
NORTHROP GRUMMAN
NASA
DRYDEN FLIGHT RESEARCH CENTER

Multi-channel combining for Airborne Flight Research

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Outline

- Motivation
- Multilink Point-to-Point Protocol Multilink (ML-PPP)
- Multi-Path TCP (MP-TCP)
- Approach
- Testbeds
- Initial Results
  - Settings
  - Caveats

Motivation

- Improve the reliability of channel bonding and thereby eliminate problems associated with communications dropouts and improve the operational efficiency of airborne science missions.
  - Iridium Satcom 4 channels at 2.4 kbps (9600 bps total!)
- Use of TCP (remote login, file transfers, etc…) over current system is problematic due to modem dropouts.
- Plain-Old-Telephone-Service (POTS) is going away.
- Enable newer technologies (radios) to be easily integrated into the NASA Airborne Science Data Acquisition and Transmission unit (*NASDAT*)

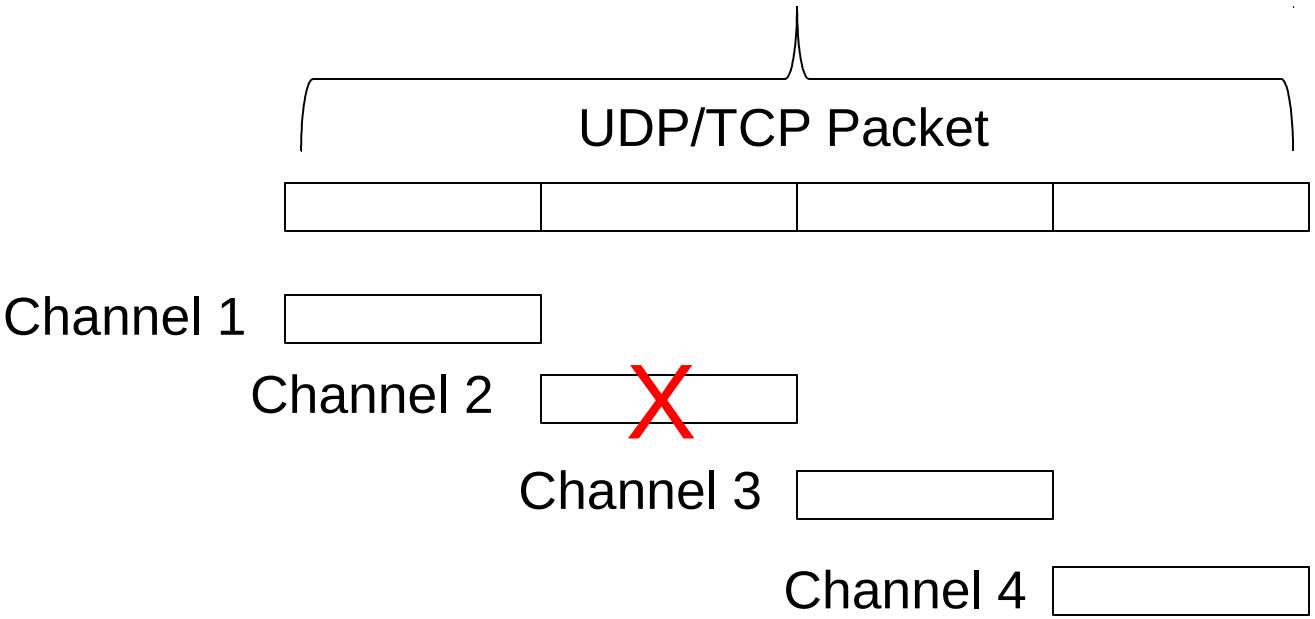
Multilink Point-to-Point Protocol

- Current solution to the channel multiplexing problem.
- Hypothesis: ML-PPP fragments UDP/TCP over multiple channels. Thus, when one modem fails, UPD/TCP protocol is heavily effected.
  - Kernel option to not fragment, but not implemented in NASA deployment
  - TCP more so due to TCP backoff and congestion control mechanisms.
- Characterizing Iridium modems, simulation and emulation in the research testbed will validate (or invalidate) this hypothesis.

