UCF / FLR Workshop on Networking Topics
Session 1: iPerf3, TCP Buffers, Science DMZ Motivation and Impact of Packet Loss

Jorge Crichigno, Elie Kfoury
University of South Carolina
http://ce.sc.edu/cyberinfra

University of Central Florida (UCF)
Florida LambdaRail (FLR)
The Engagement and Performance Operations Center (EPOC)
Energy Sciences Network (ESnet)
University of South Carolina (USC)

Orlando, Florida
February 16th, 2023

Workshop on Networking Topics

- Webpage with PowerPoint presentations:

  http://ce.sc.edu/cyberinfra/workshop_2023_feb.html

- Hands-on sessions: to access labs for the hands-on sessions, use the following link:

  https://netlab.cec.sc.edu/

- Username: email used for registration
- Password: nsf2023

NTP Lab Series

- Lab experiments

Lab 1:	Introduction to Mininet	Lab 11:	Router's Buffer Size
Lab 2:	Introduction to iPerf	Lab 12:	TCP Rate Control with Pacing
Lab 3:	WANs with latency, Jitter	Lab 13:	Impact of Maximum Segment Size on Throughput
Lab 4:	WANs with Packet Loss, Duplication, Corruption	Lab 14:	Router's Bufferbloat
Lab 5:	Setting WAN Bandwidth with Token Bucket Filter (TBF)	Lab 15:	Hardware Offloading on TCP Performance
Lab 6:	Traditional TCP Congestion Control (HTCP, Cubic, Reno)	Lab 16:	Random Early Detection
Lab 7:	Rate-based TCP Congestion Control (BBR)	Lab 17:	Stochastic Fair Queueing
Lab 8:	Bandwidth-delay Product and TCP Buffer Size	Lab 18:	Controlled Delay (CoDel) Active Queue Management
Lab 9:	Enhancing TCP Throughput with Parallel Streams	Lab 19:	Proportional Integral Controller-Enhanced (PIE)
Lab 10:	Measuring TCP Fairness	Lab 20:	Classifying TCP traffic using Hierarchical Token Bucket (HTB)

Organization of the Lab Manuals

Each lab starts with a section *Overview*

- Objectives
- Lab topology
- Lab settings: passwords, device names
- Roadmap: organization of the lab

Section 1

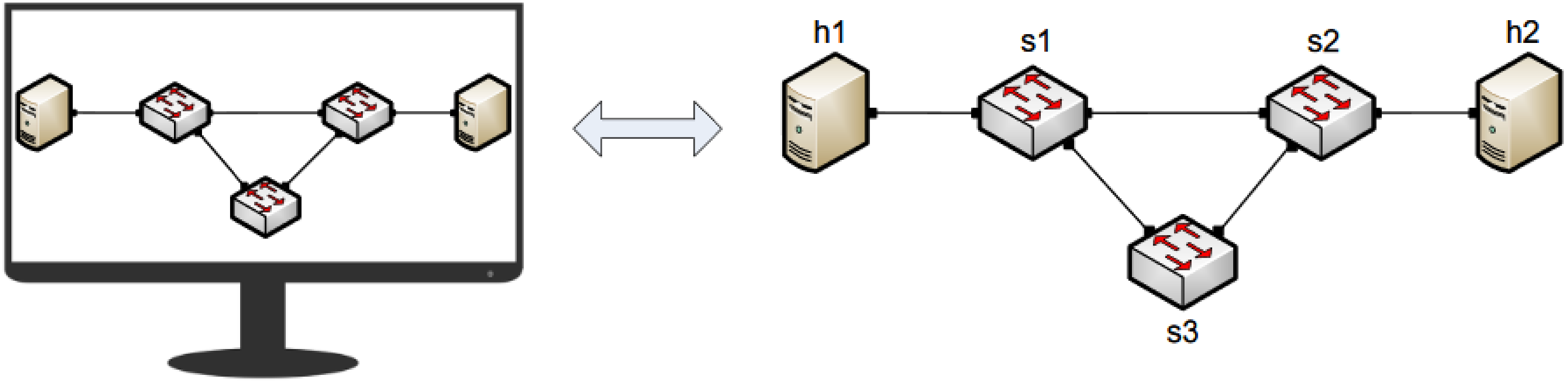
- Background information of the topic being covered (e.g., fundamentals of perfSONAR)
- Section 1 is optional (i.e., the reader can skip this section and move to lab directions)

