“ROLE OF TCP IN LARGE DATA TRANSFERS”

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NSF Award 1829698
“CyberTraining CIP: Cyberinfrastructure Expertise on High-throughput Networks for Big Science Data Transfers”

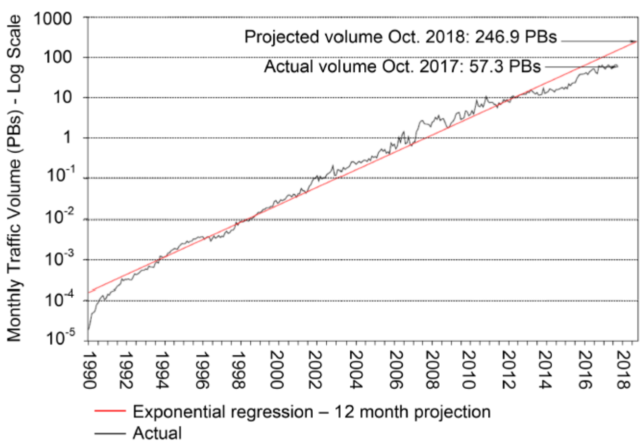
Agenda

- Motivation for a high-speed science architecture
- Enterprise network limitations
- Science DMZs
- TCP considerations
  - Congestion control algorithms
  - Parallel streams
  - Maximum Segment Size (MSS)
  - Pacing, fairness, TCP buffers, router's buffers, … (discussed in labs)

Motivation for a High-Speed Science Architecture

- Science and engineering applications are now generating data at an unprecedented rate
- Instruments produce hundreds of terabytes in short periods of time (“big science data”)
- Data must be typically transferred across **high-bandwidth high-latency** Wide Area Networks (WANs)

Applications

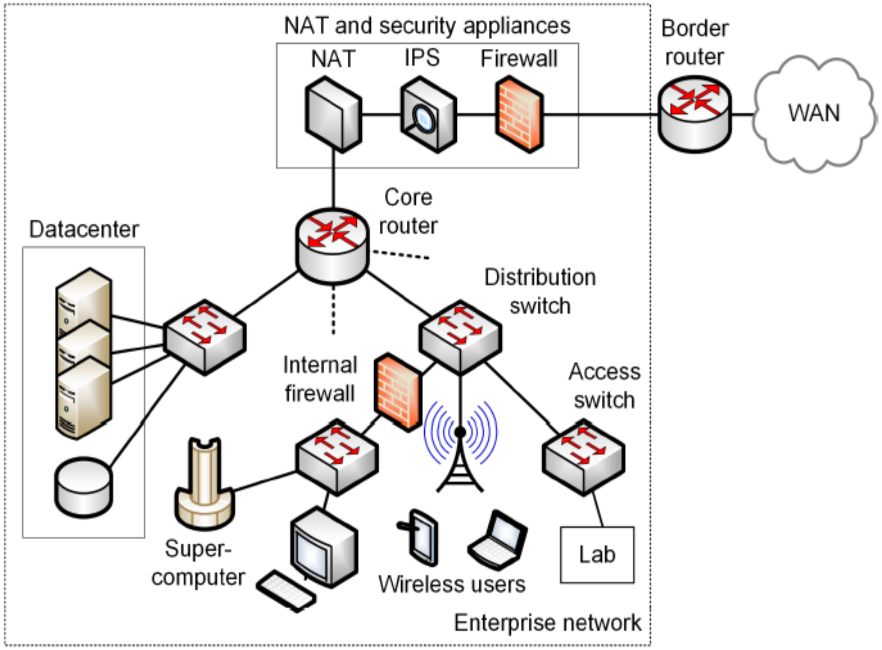


ESnet traffic

The Energy Science Network (ESnet) is the backbone connecting U.S. national laboratories and research centers

