Mystique: A Fine-grained and Transparent Congestion Control Enforcement Scheme

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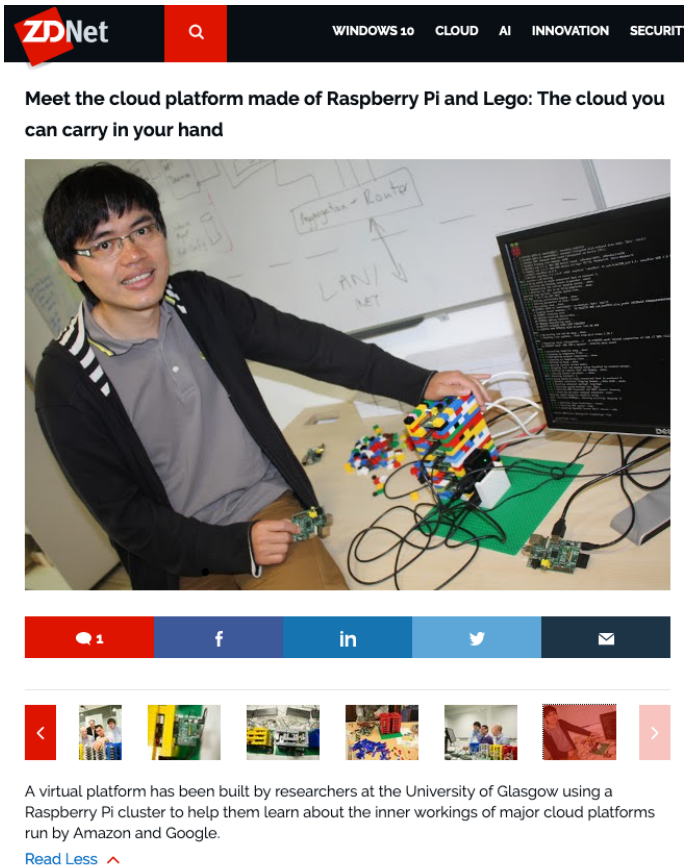
Who am I?

- Senior Lecturer (UK's equivalent to Associate Professor)
- Grew up and educated in Hong Kong
- Like building networked systems
- Received over £1M research funding



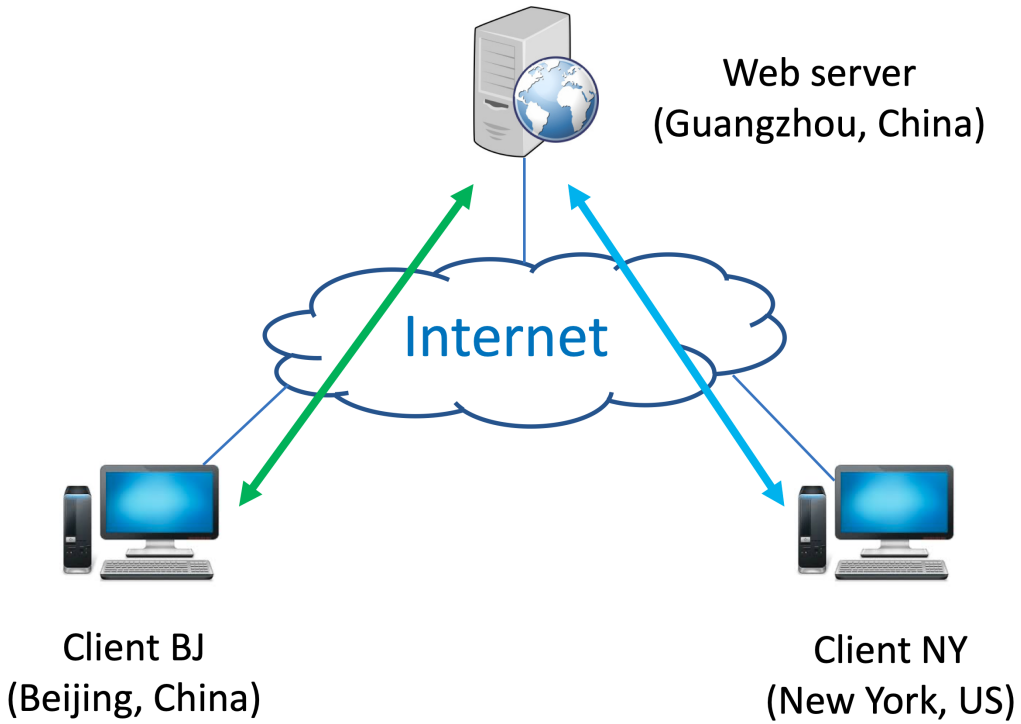
Where are we?