Section 2… n

- Step-by-step directions

Mininet

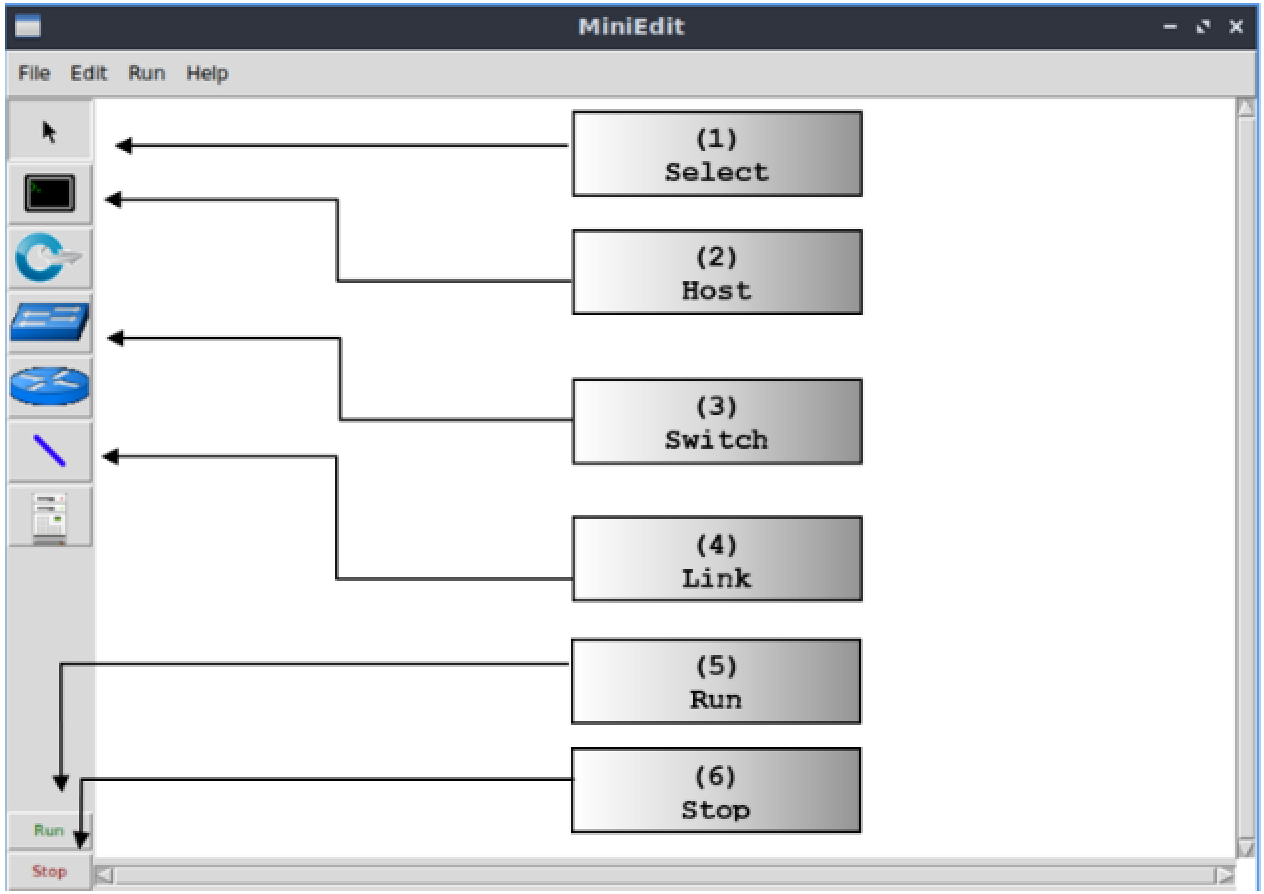
- Mininet provides network *emulation* opposed to simulation, allowing all network software at any layer to be simply run as is
- Mininet's logical nodes can be connected into networks
- Nodes are sometimes called containers, or more accurately, *network namespaces*
- Containers consume sufficiently few resources that networks of over a thousand nodes have been created, running on a single laptop