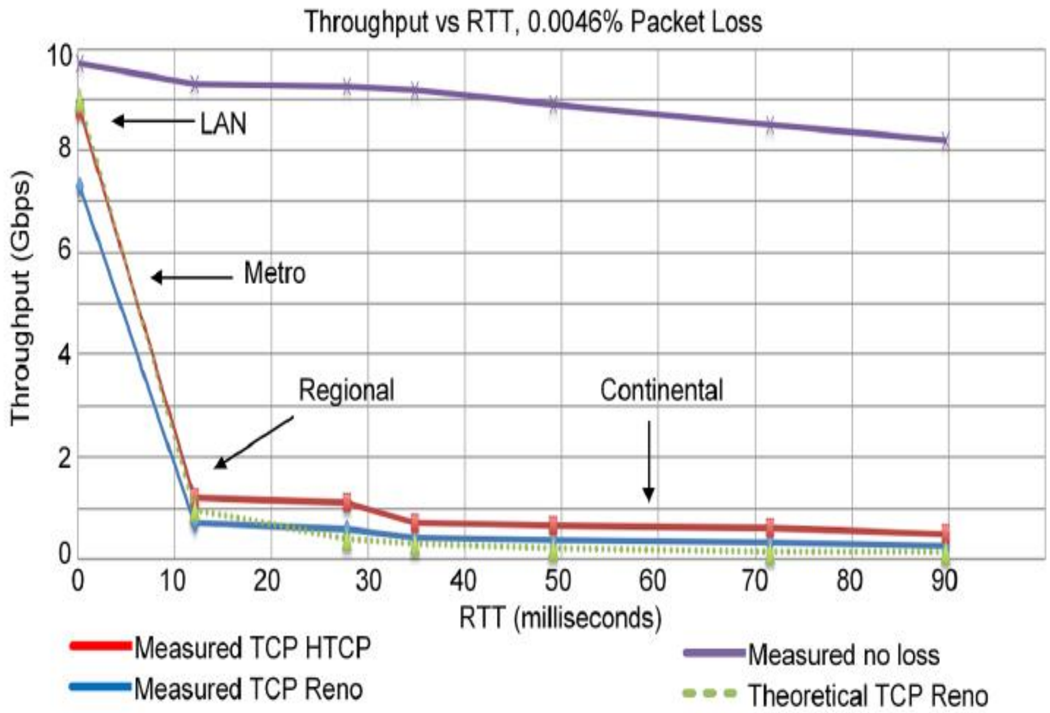
Enterprise Network Limitations

- Security appliances (IPS, firewalls, etc.) are CPU-intensive
- Inability of small-buffer routers/switches to absorb traffic bursts
- End devices incapable of sending/receiving data at high rates
- Lack of data transfer applications to exploit available bandwidth
- Many of the issues above relate to TCP



Enterprise Network Limitations

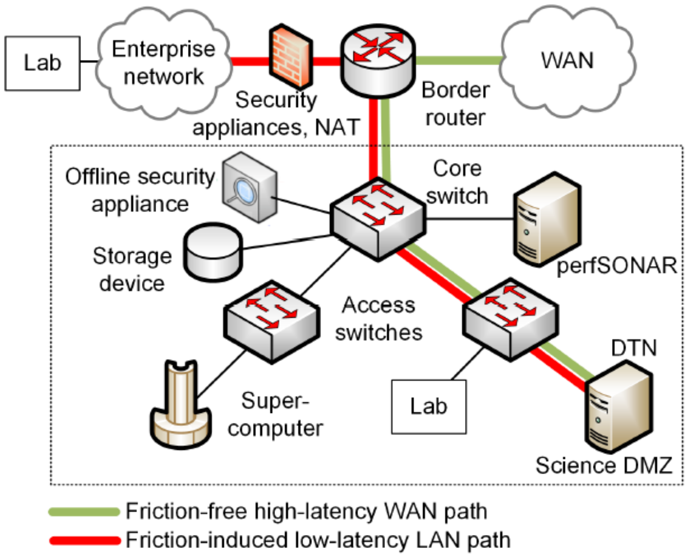
- Effect of packet loss and latency on TCP throughput



E. Dart, L. Rotman, B. Tierney, M. Hester, J. Zurawski, "The science dmz: a network design pattern for data-intensive science," *International Conference on High Performance Computing, Networking, Storage and Analysis*, Nov. 2013.

Science DMZ

- The Science DMZ is a network designed for big science data
- Main elements
  - High throughput, friction free WAN paths
  - Data Transfer Nodes (DTNs)
  - End-to-end monitoring = perfSONAR
  - Security tailored for high speeds



