UDT: UDP based Data Transfer

Protocol, Results, and Implementation Experiences

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Outline

- UDT Protocol
- UDT Congestion Control
- Implementation/Simulation Results
- Implementation Experiences at ANL

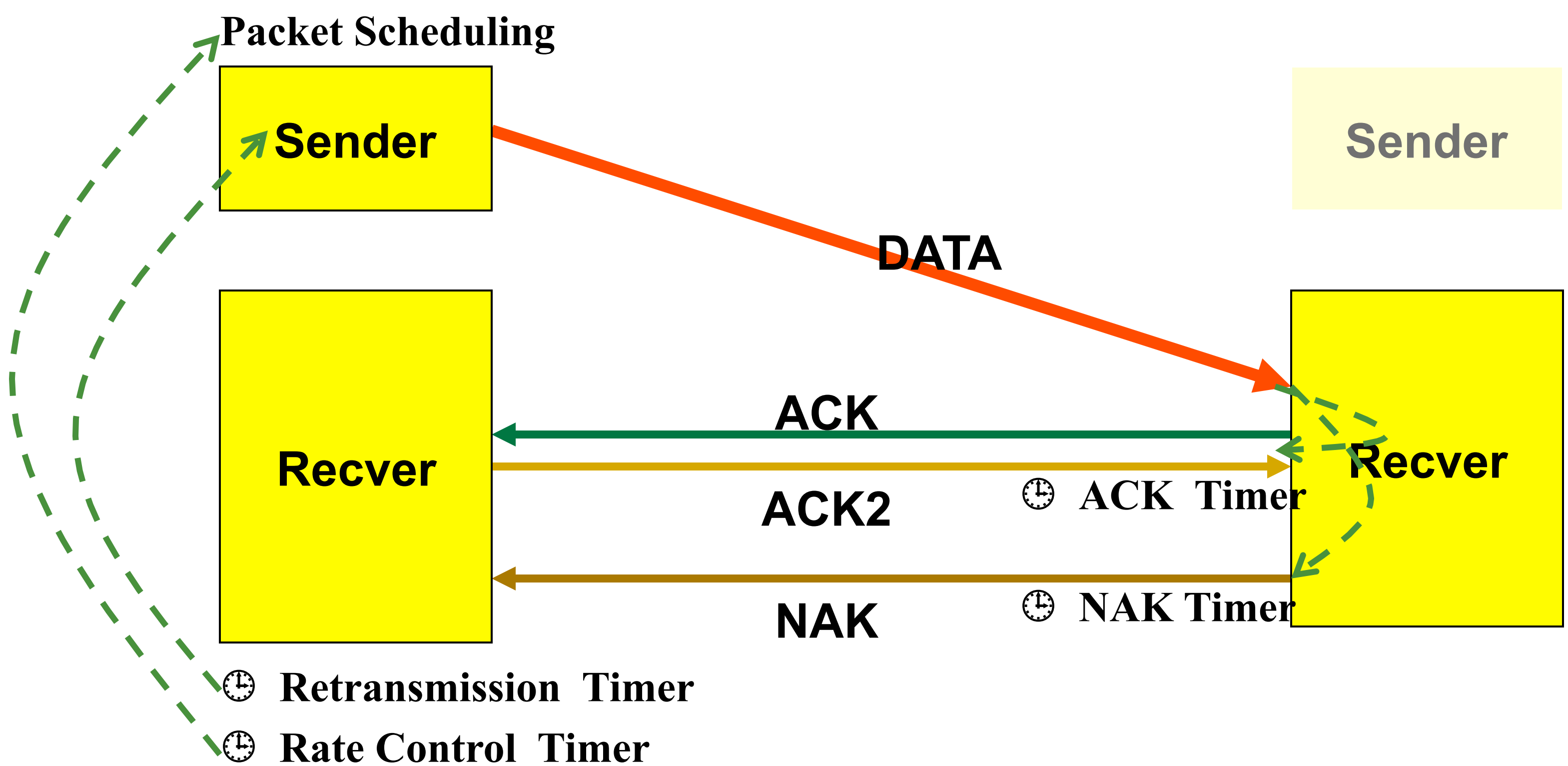
Design Goals and Assumptions

- Fast, Fair, Friendly
  - High utilization of the abundant bandwidth with either single or multiplexed connections
  - Intra-protocol fairness, RTT independence
  - TCP compatibility
- Low concurrency, high bandwidth, bulk data
  - A small number of sources share abundant bandwidth
  - Most of the packets can be packed in maximum segment size (MSS)

What's UDT?