Mininet Emulated Network **Hardware Network**

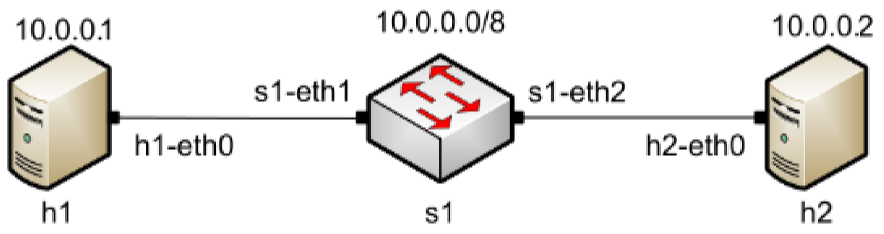
MiniEdit

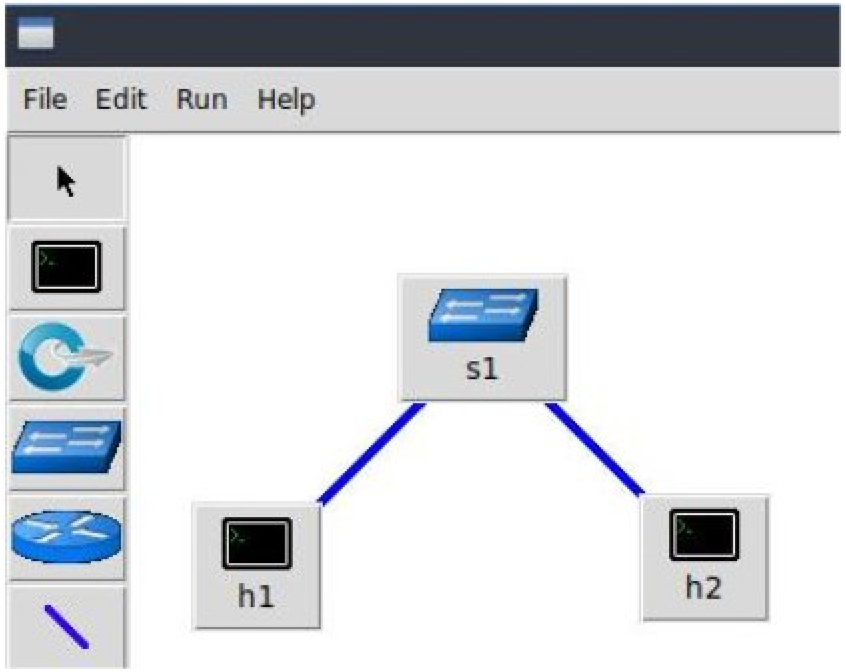
- MiniEdit is a simple GUI network editor for Mininet



MiniEdit

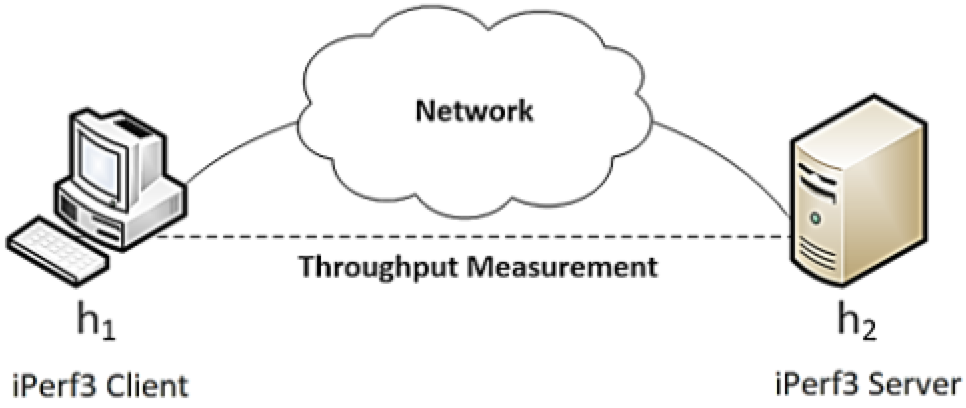
- To build Mininet's minimal topology, two hosts and one switch must be deployed





iPerf3

- iPerf3 is a real-time network throughput measurement tool
- It is an open source, cross-platform client-server application that can be used to measure the throughput between the two end devices
- Measuring throughput is particularly useful when experiencing network bandwidth issues such as delay, packet loss, etc.