Loughborough University is a top 10 public research university in the UK.

TCP Congestion Control

- Congestion is not uncommon on the Internet [Singla, HotNets'14]
- Latency does matter
  - 80th latency exceeds 100 times the speed of light [Bozkurt, PAM'17]
  - 100ms latency penalty contributes to 1% revenue loss [Flach, SIGCOMM'13]
- New TCP congestion control (CC) schemes have been proposed
  - e.g., Sprout, PCC, BBR, PCC-vivace, Copa, etc.

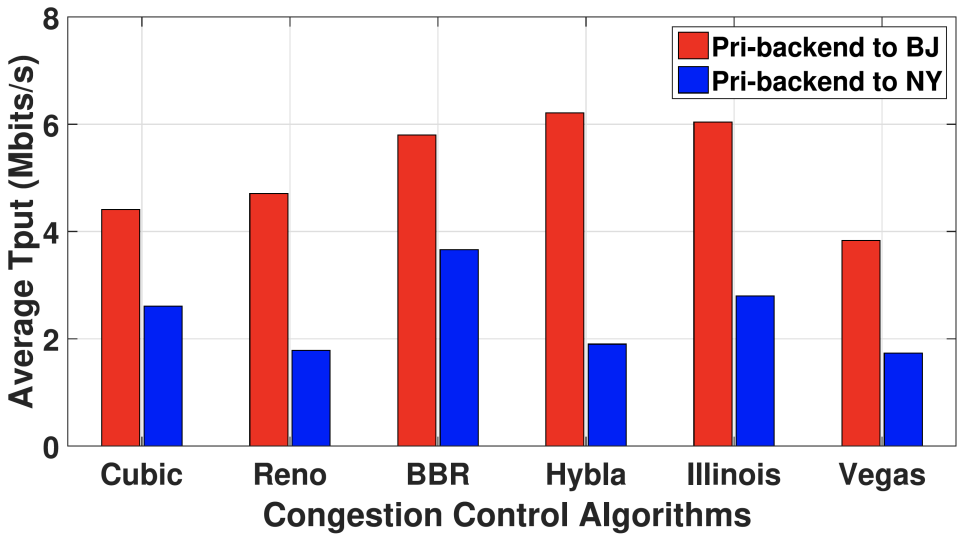
But, can one CC rule them all?



We set out to find the answer.

But, can one CC rule them all?

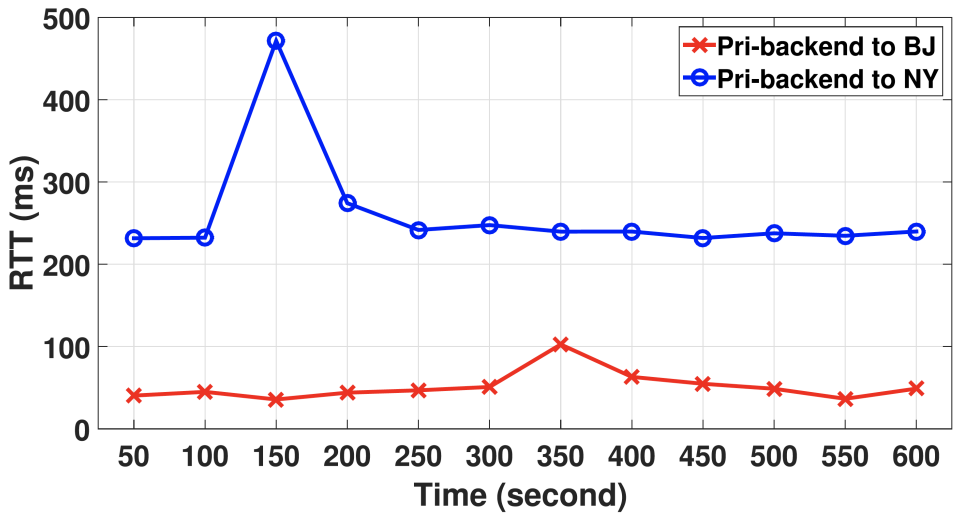
- CC only reaches peak performance in 'prescribed' scenarios.
  - e.g., RTT, loss ratio, ...



