Virtualized Congestion Control

Bryce Cronkite-Ratcliff, et. Al.
VMware, Stanford University, Technion

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Outline

- Introduction
- Virtualized Congestion Control Design
  - Hypervisor translation techniques
  - Explicit Congestion Notification (ECN) Unfairness
  - Evaluation
- Conclusion

Introduction

- Hyperscale datacenters → Huge growth in network communication
- Large datacenters are deploying new congestion control algorithms
  - DCTCP, TIMELY, etc.
- Problem: How about **multitenant datacenters**?

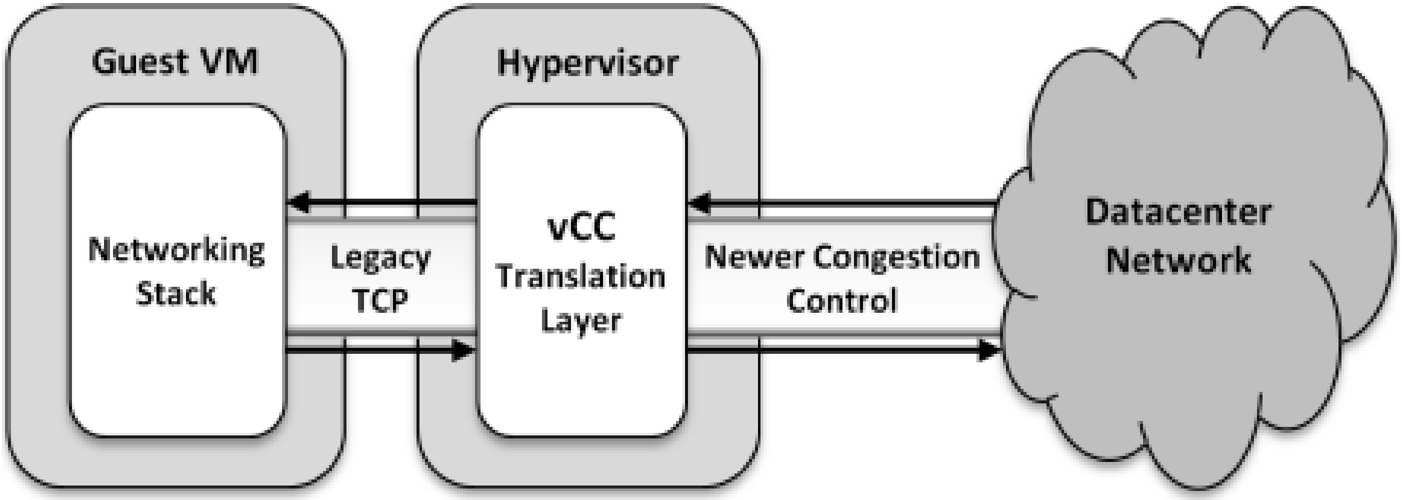
Multitenant datacenter

- Data centers operated by third parties for the benefit of multiple enterprise tenants
  - Many tenants lease and share a common physical infrastructure

- Tenants implement their own congestion control algorithm

- What will happen if
  - Tenants VMs' OSes use different congestion control algorithms?
  - Tenants VMs' OSes use old-fashioned congestion control algorithms?

Problem illustration



- Guest VM uses legacy TCP
- Datacenter hypervisor applies new congestion control

➔ Datacenter must ensure that they **play well together**

How to solve it?