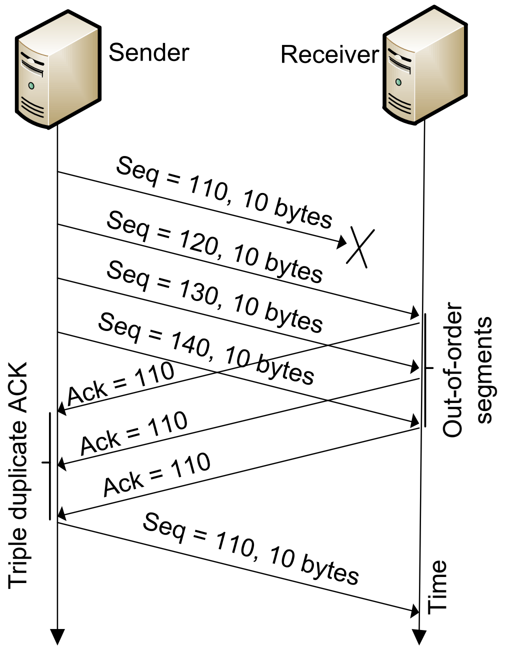
iPerf3

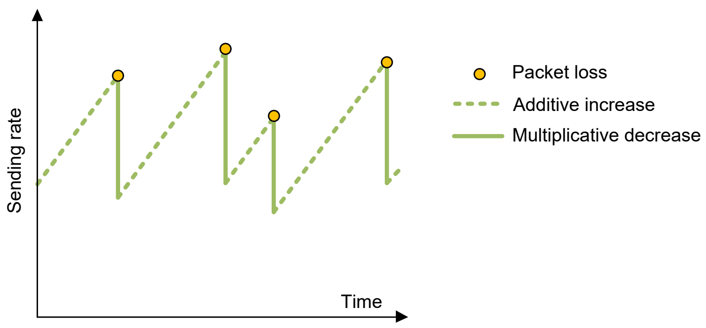
- iPerf3 can operate on TCP, UDP, and SCTP, unidirectional or bidirectional way
- In iPerf3, the user can set *client* and *server* configurations via options and parameters
- iPerf3 outputs a timestamped report of the amount of data transferred and the throughput measured

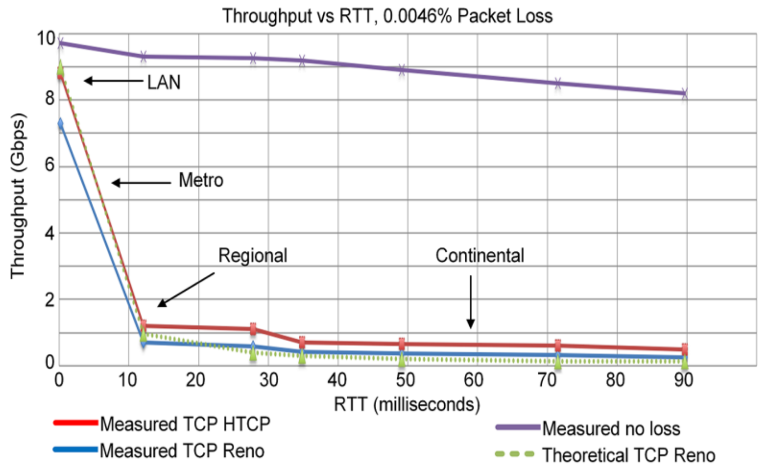
```
Connecting to host 10.0.0.2, port 5201
[ 13] local 10.0.0.1 port 59414 connected to 10.0.0.2 port 5201
[ ID] Interval           Transfer     Bitrate         Retr  Cwnd
[ 13]   0.00-1.00   sec  5.18 GBytes  44.5 Gbits/sec    0    843 KBytes
[ 13]   1.00-2.00   sec  5.21 GBytes  44.7 Gbits/sec    0   1.11 MBytes
[ 13]   2.00-3.00   sec  5.20 GBytes  44.7 Gbits/sec    0   1.18 MBytes
[ 13]   3.00-4.00   sec  5.21 GBytes  44.7 Gbits/sec    0   1.24 MBytes
[ 13]   4.00-5.00   sec  5.19 GBytes  44.6 Gbits/sec    0   1.24 MBytes
[ 13]   5.00-6.00   sec  5.22 GBytes  44.8 Gbits/sec    0   1.30 MBytes
[ 13]   6.00-7.00   sec  5.24 GBytes  45.0 Gbits/sec    0   1.44 MBytes
[ 13]   7.00-8.00   sec  5.22 GBytes  44.9 Gbits/sec    0   1.44 MBytes
[ 13]   8.00-9.00   sec  5.21 GBytes  44.8 Gbits/sec    0   1.45 MBytes
[ 13]   9.00-10.00  sec  5.22 GBytes  44.8 Gbits/sec    0   1.52 MBytes
- - - - - - - - - - - - - - - - - - - - - - - - -
[ ID] Interval           Transfer     Bitrate         Retr
[ 13]   0.00-10.00  sec  52.1 GBytes  44.8 Gbits/sec    0             sender
[ 13]   0.00-10.04  sec  52.1 GBytes  44.6 Gbits/sec                  receiver

iperf Done.
root@admin-pc:~#
```