- UDT: UDP based Data Transfer
  - Reliable, application level, duplex, transport protocol, over UDP with reliability, congestion, and flow control
  - Implementation: Open source C++ library
- Two orthogonal parts
  - The UDT protocol framework that can be implemented above UDP, with any suitable congestion control algorithms
  - The UDT congestion control algorithm, which can be implemented in any transport protocols such as TCP

UDT Protocol



UDT Protocol

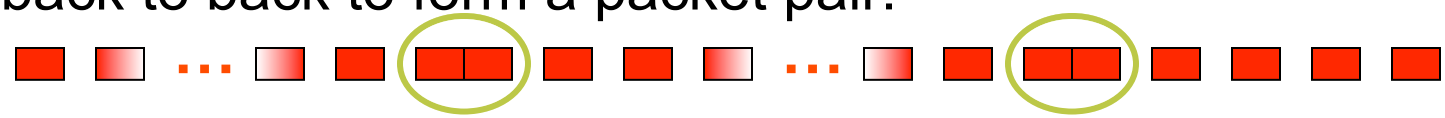
- Packet based sequencing
- ACK sub-sequencing
- Explicit loss information feedback (NAK)
- Four timers: rate control, ACK, NAK and retransmission timer
  - Rate control and ACK are triggered periodically
  - NAK timer is used to resend loss information if retransmission is not received in an increasing time interval

Congestion Control

- Rate based congestion control (Rate Control)
  - RC tunes the packet sending period.
  - RC is triggered periodically.
  - RC period is constant of 0.01 seconds.
- Window based flow control (Flow Control)
  - FC limits the number of unacknowledged packets.
  - FC is triggered on each received ACK.
- Slow start is controlled by FC
  - Similar to TCP, but only occurs at the session beginning.

Rate Control

- AIMD: Increase parameter is related to link capacity and current sending rate; Decrease factor is 1/9, but not decrease for all loss events.
- Link capacity is probed by packet pair, which is sampled UDT data packets.
  - Every 16th data packet and it successor packet are sent back to back to form a packet pair.



  - The receiver uses a median filter on the interval between the arrival times of each packet pair to estimate link capacity.

Rate Control

- Number of packets to be increased in next rate control period (RCTP) time is:

  $$inc = \max(10^{\lceil \log_{10}((B-C)\times MSS\times 8)\rceil} \times \beta / MSS, 1/MSS)$$

  where *B* is estimated link capacity, *C* is current sending rate. Both are in packets per second. MSS is the packet size in bytes. β = 1.5 * 10^{-6}.
- Decrease sending rate by 1/9 when a NAK is received, but only if
  1. largest lost sequence number in NAK is greater than the largest sequence number when last decrease occurred; or
  2. The number of NAKs since last decrease has exceeded a threshold, which increases exponentially and is reset when condition 1 is satisfied.