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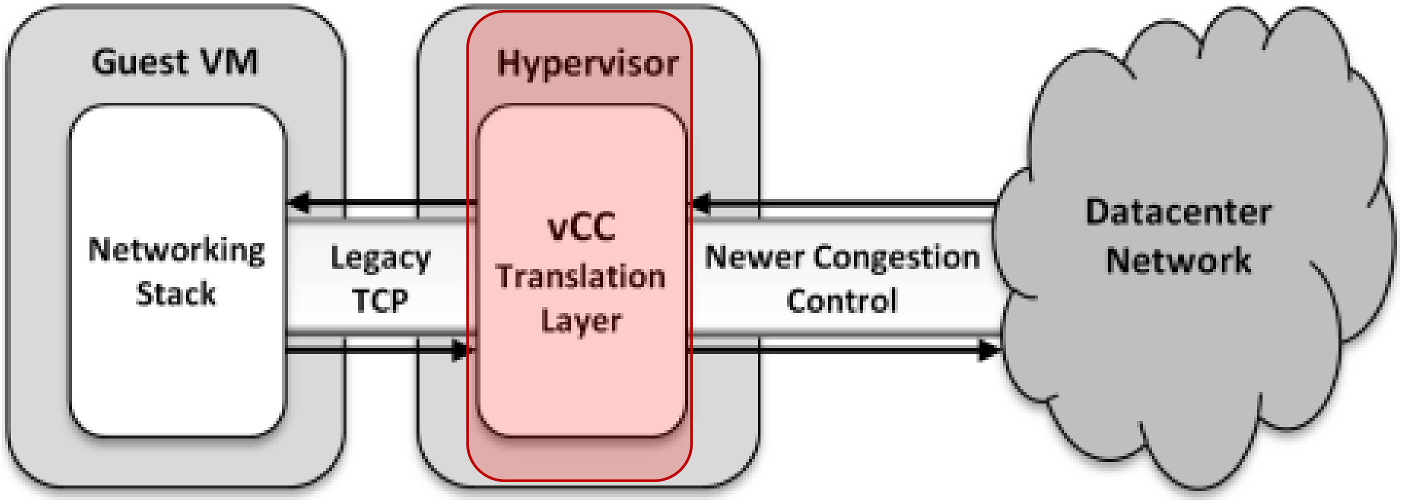
as the number of tenant algorithms increases,
this approach becomes harder to deploy

Authors' solution



- Introducing a **translation layer**
- Giving the illusion to each of the VM guests that it keeps using its own congestion control algorithm
- Taking advantage of the fact that all traffic passes through hypervisors

Virtualized Congestion Control (vCC)

$$g(T(x)) = f(x).$$

- x: input sequence
- f(x): output obtained by datacenter congestion control
- T(x): output of vCC translation
- g(x): output obtained by VM congestion control

vCC design

Hypervisor translation techniques

- vCC translates between congestion control in the guest VM and data center

- Candidates for above goal
  - Write into/read from guest memory
  - Split connection
  - Buffer packets/ACKs
  - Duplicate ACKs
  - Throttle the window
  - Modify the 3-way handshake

Write into/read from guest memory

- Modern hypervisors can monitor guest VMs
- Hypervisor can directly write TCP parameters in the guest memory and registers
- Hypervisor also can read TCP parameters in the guest VMs

➔ Tenants may not accept that the hypervisor writes into/read from the VM memory

Split connection

- The split-connection approach breaks a TCP connection into several sub-connections
- Acknowledge packets to the guest VM at some desired rate
- Send them on the datacenter network using the desired target congestion control algorithm

➔ The solution goes against TCP end-to-end semantics

Buffer packets/ACKs

- Buffer in-flight packets and ACKs

- vCC can buffer in-flight packets and retransmit according to its own RTOmin buffer

- Hypervisor can pace ACKs to make TCP less bursty

➔ The hypervisor needs to manage packet/ACK buffer

Duplicate ACKs

- Hypervisor can duplicate and resend the last sent ACK
- Force the guest to halve its congestion window

➔ This technique may violate TCP semantics

Throttle the receive window

- Hypervisor can decrease the receive window (to guest VM)

- Force the guest to have fewer outstanding packets
  - # of packets in flight is upper-bounded by the minimum of the congestion and the receive windows

➔ This technique can make the congestion window meaningless, conflicting with common implementations of the TCP buffer management

Modify the 3-way handshake

- Hypervisor can change the options that are negotiated when setting up the connection
  - Modify the negotiated MSS, or enable timestamps