TCP Traditional Congestion Control

- The principles of window-based CC were described in the 1980s[1]
- Traditional CC algorithms follow the additive-increase multiplicative-decrease (AIMD) form of congestion control



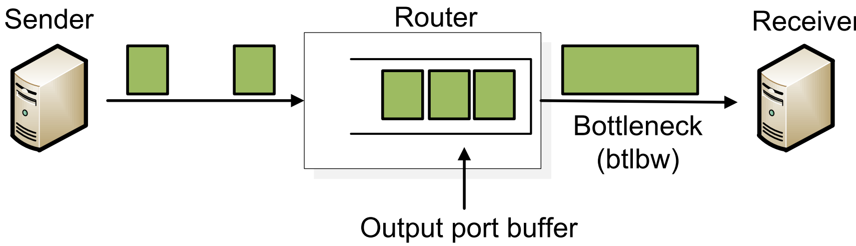


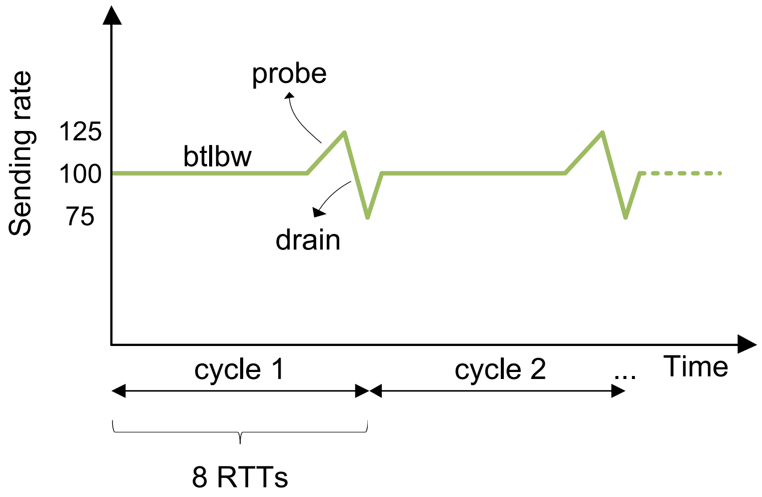


1. V. Jacobson, M. Karels, Congestion avoidance and control, ACM SIGCOMM Computer Communication Review 18 (4) (1988).

BBR: Model-based CC

- TCP Bottleneck Bandwidth and RTT (BBR) is a rate-based congestion-control algorithm[1]
- BBR represented a disruption to the traditional CC algorithms:
  - is not governed by AIMD control law
  - does not the use packet loss as a signal of congestion
- At any time, a TCP connection has one slowest link bottleneck bandwidth (btlbw)





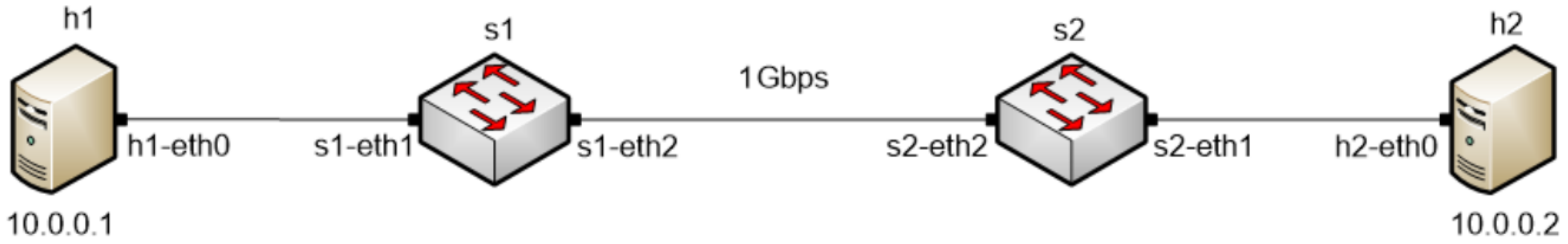
1. N. Cardwell et al. "BBR v2, A Model-based Congestion Control." IETF 104, March 2019.