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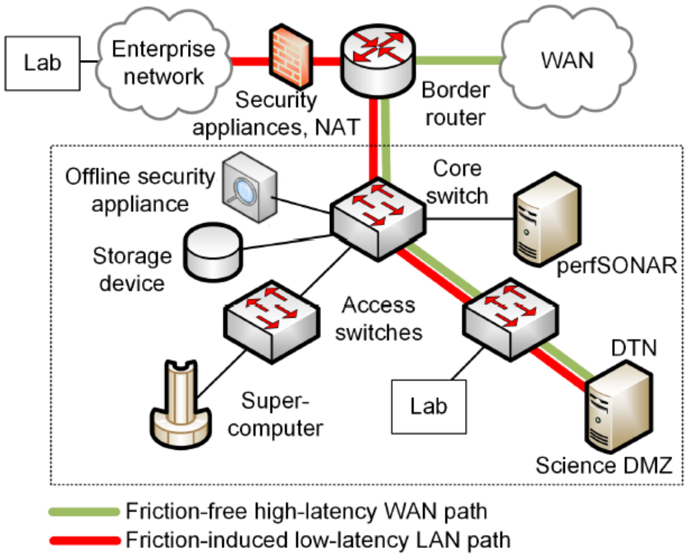
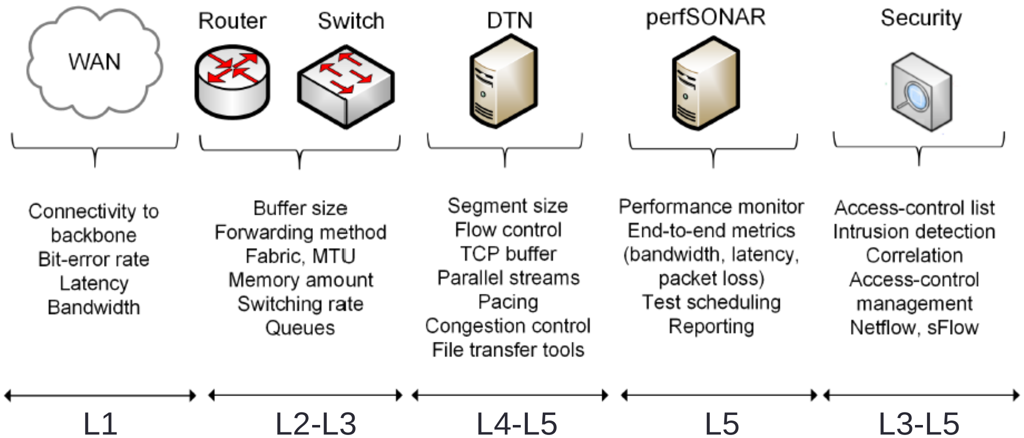
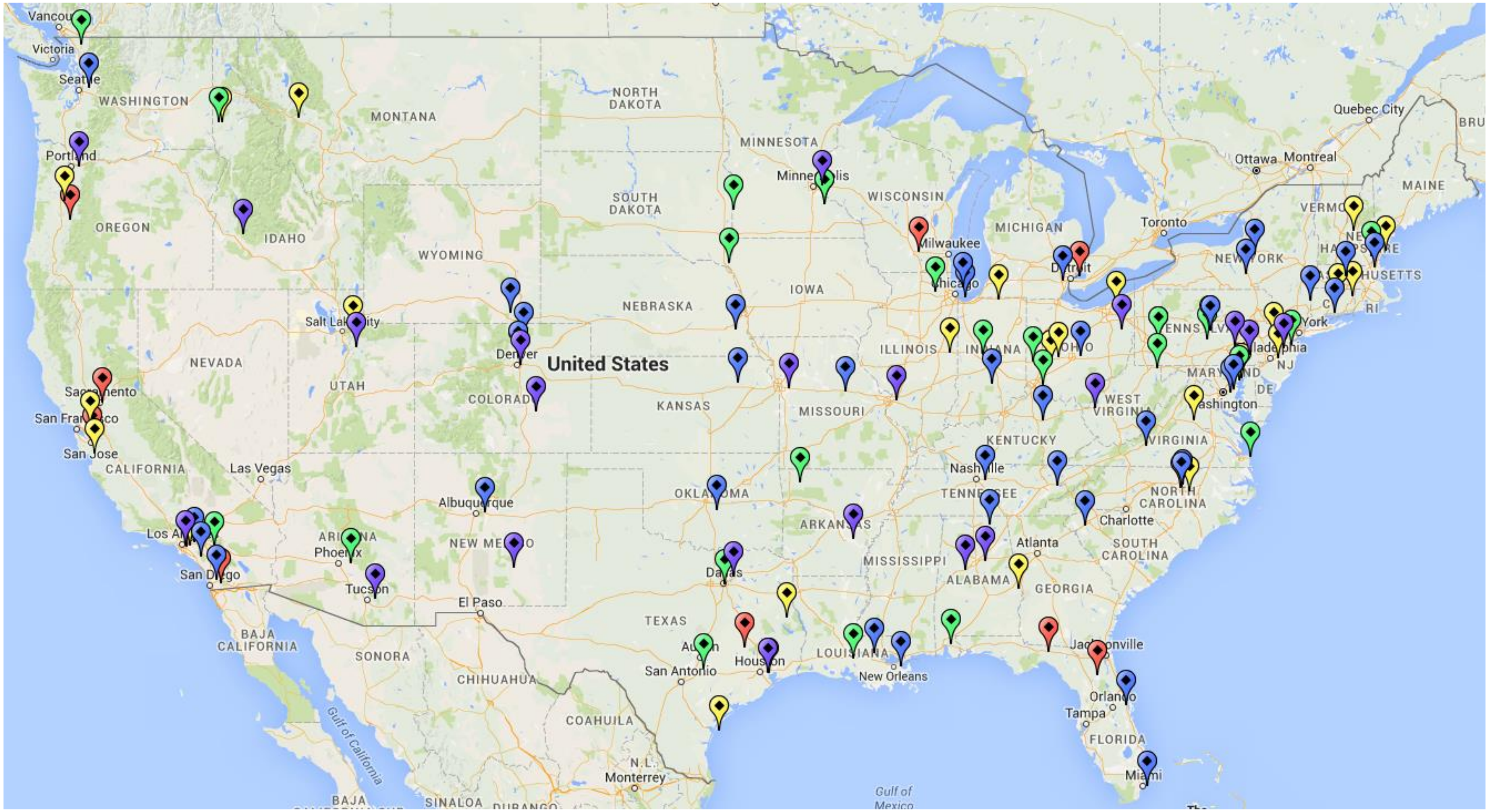




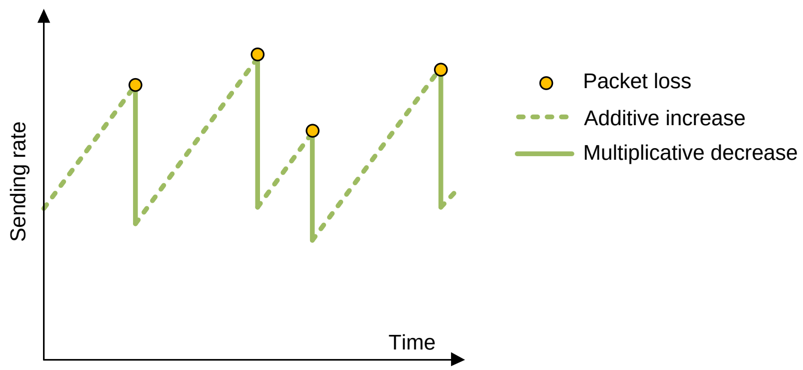
Science DMZ

- Science DMZ deployments, U.S.