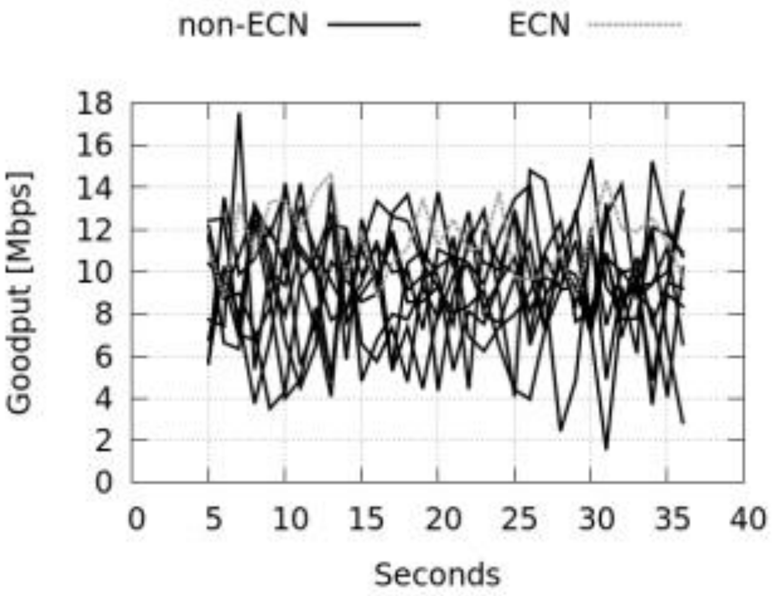
➔ The technique can barely help for most practical benefits without additional techniques

Scenario: ECN unfairness

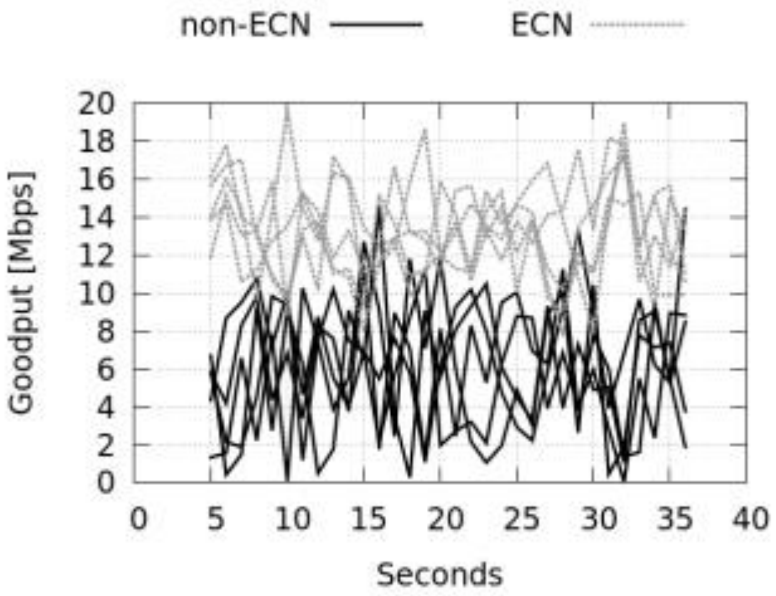
ECN unfairness

- ECN allows flows to react to congestion before any data has been lost
- ECN has not been widely supported in operating systems until recently
- A lack of ECN support can cause such legacy systems to suffer