Rate Control

B = 10Gbps, MSS = 1500 bytes

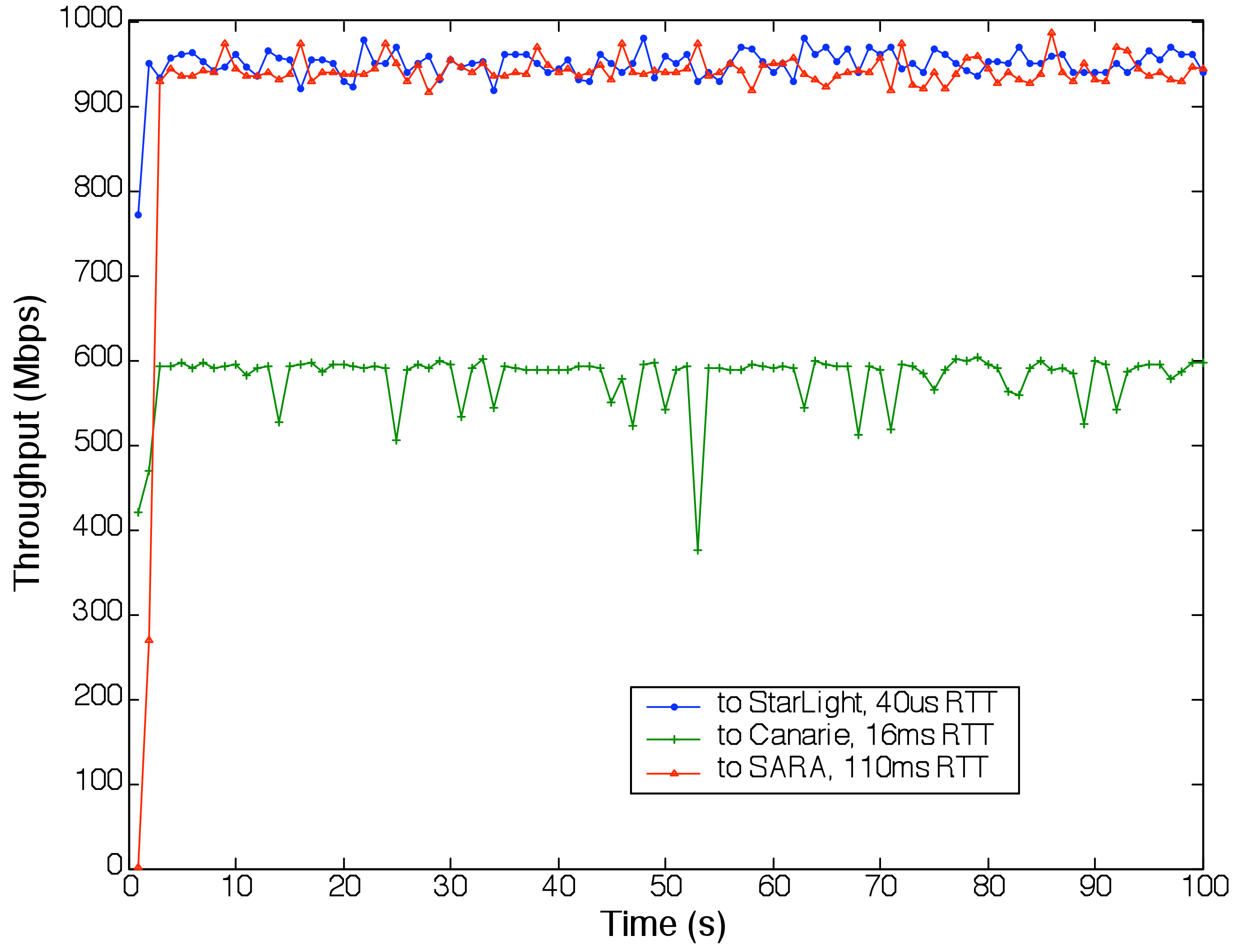
C (Mbps)	B - C (Mbps)	Increase Param. (Pkts)
[0, 9000)	(1000, 10000]	10
[9000, 9900)	(100, 1000]	1
[9900, 9990)	(10, 100]	0.1
[9990, 9999)	(1, 10]	0.01
[9999, 9999.9)	(0.1, 1]	0.001
9999.9+	<0.1	0.00067