TCP Traditional Congestion Control (CC)

- The CC algorithm determines the sending rate
- Traditional CC algorithms follow an additive-increase multiplicative-decrease (AIMD) form of congestion control



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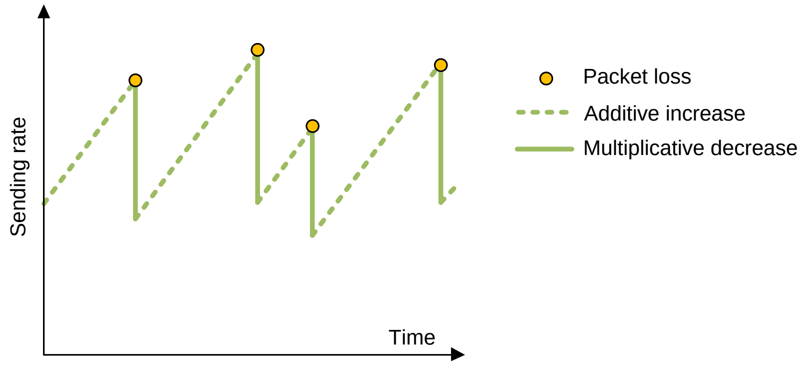

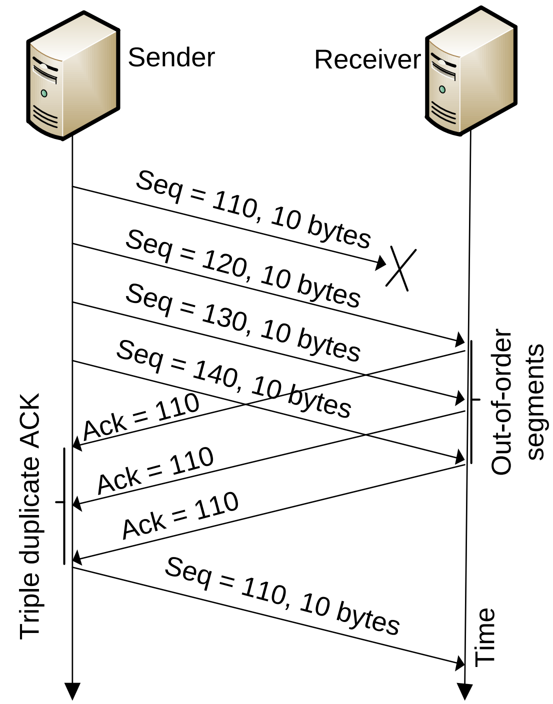

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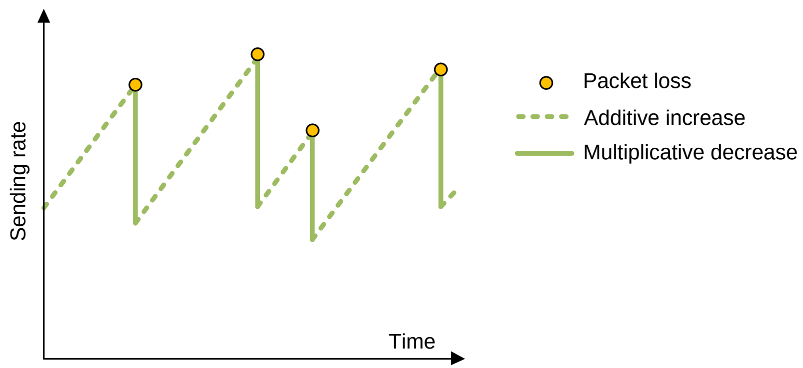
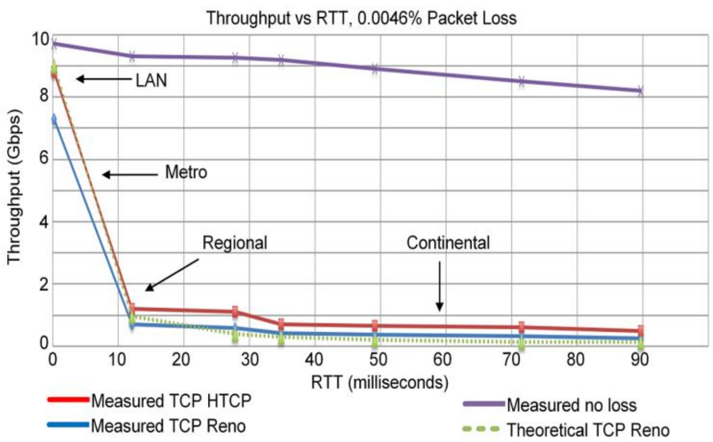
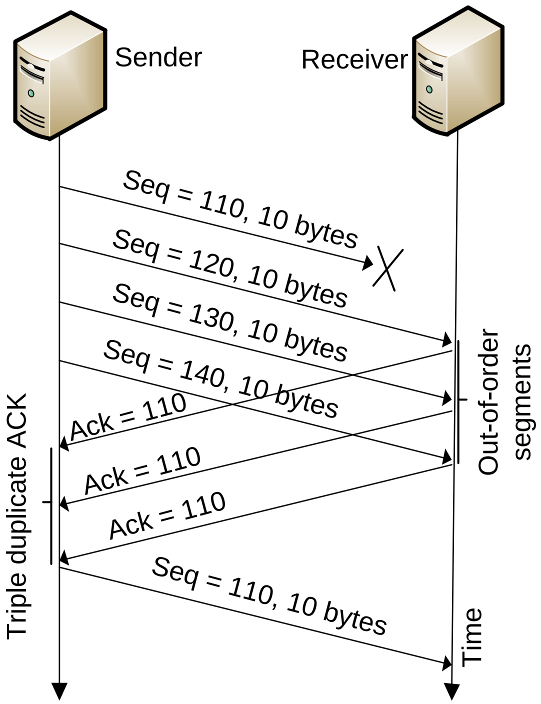
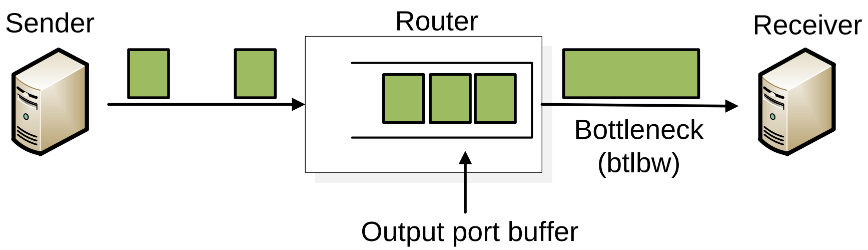