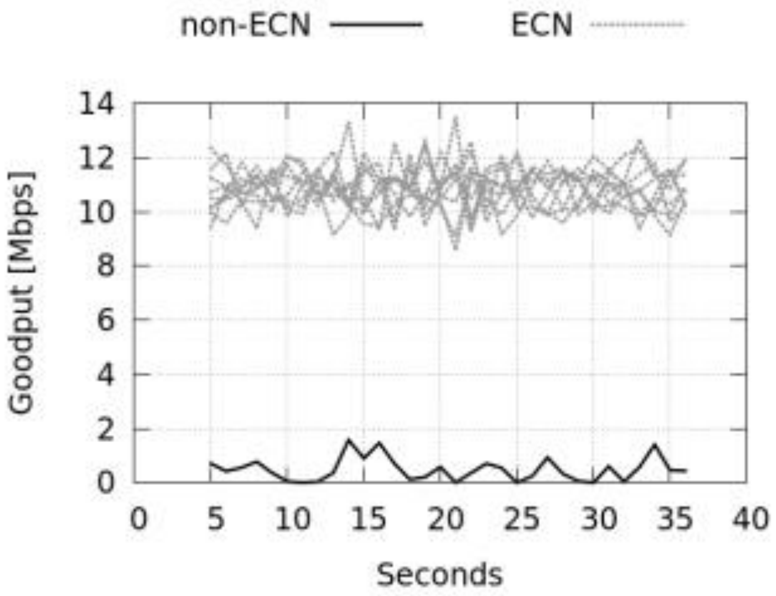
ECN unfairness



(a) 9 non-ECN vs. 1 ECN flows



(b) 5 non-ECN vs. 5 ECN flows



(c) 1 non-ECN vs. 9 ECN flows

- Non-ECN flows show lower goodput than ECN flows
- The greater # of ECN flows, the greater the unfairness

Analysis on ECN unfairness

- The average queue length measured by the switch grows beyond RED (Random Early Drop) threshold eventually
- **ECN** flow's packets are just marked → halve the window → Congestion avoidance phase
- **Non-ECN** flow's packets are dropped → timeout occurs → Slow start phase ➔ **Low throughput**