Flow Control

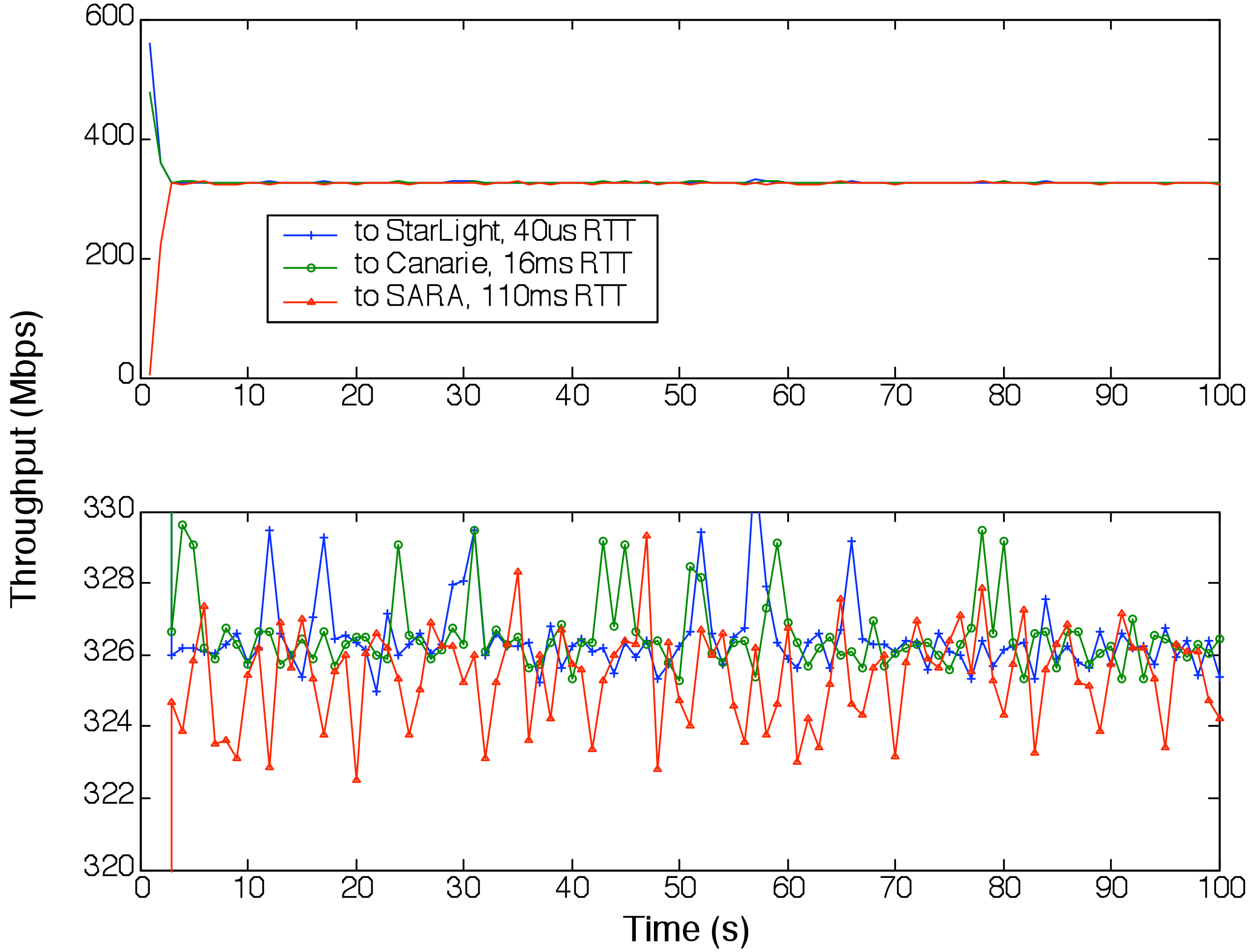
BDP

- W = W*0.875 + *AS**(RTT+ATP)*0.125
- ATP is the ACK timer period, which is a constant of 0.01 seconds.
- *AS* is the packets arrival speed at receiver side.
  - The receiver records the packet arrival intervals. *AS* is calculated from the average of latest 16 intervals after a median filter.
  - It is carried back within ACK.