Reno has better performance than Cubic for Pri-backend$\longrightarrow$BJ, but worse from Pri-backend$\longrightarrow$NY.

But, can one CC rule them all?

- Also, network condition, i.e. RTT, oscillates dynamically
  - e.g., RTT, loss ratio, ...



Implication:Different congestion control algorithms can be the most efficient at certain times even for a single TCP connection

Adjusting servers' CC is difficult, if not impossible

- Consider multi-tenant cloud environment
  - Admins can not control server TCP stacks
  - Servers are setup and managed by different tenants
- For a single tenant:
  - Large amount of servers
  - Diverse versions of OS
- Per-socket basis CC:
  - Need to modify every application's implementation

We need a better solution

We aim to design a scheme to deploy and schedule CC with following properties:

- Transparent: NO modification to the OS of servers
- Fine-grained: flow-level CC enforcement
- Dynamic: network-awareness

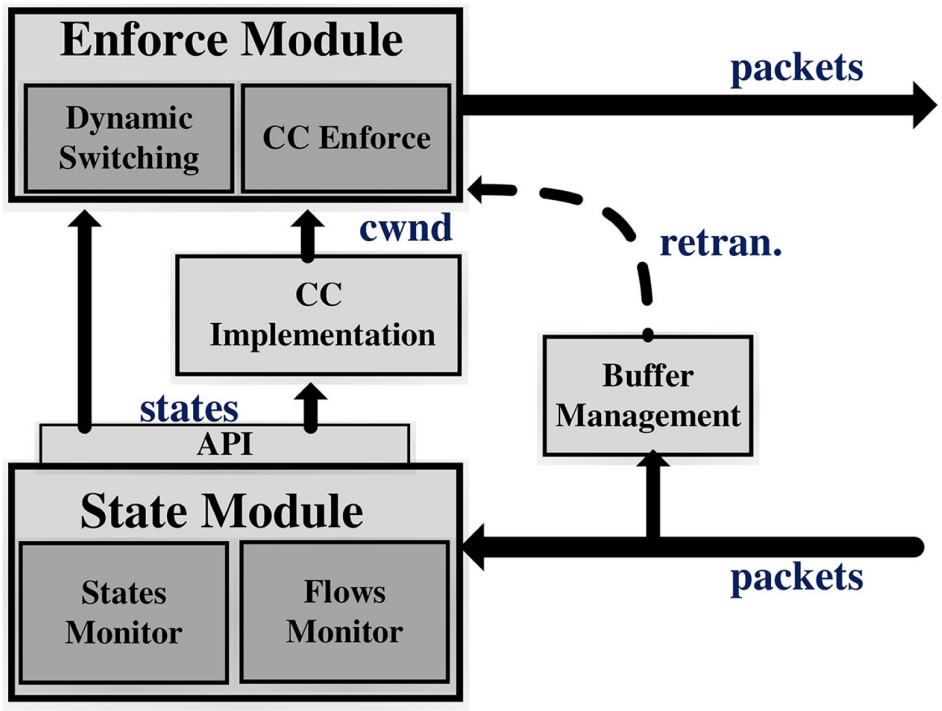
Design objectives

- Implements TCP congestion control in OVS
  - No modifications to Web servers' kernel
  - Per-flow basis congestion control switching
- Dynamically employ the most suitable CC
  - switch CC according to corresponding network condition

Comparing Mystique with other schemes

	Dynamic CC switching	**No TCP stack modification**	**Granularity**
AC/DC	✗	✓	OS Level
vCC	✗	✓	OS Level
NetKernel	✗	✗	OS Level
CCP	✗	✗	OS Level
MCC	✓	✗	Per-flow
Mystique	✓	✓	Per-flow

Mystique: High Level View



Implication:Implementing in OVS requires no modification on servers

Obtaining Congestion Control States

- Per-flow connection tracking
  - All traffic goes through the Open vSwitch (OVS)
  - We can reconstruct CC via monitoring all the packets of a connection

    Packets $\longrightarrow$ Flow classification $\longrightarrow$ Updating CC variables
- Maintain per-flow congestion control variables
  - E.g., CC-related RTTs, Bandwidth, loss etc.