BBR: Rate-based CC

- TCP Bottleneck Bandwidth and RTT (BBR) is a rate-based congestion-control algorithm
- At any time, a TCP connection has one slowest link or bottleneck bandwidth (btlbw)



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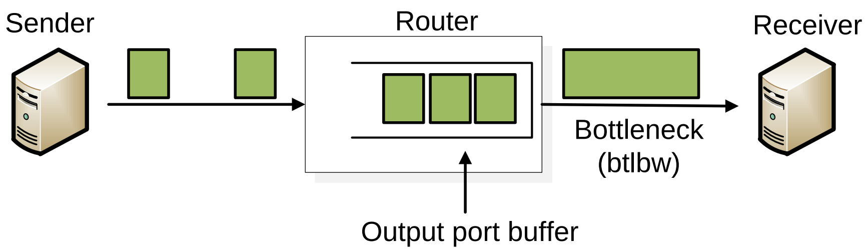
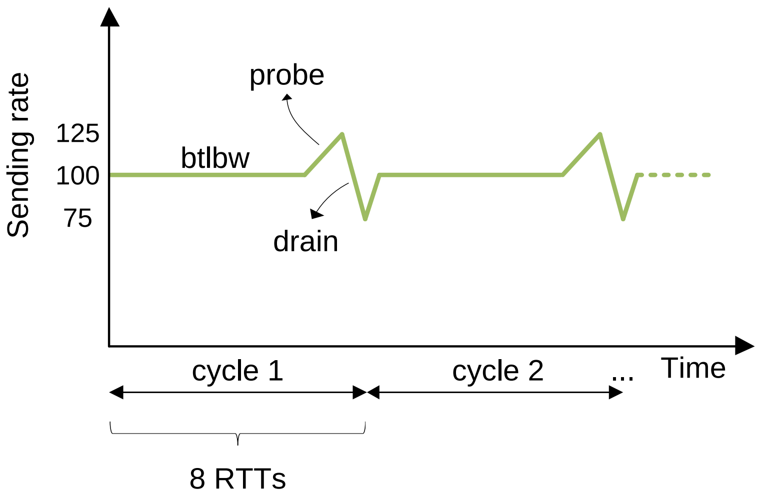
- BBR tries to find btlbw and set the sending rate to that value
  - The sending rate is independent of current packet losses; no AIMD rule





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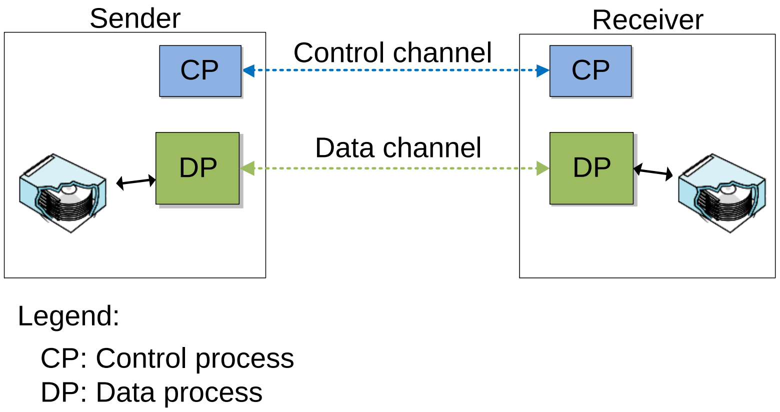
Parallel Streams

- Conventional file transfer protocols use a control channel and a (single) data channel (FTP model)