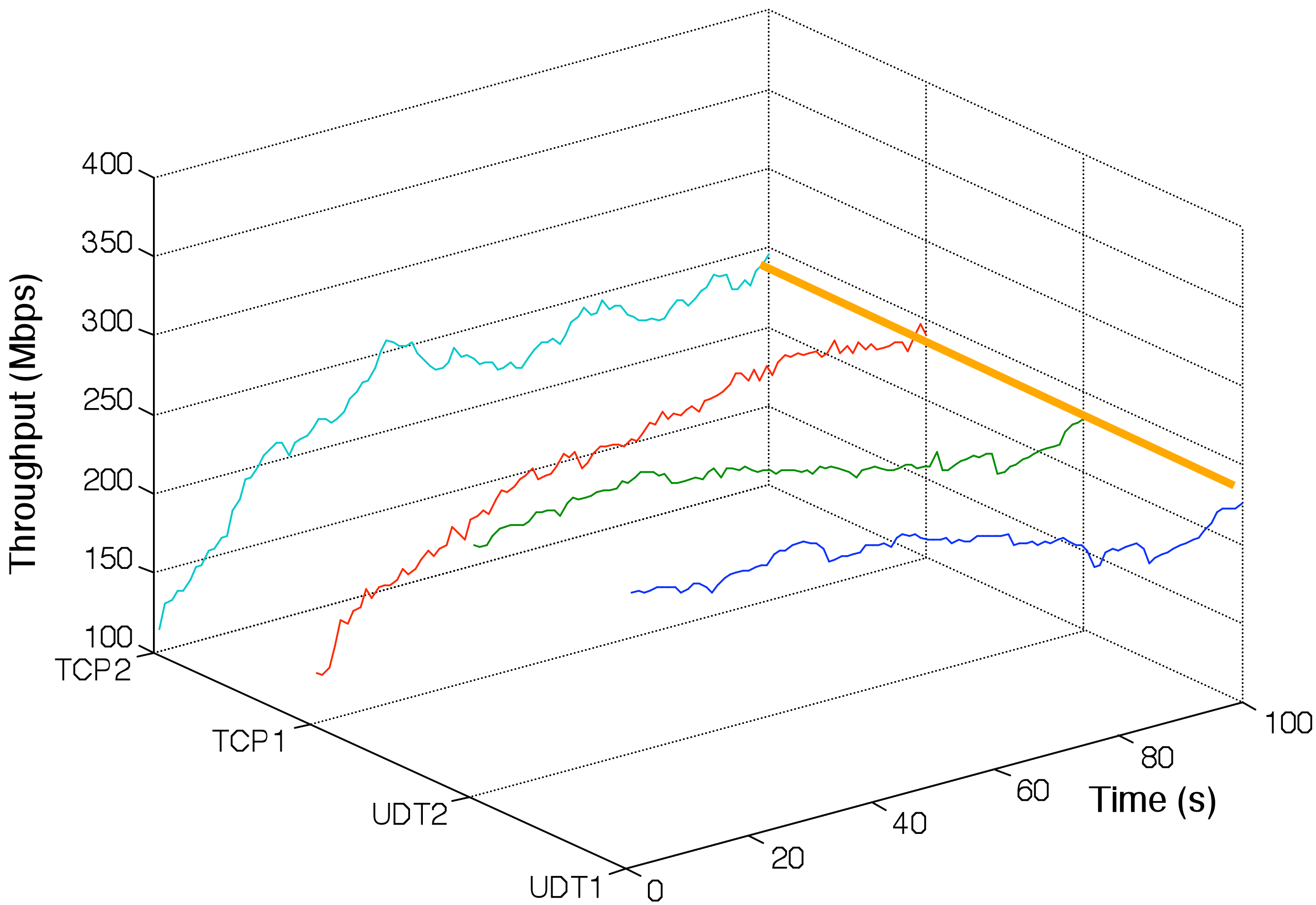
Implementation: Performance



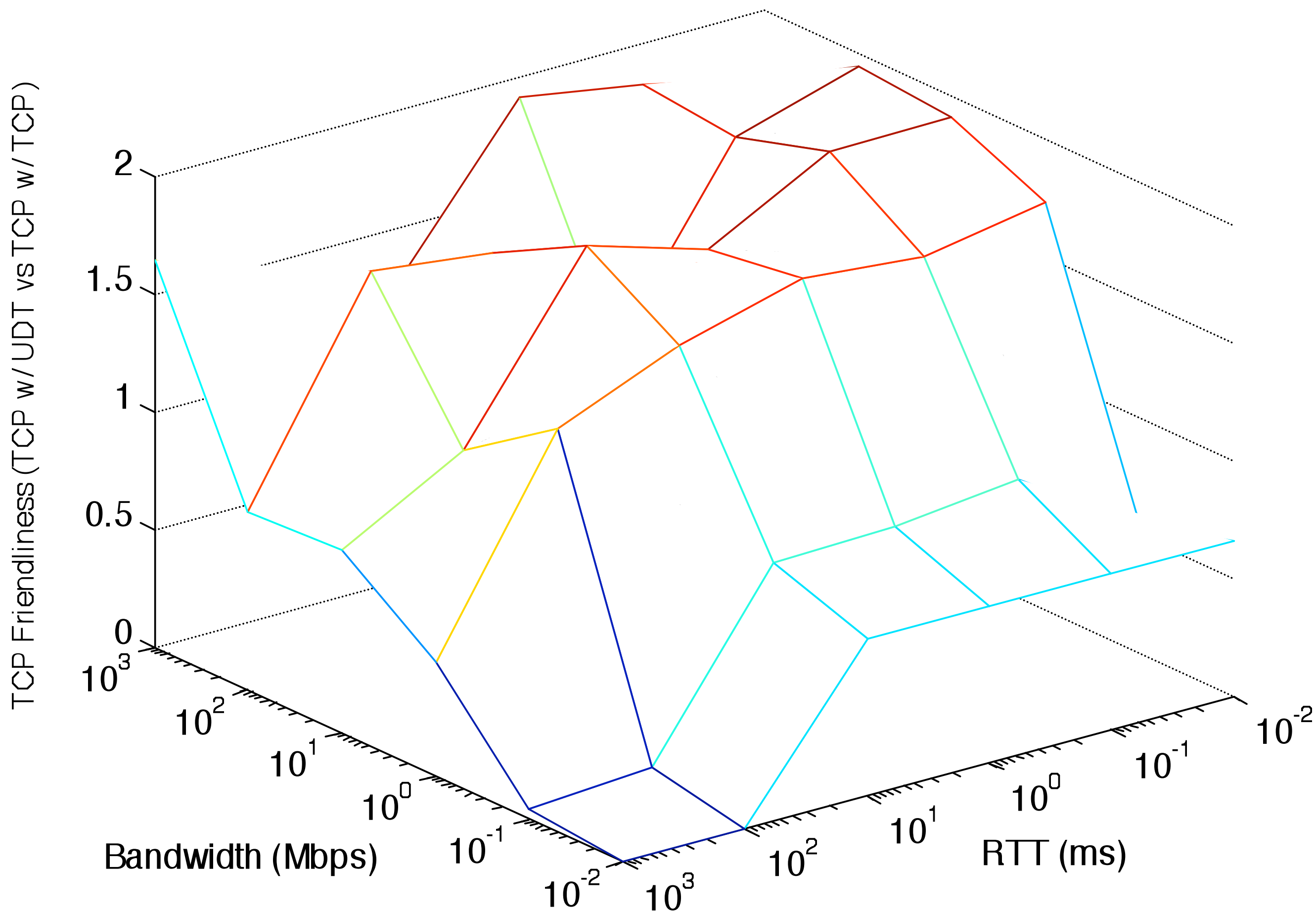
Implementation: Intra-protocol Fairness



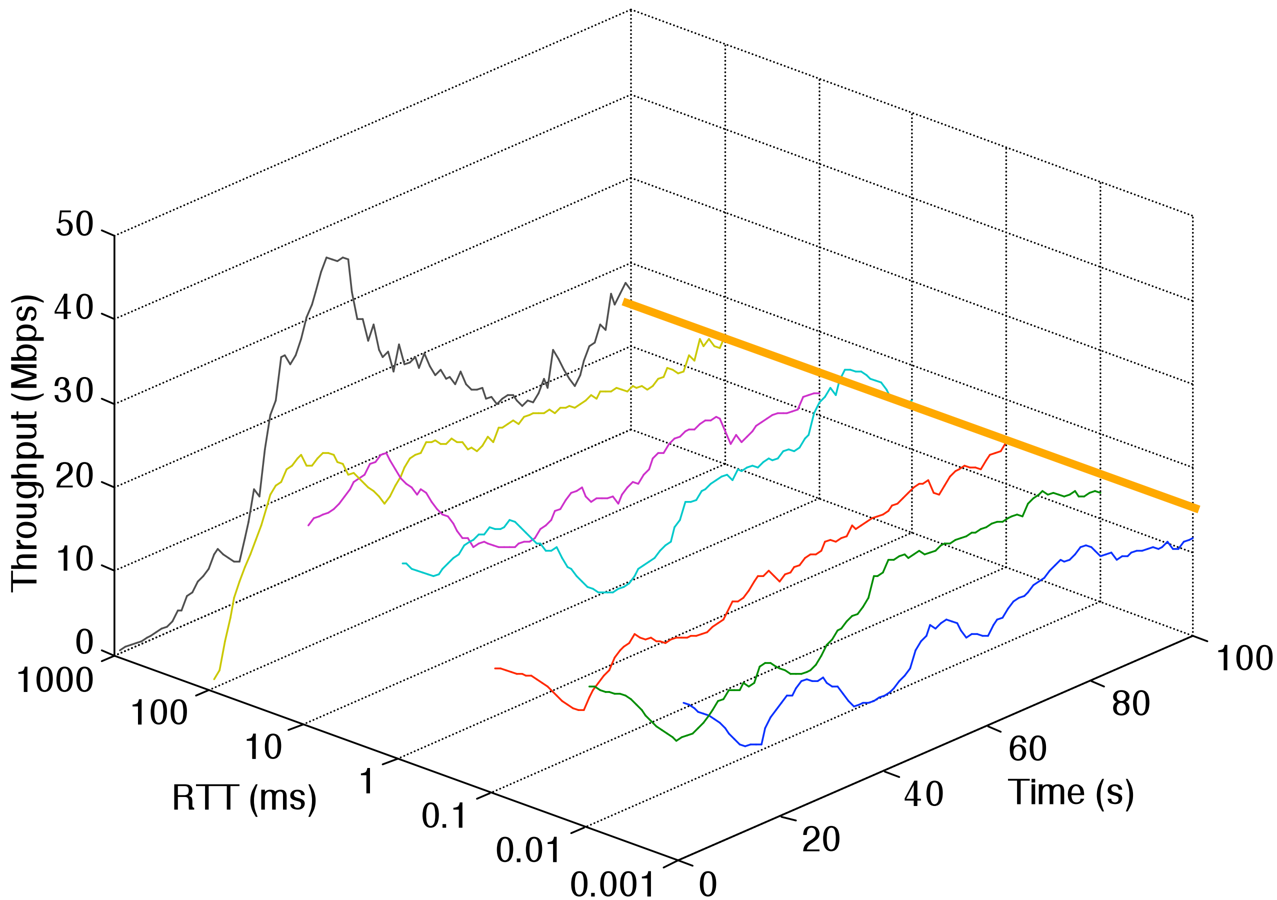
Implementation: TCP Friendliness



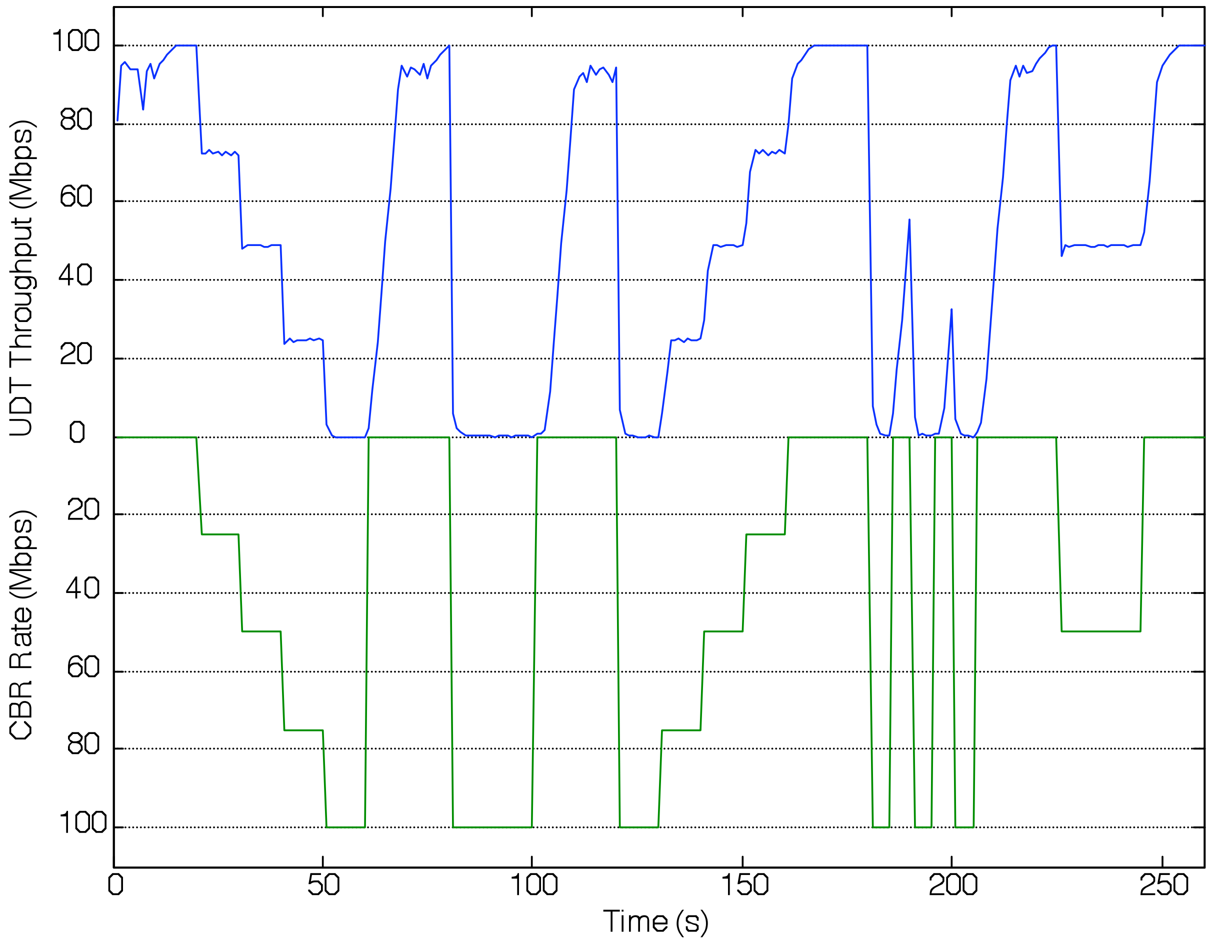
Simulation: TCP Friendliness



Simulation: RTT Independence



Simulation: Convergence/Stability



For More Information

- LAC: www.lac.uic.edu
- Internet Draft: draft-gg-udt-xx.txt
- UDT: sourceforge.net/projects/dataspace

Implementation Experiences of UDT Driver for Globus XIO