APIs provided by Mystique

- Implement and deploy new CC schemes
- CC switching logic

Methods	**Descriptions**
getCRTT()	Obtain state *c_rtt*'s value
getCBW()	Get state *c_bw*'s value
getMinRTT()	Get state *min_rtt*'s value
getMaxBW()	Get state *max_bw*'s value
setPeriod()	Set parameter *period*'s value
setTstep()	Set parameter *t_step*'s value
setBWstep()	Set parameter *bw_step*'s value
isLoss()	Offer loss feedback
setCwnd()	Set new congestion window

Enforcing Congestion Control

- TCP sends min(cwnd, rwnd)
  - cwnd is congestion control window (congestion control)
  - rwnd is receiver's advertised window (flow control)
- Mystique reuses rwnd for congestion control purpose
  - Web servers with unaltered TCP stacks will naturally follow our enforcement
- Congestion signals should not be sent to web servers
  - Keep the servers' cwnd at high level
  - Flows' sending rate is throttled by Mystique

Dynamic Switching – an example

Algorithm 1 Congestion control switching logic example

Require: Congestion states, e.g, loss, RTT
  if no loss **then**
    Return Hybla
  else if RTT $< 50ms$ **then**
    Retrun Illinois
  else
    Return BBR
  end if

Implementable locations

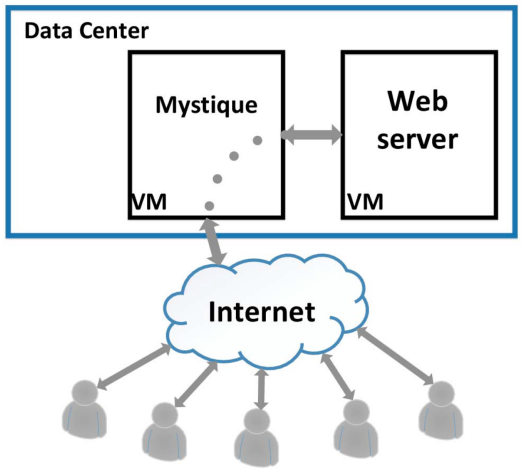
- VMs
  - allowed to setup new servers or release old ones dynamically
  - requires routers/switches redirecting desired traffic
- Hypervisors
  - easy scaling with numbers of servers
  - no route redirection is required
  - flexibility and scalability are limited
- Routers/Switches
  - easily enforce congestion control without route redirection
  - difficult to perform load balancing

Implementation

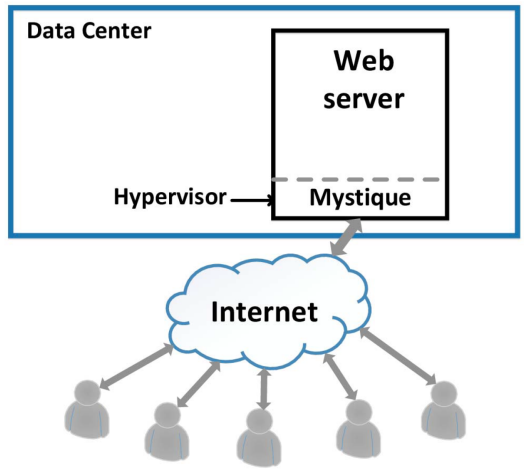
- Prototype implementation in Open vSwitch (OVS) kernel datapath
  - 1400 LoC added
- Leverages available techniques to improve performance
  - RCU-enabled hash tables to perform connection tracking
  - skb_clone is used for packet buffering to prevent deep-copy of data
  - Multi-threading technique is used for faster processing
  - Leverages NIC TSO (TCP segmentation offload) to increase performance

Testbed setting

- Mystique and Web servers
  - Private cloud: Campus DC in Jinan University, Guangzhou
  - Public cloud: AWS at Singapore
- Five clients
  - Guangzhou, China (GZ)
  - Shenzhen, China (SZ)
  - Beijing, China (BJ)
  - London, UK (Lon)
  - New York, US (NY)