FTP model

Parallel Streams

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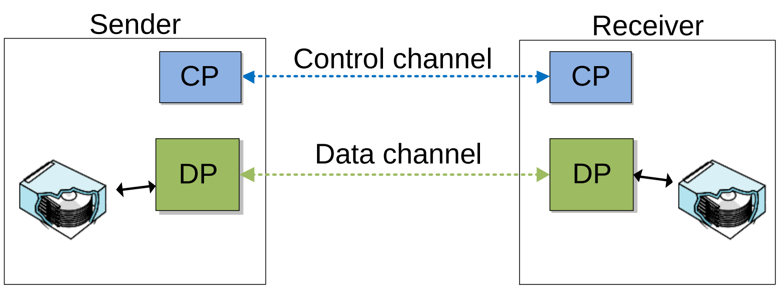
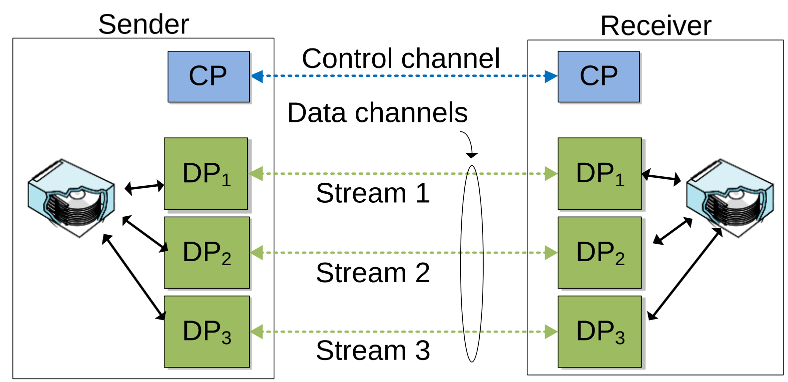
- gridFTP is an extension of the FTP protocol
- A feature of gridFTP is the use of parallel streams



Legend:
CP: Control process
DP: Data process

FTP model



gridFTP model

Advantages of Parallel Streams

- Combat random packet loss not due congestion[1]
  - Parallel streams increase the recovery speed after the multiplicative decrease

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  - Increase bandwidth allocated to big science flows

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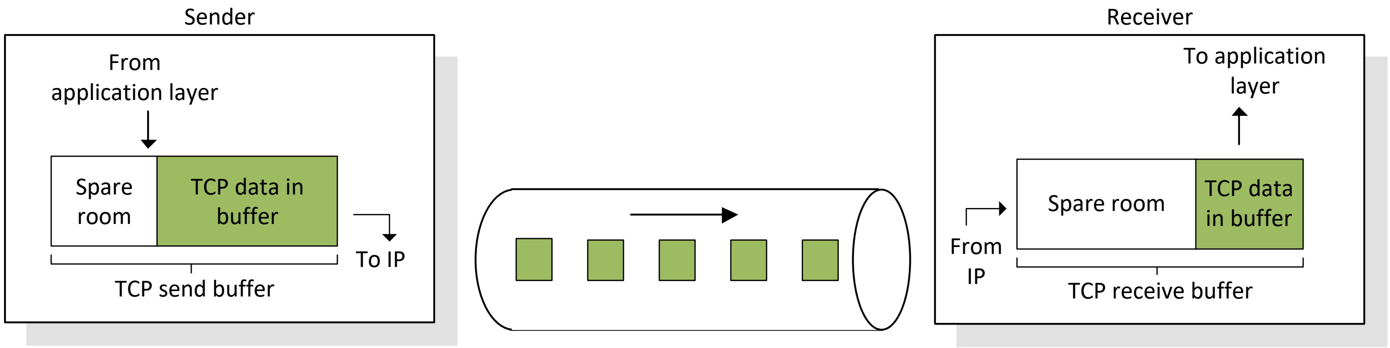
- Overcome TCP buffer limitations
  - An application opening K parallel connections creates a virtual large buffer size on the aggregate connection that is K times the buffer size of a single connection



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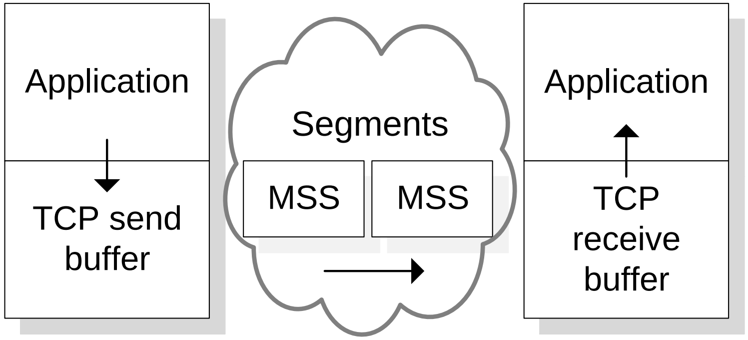
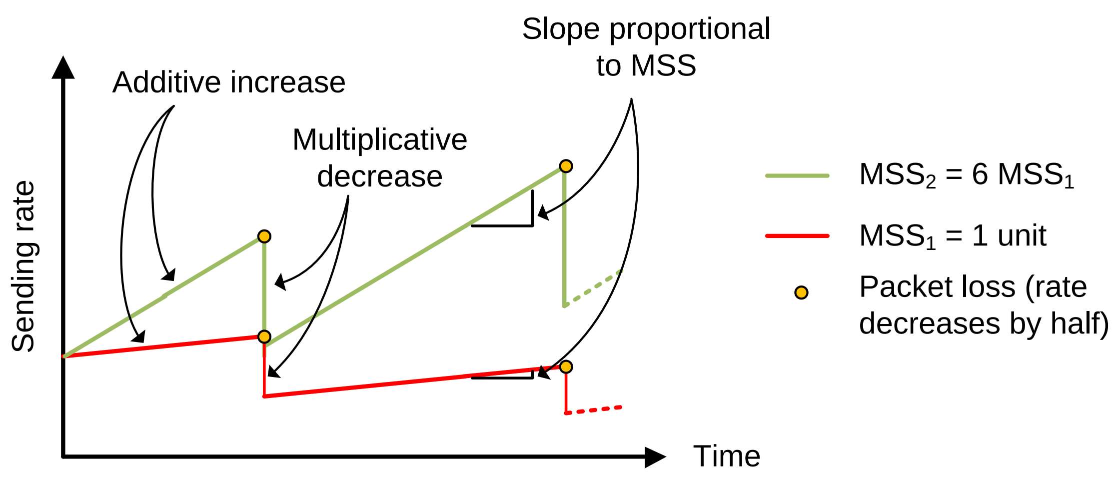
Maximum Segment Size (MSS)