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Globus XIO

- Extensible input/output library for the Globus toolkit®.
- Simple intuitive open/close/read/write API.
- Provides a driver development interface.
- Framework takes care of non-protocol ancillary requirements such as error handling etc.
- As Globus XIO has a built in UDP driver, the framework assists greatly in developing reliable layers on top of UDP.
- More details can be found at http://www-unix.globus.org/developer/xio

Improvements Made to UDT

- To make UDT closely resemble TCP, developed server interface to handle multiple connection requests
- Server listens on a known port for receiving connection requests
- Upon receiving a request, a new socket created and the port information communicated to the client

Improvements Made to UDT (cont.)

- Client establishes a new connection to this port for data transfer
- Introduced some changes to the handshake mechanism
- Requirements that we had
  - Receiver not expected to know the transfer size.
  - Sender does not communicate the transfer size to the receiver.

Improvements Made to UDT (cont.)

- Completion of transfer intimated by closing UDT
- Had to introduce a close state machine into the protocol
- Included new control messages for close handling

Performance

- Initial results
  - Average throughput of 97 MBps on a GigE LAN
  - Average throughput of 33 MBps over the wide area link from ANL to LBL (bottleneck is OC12 link)
  - Throughput over the wide area link is low compared to the throughput achieved by the UIC implementation

Performance (cont.)

- Exploring the cause for the difference in performance
- Known differences
  - Used non threaded flavor of Globus
  - Smaller protocol buffer
  - Driver operates on vectors as opposed to buffers