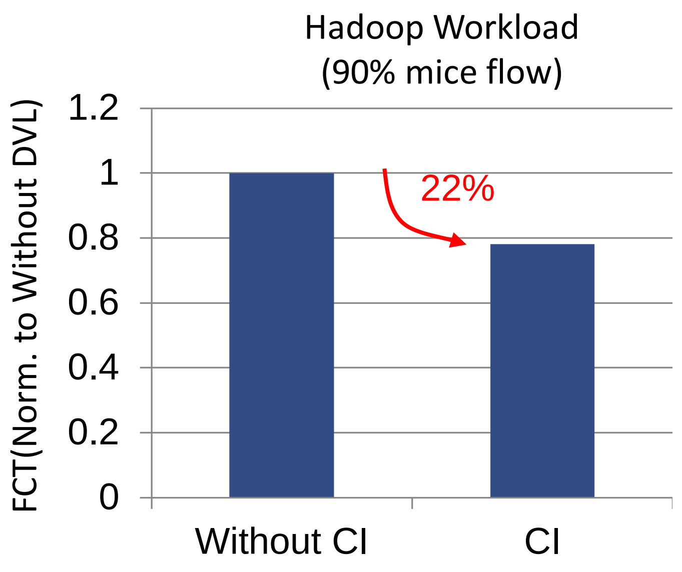
Comparison for different scale

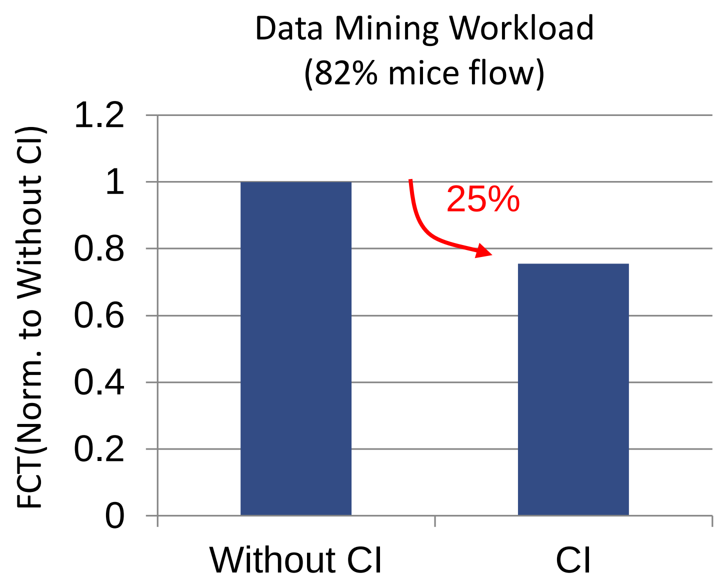


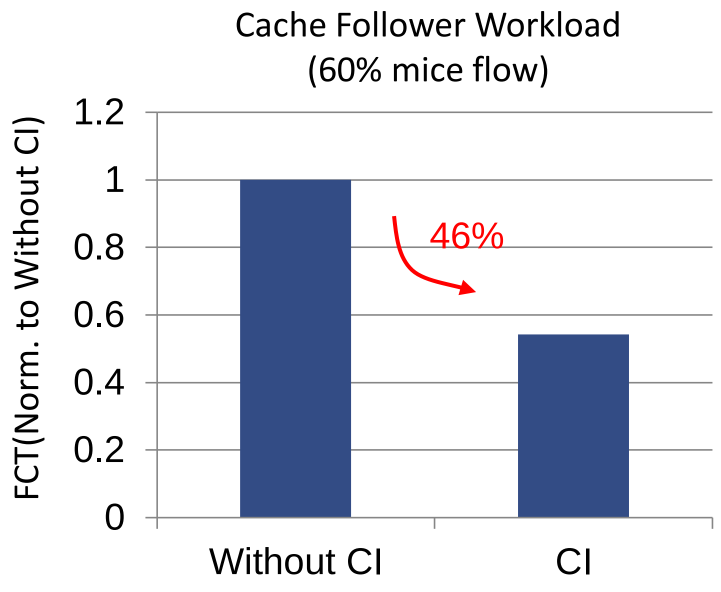
Comparison for different workload – Flow Completion Times











Summary

- Current data center design will be challenged to support the needs of large scale, low-latency, lossless networks.
- Congestion Isolation provides the following benefits:
  - Supports lossless as well as low-latency
  - Mitigates Head-of-Line blocking caused by PFC
  - Improves average flow completion times
  - Reduces or eliminates the need for PFC on non-congested flow queues
- Next Steps
  - Call for interest in creating a project
  - Respond to comments and feedback

Thank you

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