(a) *Mystique* in VM



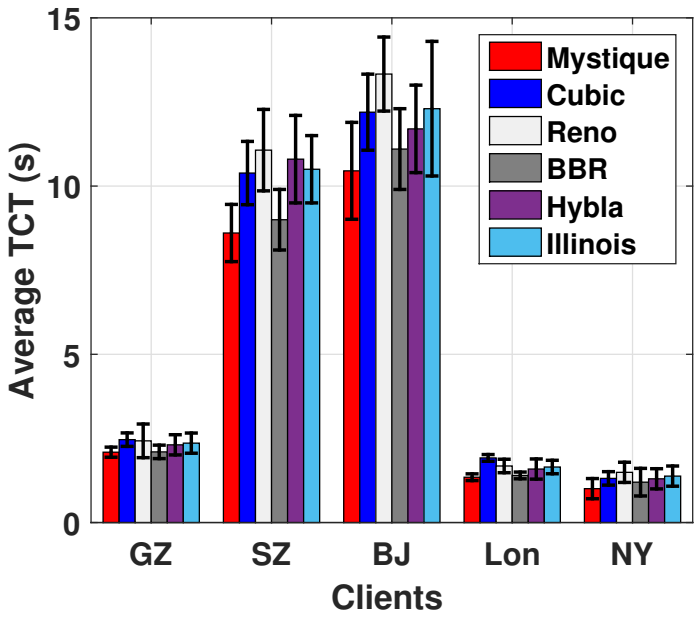
(b) *Mystique* in Hypervisor

Metrics

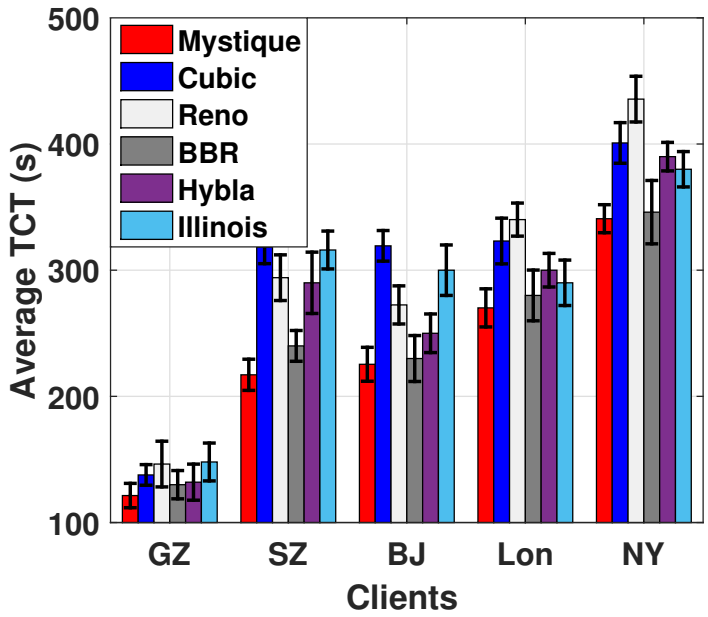
- Transfer Completion Time (TCT) and throughput
  - Transfer time and throughput of both large file (1.2MB) and small file (95.9MB)
- Loading time of websites
  - Loading time of five websites, e.g., CNN, Guardian, Stack Overflow, Walmart, Yahoo.

- We compare Mystique with Cubic, Reno, BBR, Hybla, and Illinois, respectively.
  - Run corresponding stack on Web server kernel
  - Mystique
    - Add additional one hop to Web server
    - Run Algorithm1 for dynamic switching
    - Run Cubic stack on the Web server