- TCP receives data from application layer and places it in send buffer
- Data is typically broken into MSS units
- A typical MSS is 1,500 bytes, but it can be as large as 9,000 bytes



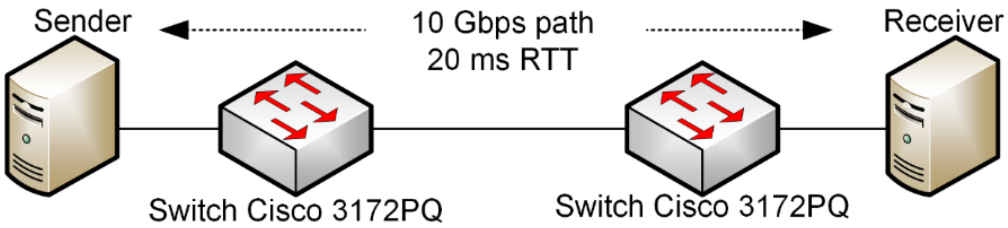
Advantages of Large MSS

- Less overhead
- The recovery after a packet loss is proportional to the MSS
  - During the additive increase phase, TCP increases the congestion window by approximately one MSS every RTT
  - By using a 9,000-byte MSS instead of a 1,500-byte MSS, the throughput increases six times faster



Results on a 10 Gbps Network

- 70-second experiments (first 10 seconds not considered)
- Ten experiments conducted and the average throughput is reported
- Impact of MSS and parallel streams on BBR, Reno, HTCP, Cubic



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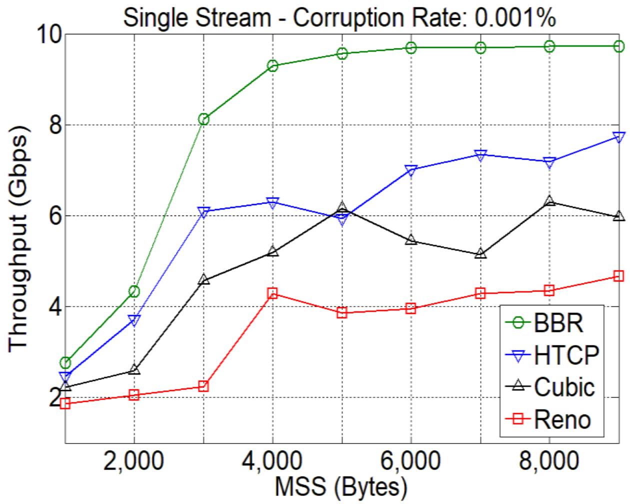

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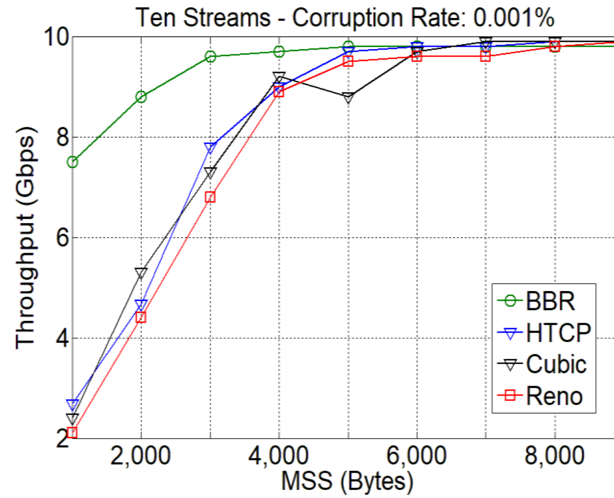

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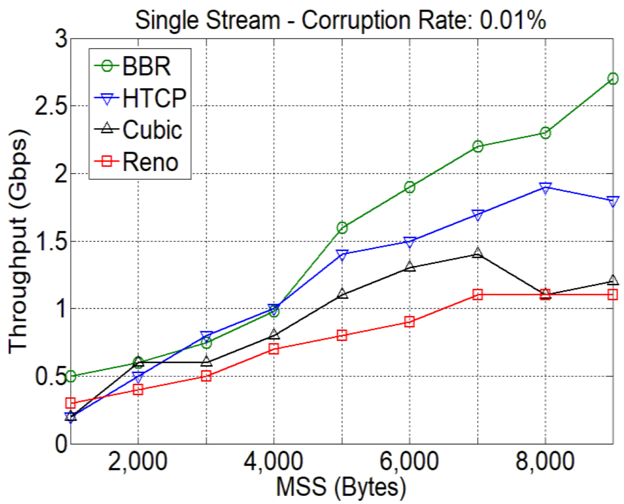