TCP Buffer Size

- In many WANs, the round-trip time (RTT) is dominated by the propagation delay
- To keep the sender busy while ACKs are received, the TCP buffer must be:

Traditional congestion controls: **TCP buffer size ≥ 2BDP**

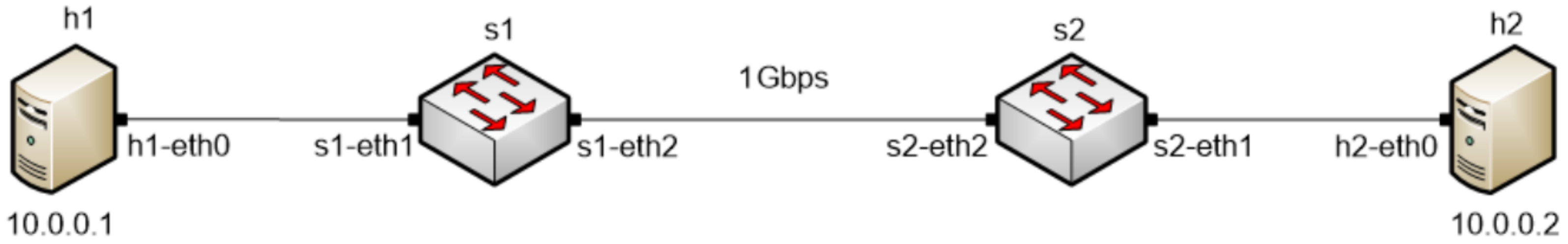
BBRv1 and BBRv2: **TCP buffer size must be considerable larger than 2BDP**



Lab 7: Understanding Rate-based TCP Congestion Control (BBR)