vCC's solution

- vCC transforms non-ECN flows to virtual-ECN flows

Modifying 3-way handshakes

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Throttling receive window

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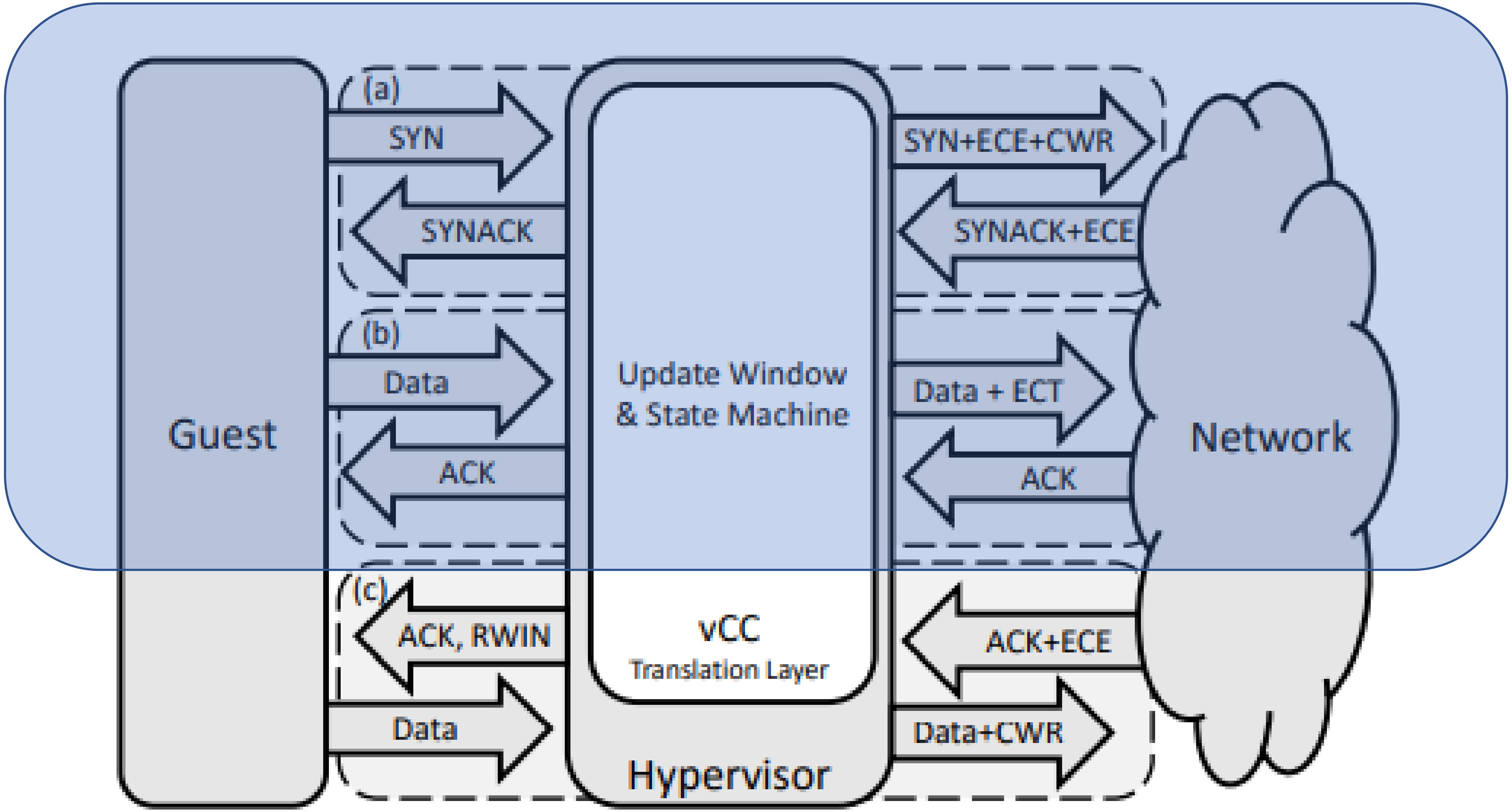
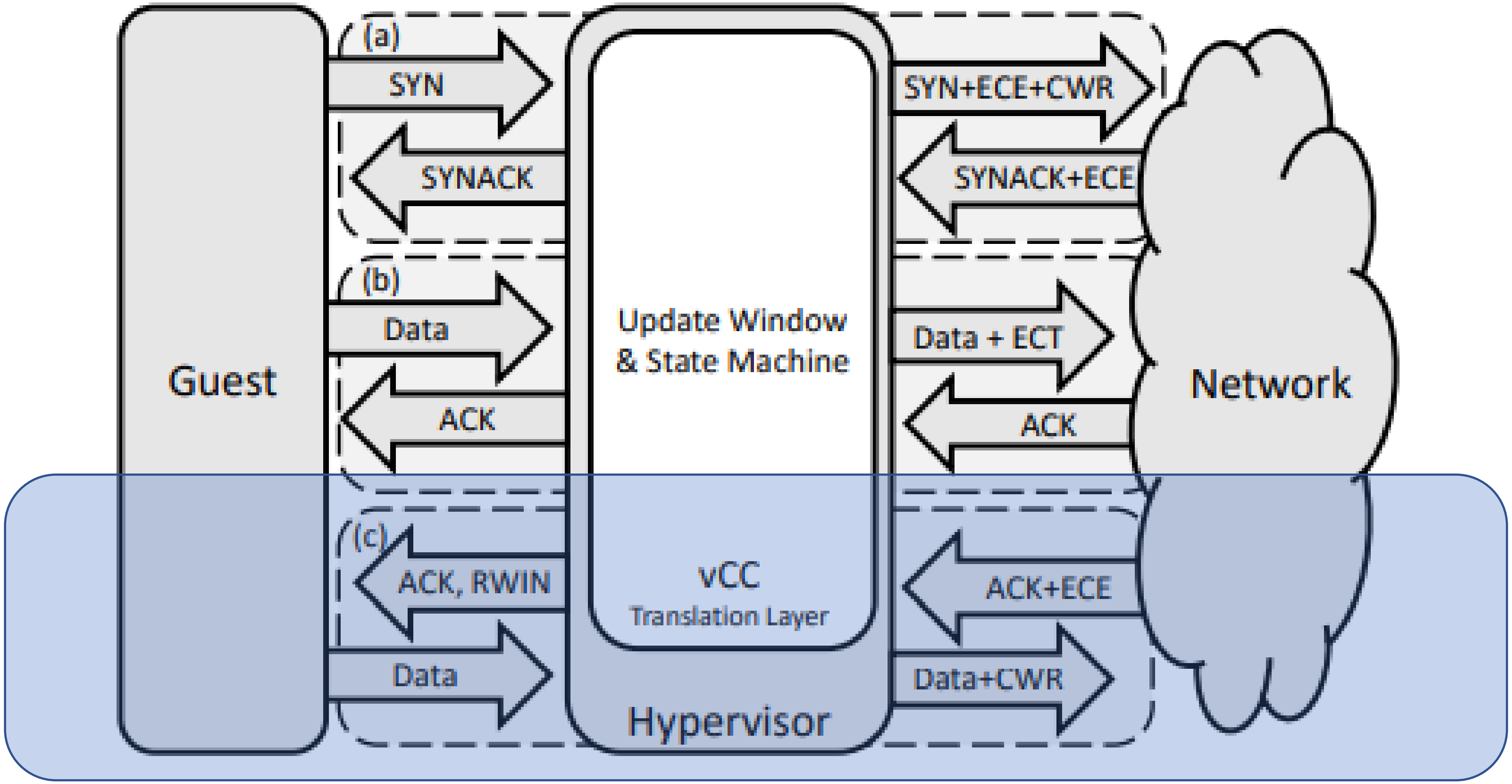
Virtualized ECN flows