Deployment in VMs



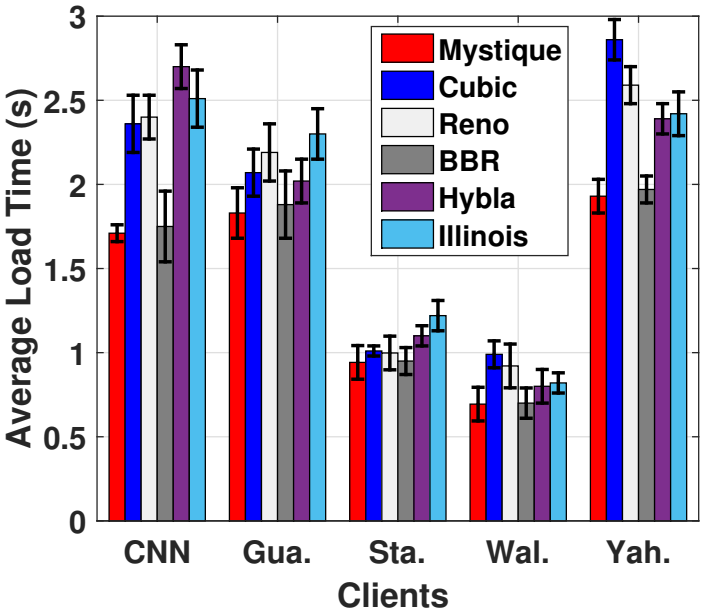
(a) Small file in private cloud



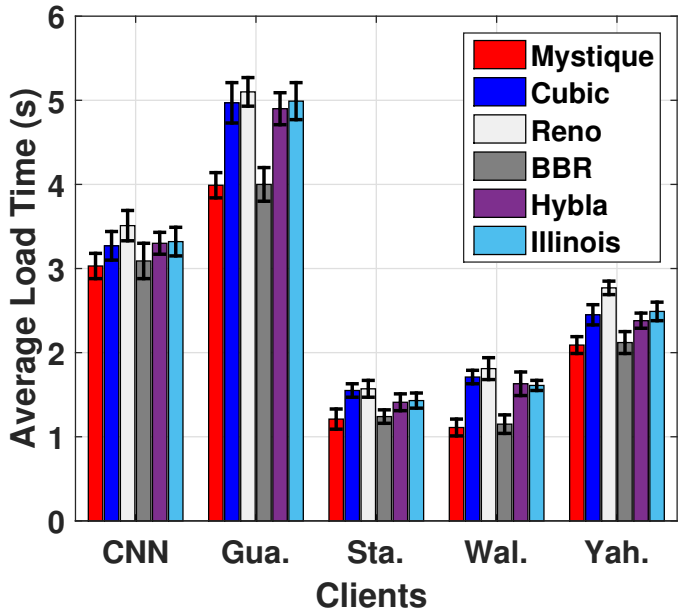
(b) Large file in private cloud

Mystique outperforms Cubic more than **20%** on average, even with additional one-hop delay.

Deployment in Hypervisors



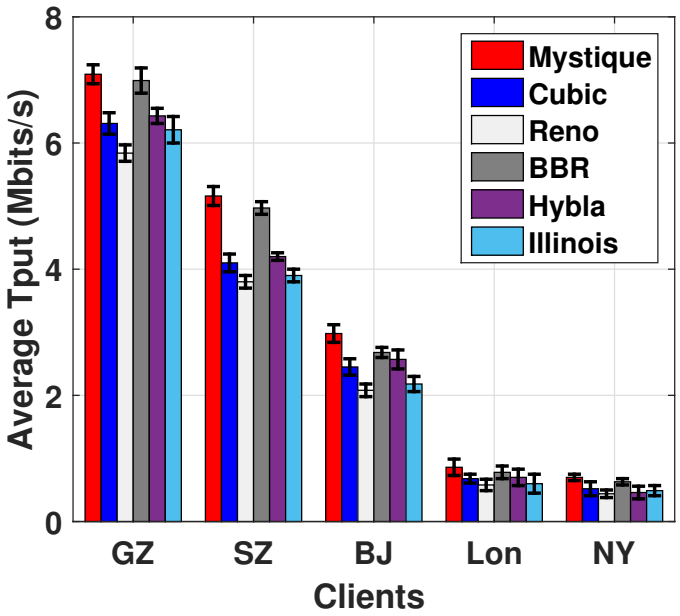
(a) Private cloud



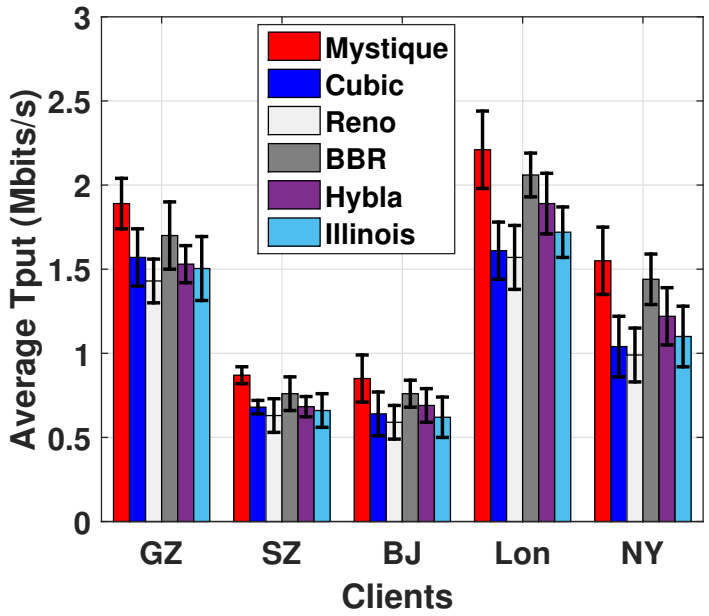
(b) Public cloud

Mystique on Hypervisors reduces
the load time by up to **28.75%**, compared to Cubic.