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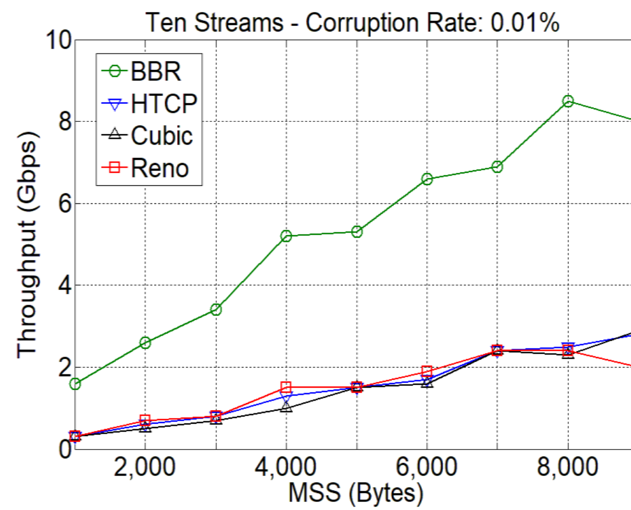

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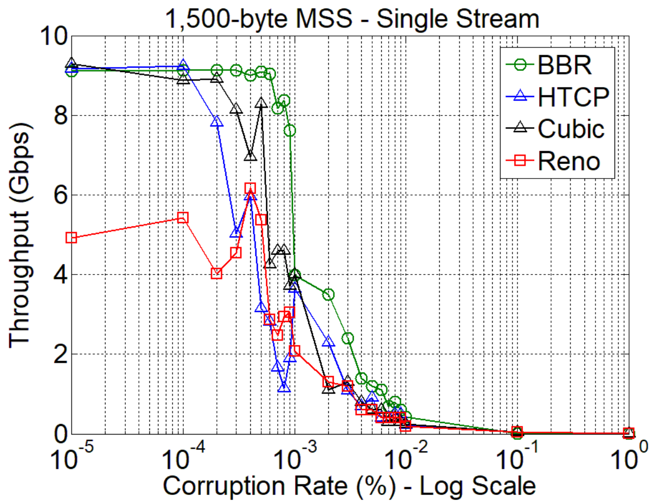

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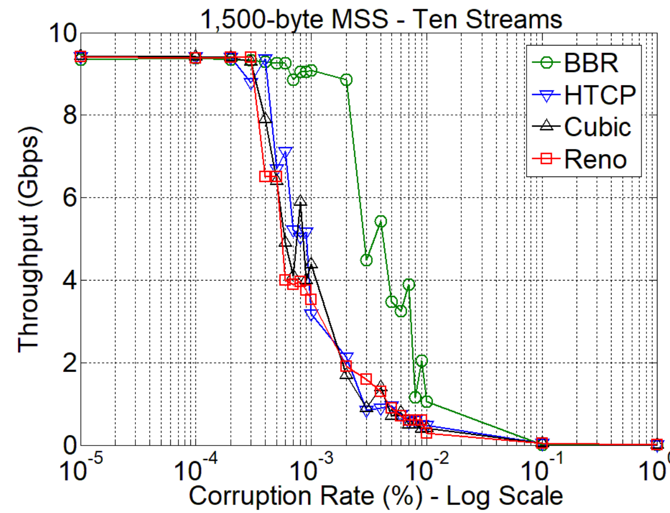

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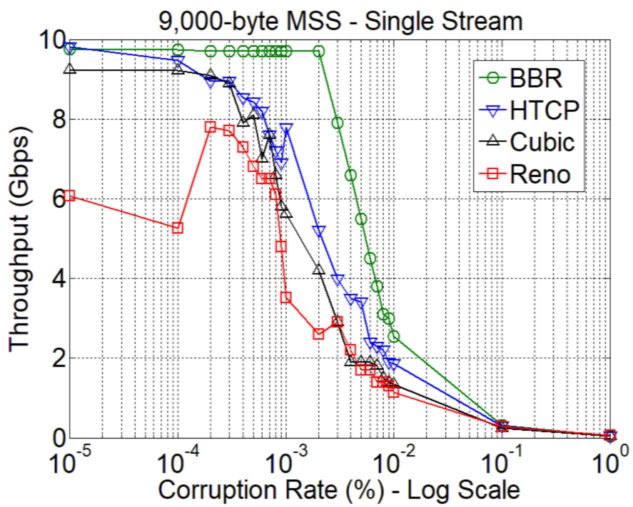

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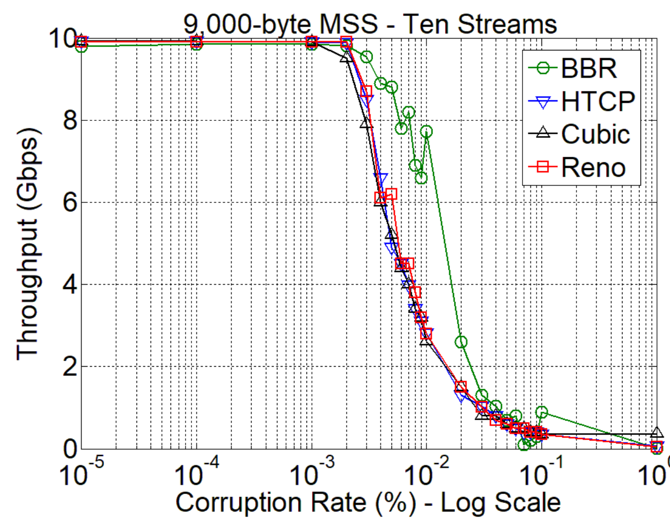

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Summary

- There are many aspects of TCP / transport protocol that are essential to consider for high-performance networks
  - Parallel streams
  - MSS
  - TCP buffers
  - Router’s buffers, and others
- Still there is a need for applied research; e.g.,
  - Performance studies of new congestion control algorithms
  - TCP pacing
  - Application of programmable switches