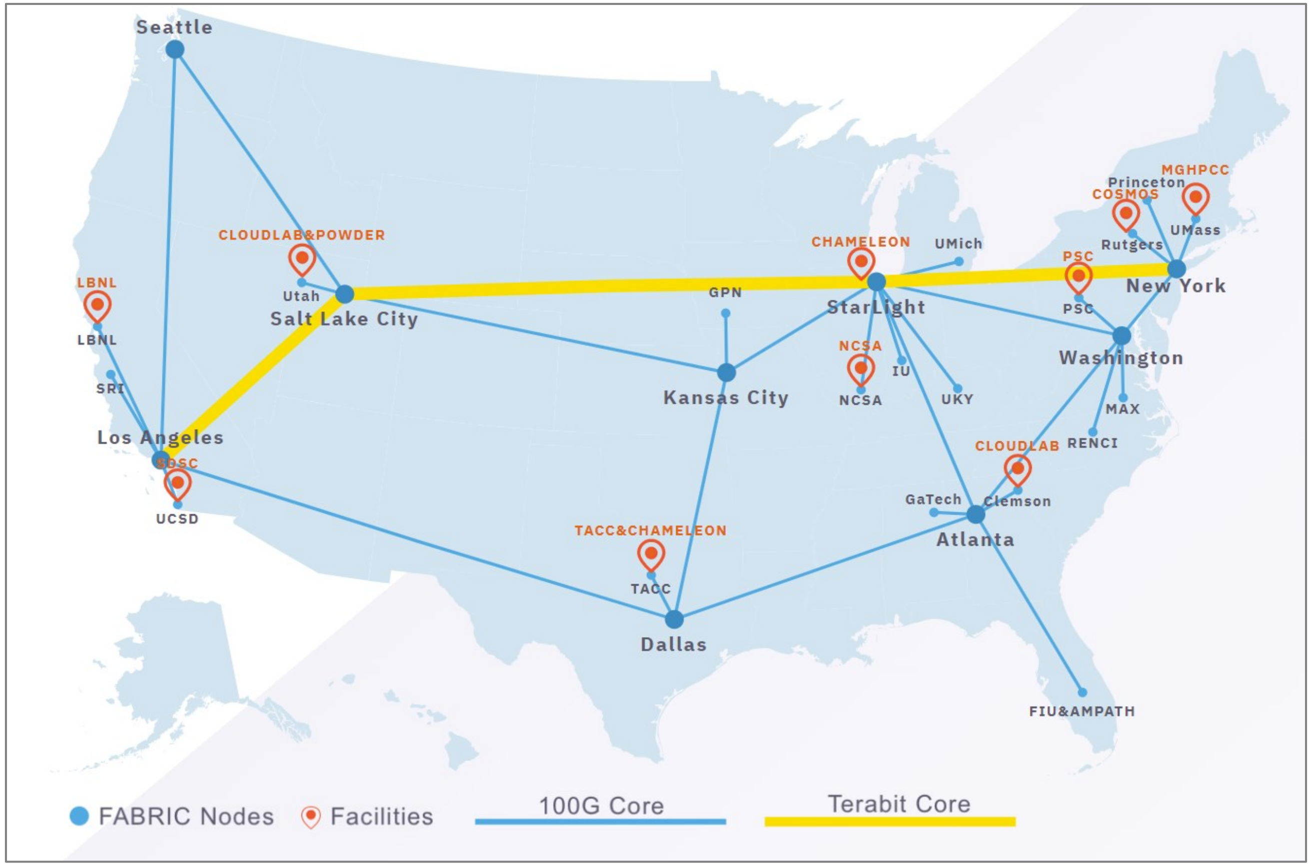
Lab Goal and Topology

- Deploy emulated WANs in Mininet
- Modify the TCP congestion control algorithm in Linux using sysctl tool
- Compare the performance of TCP Reno and TCP BBR in high-throughput high-latency networks
  - Without 30ms propagation delay
  - With 30ms propagation delay
- Demonstrating the impact of packet loss on the throughput of TCP
- Lab topology:



Additional Slides

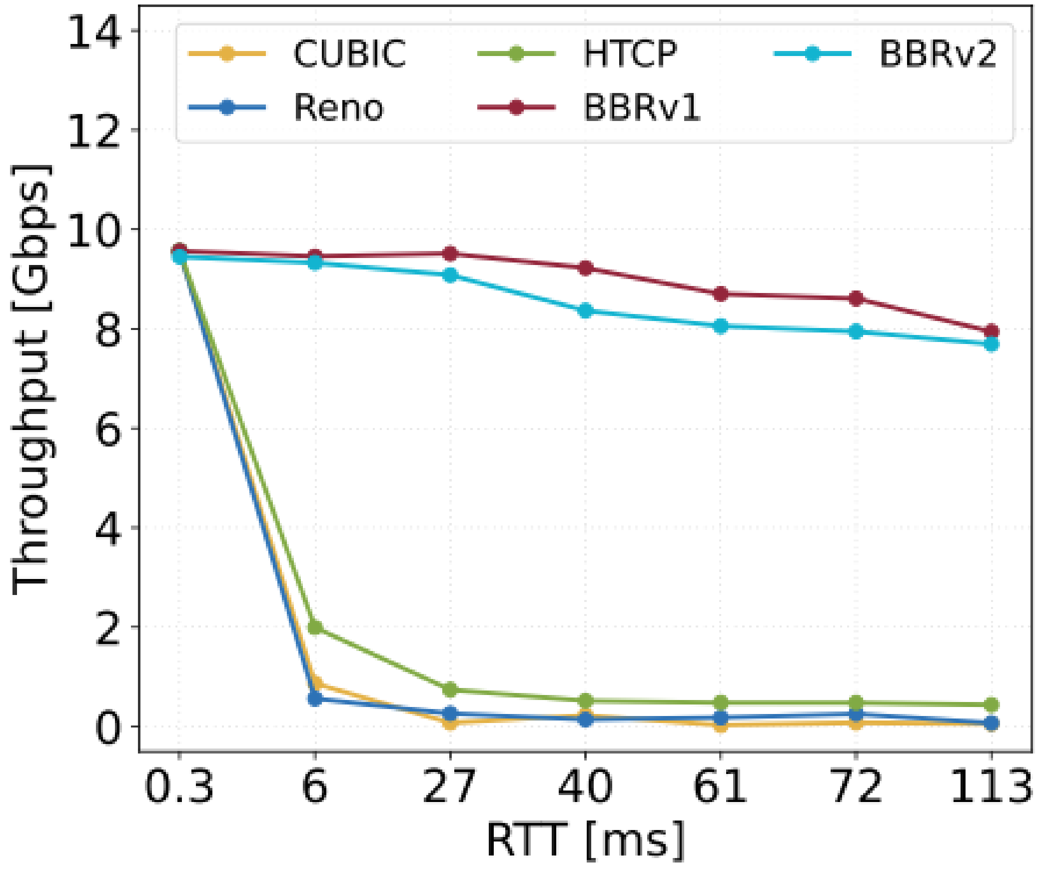
- BBR performance on FABRIC
- Performance measurements for a single flow, 0.0046% packet loss rate