Deployment in Routers/Switches



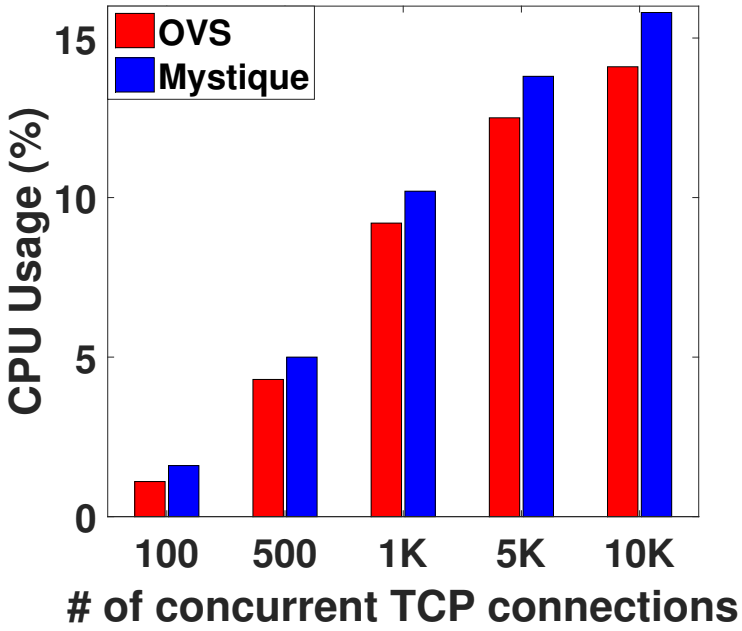
(a) Private cloud



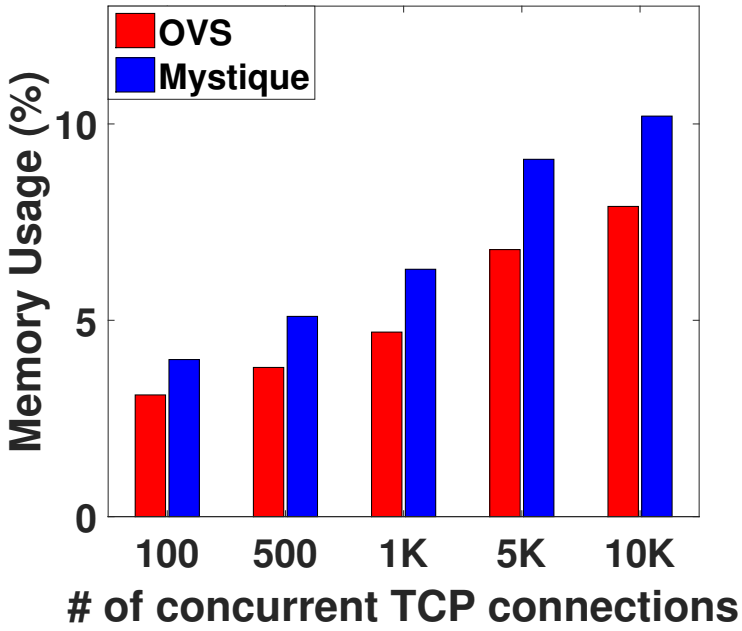
(b) Public cloud

Mystique on Routers/Switches increases the throughput by up to **20.38%**, compared to Cubic.

Overhead



(a) CPU overhead



(b) Memory overhead

CPU: The largest difference is **2**%. Memory: The largest difference is **3**%.

Conclusion

- Mystique enforces more appropriate congestion control algorithm for corresponding network environment
- Extensive test-bed results have demonstrated the effectiveness of Mystique
- We plan to investigate and implement more newly proposed congestion controls
- We would like to hear about your comments too

Questions and suggestions are welcome

Thank You

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