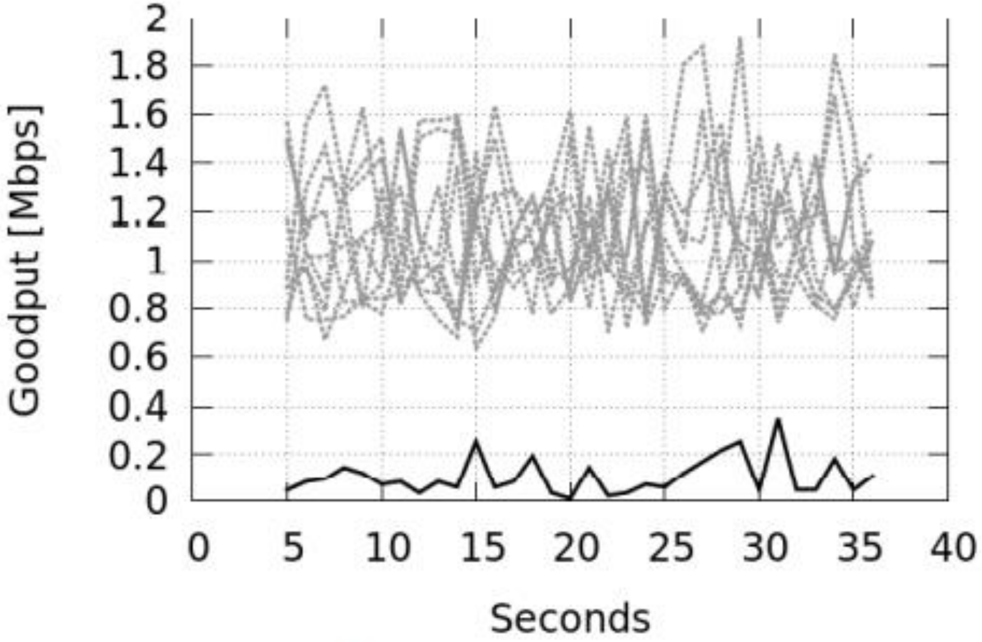
Modifying 3-way handshake



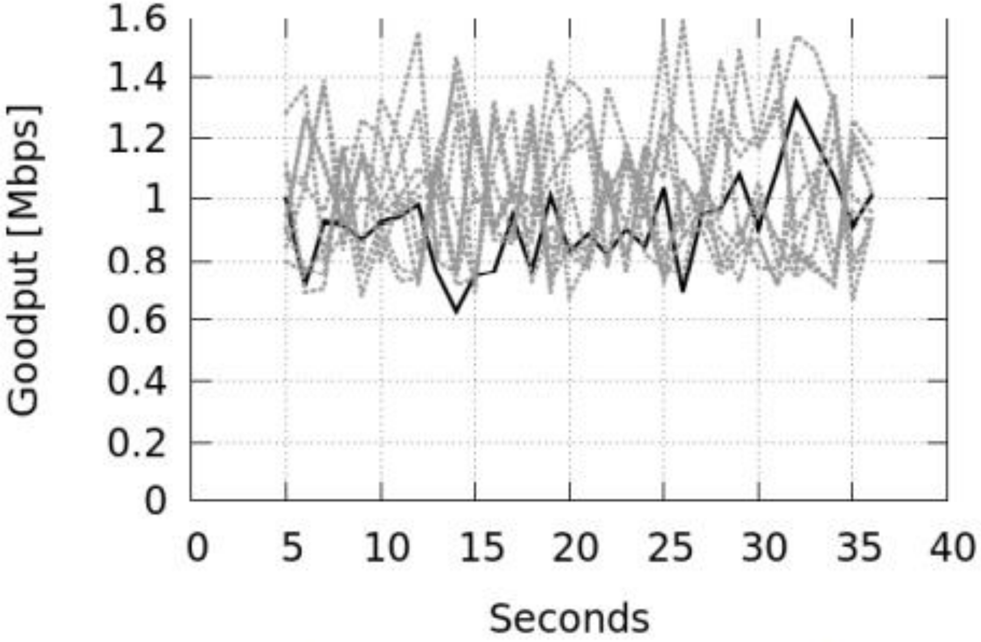
Receive window throttling



Evaluation



(a) 9 ECN flows and one non-ECN flow



(b) 9 ECN flows with one virtual-ECN flow

- Non-ECN flow is starved by multiple ECN flows
- Virtual-ECN flow shows similar performance to ECN flows in terms of goodput

Conclusion

- Multitanent datacenters can suffer from differences in congestion control algorithms between guest VMs and the hypervisor

- vCC enables the datacenter owner to introduce a new congestion control algorithm in the hypervisors

- Hypervisors translate between the new congestion control algorithm and the old legacy congestion control

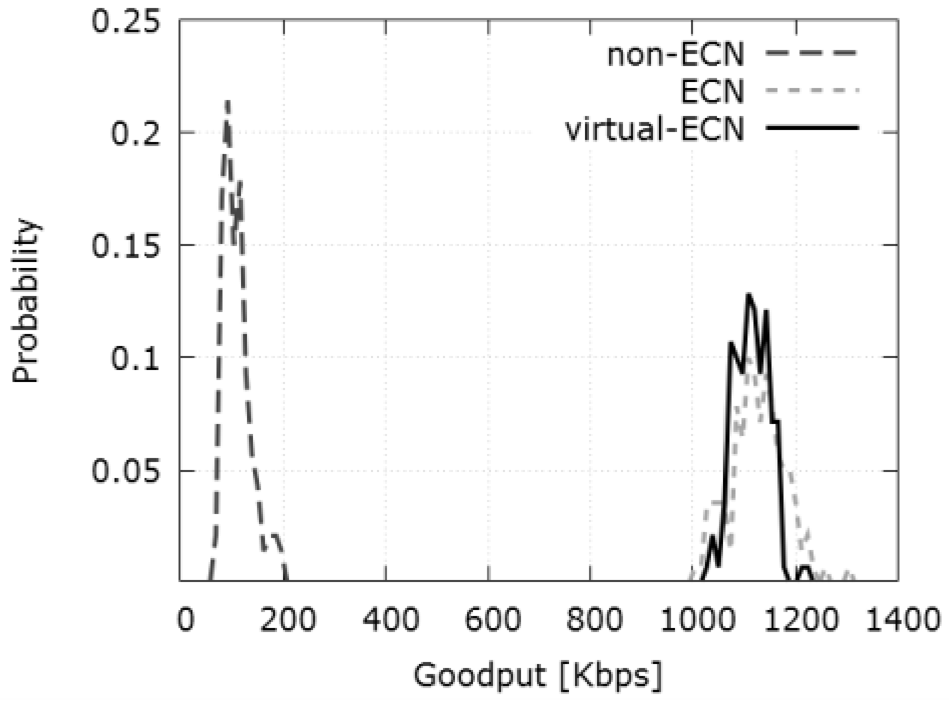


Figure 1: 10 flows share the same bottleneck link: an ECN-unaware flow (*non-ECN*), 8 ECN-enabled flows (*ECN*), and a non-ECN flow augmented by vCC translation (*virtual-ECN*). The figure plots the probability density function, over many runs, of the average goodput of each flow. The non-ECN flow is starved, reaching only 10% of the ECN goodput on average. After translation to virtual-ECN, the average goodput is near identical to that of ECN.

Parameter	Value		
	RED1	RED2	RED3
RED_{min}	90000	30000	30000
RED_{max}	90001	90000	90000
RED_{limit}	1M	400K	400K
RED_{burst}	61	55	55
RED_{prob}	1.0	0.02	1.0

Table 1: RED Parameters used in the experiments.