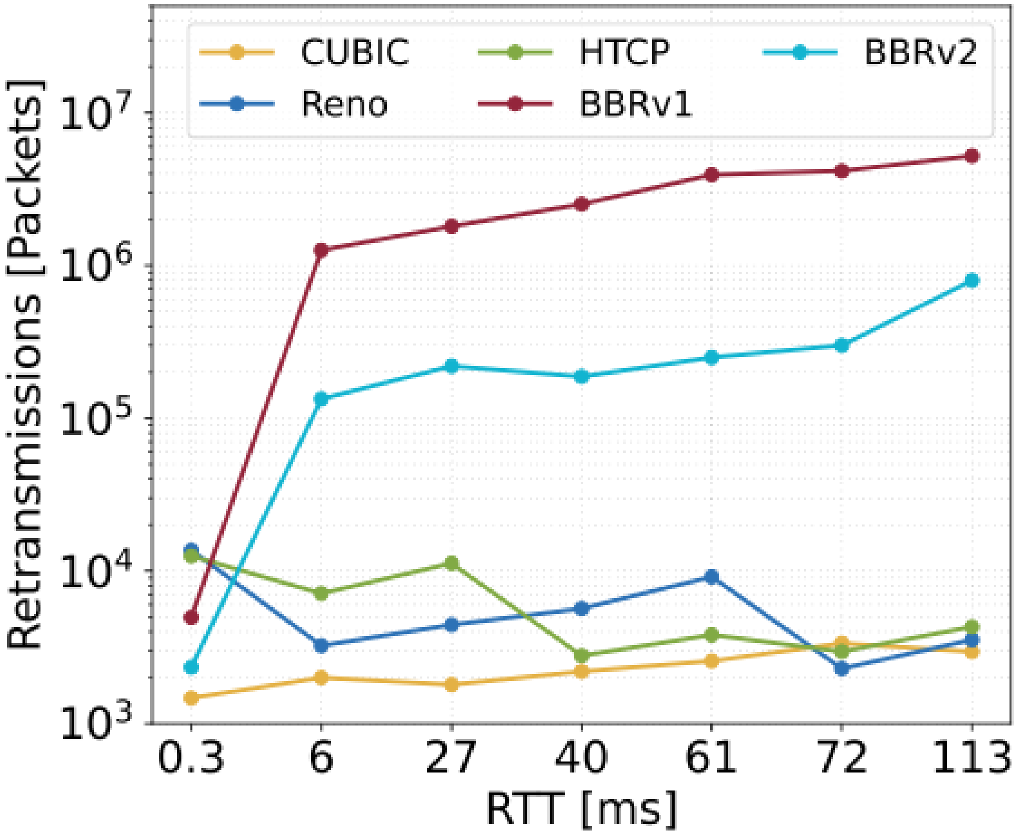


Site 1	Site 2	RTT
TACC (TX)	TACC (TX)	0.3ms
DALL (TX)	TACC (TX)	6ms
DALL (TX)	WASH (DC)	27ms
SALT (UT)	FIU (FL)	44ms
GPN (MO)	DALL (TX)	61ms
UTAH (UT)	WASH (DC)	72ms
GPN (MO)	FIU (FL)	113ms

Additional Slides

- BBR performance on FABRIC
- Performance measurements for a single flow, 0.0046% packet loss rate





BDP

- Bandwidth = 1Gbps
- RTT = 30ms
- BDP (bytes) = 3,750,000 bytes
- BDP (MB) = 3.57MB