ML-PPP

Problem

- Nothing gets through while any modem is down for UDP or TCP
- TCP Congestion Control:
  - Lost Sub-Packet = lost packet
    - Half rate (not really a problem at super low rates)
    - Backoff retransmission timer
      - generally exponential backoff with some limit (e.g. 64 seconds)



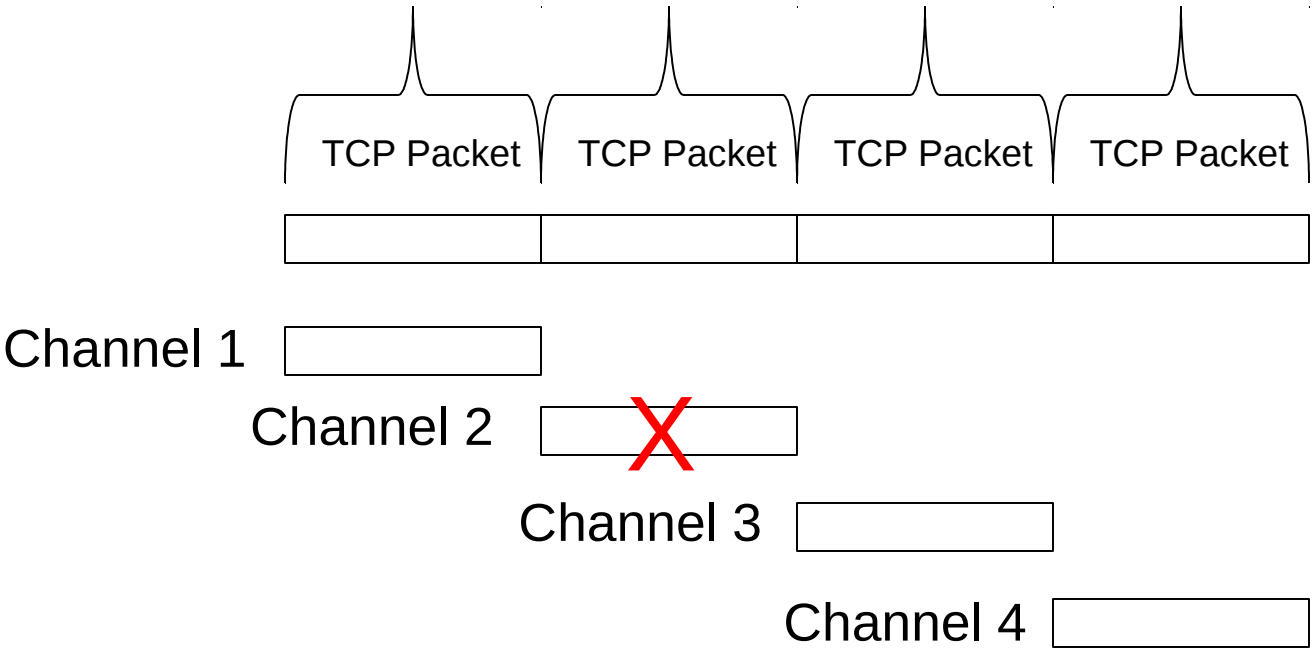
MP-TCP

- Multipath TCP (MPTCP) is a set of extensions to regular TCP to provide a Multipath TCP service, which enables a transport connection to operate across multiple paths simultaneously
- Provides a bidirectional byte stream between two hosts communicating like normal TCP, and, thus, does not require any change to the applications.
- Enables the hosts to use different paths with different IP addresses to exchange packets belonging to the MPTCP connection.
- The number of subflows that are managed within a Multipath TCP connection is not fixed and it can fluctuate during the lifetime of the Multipath TCP connection.

MPTCP

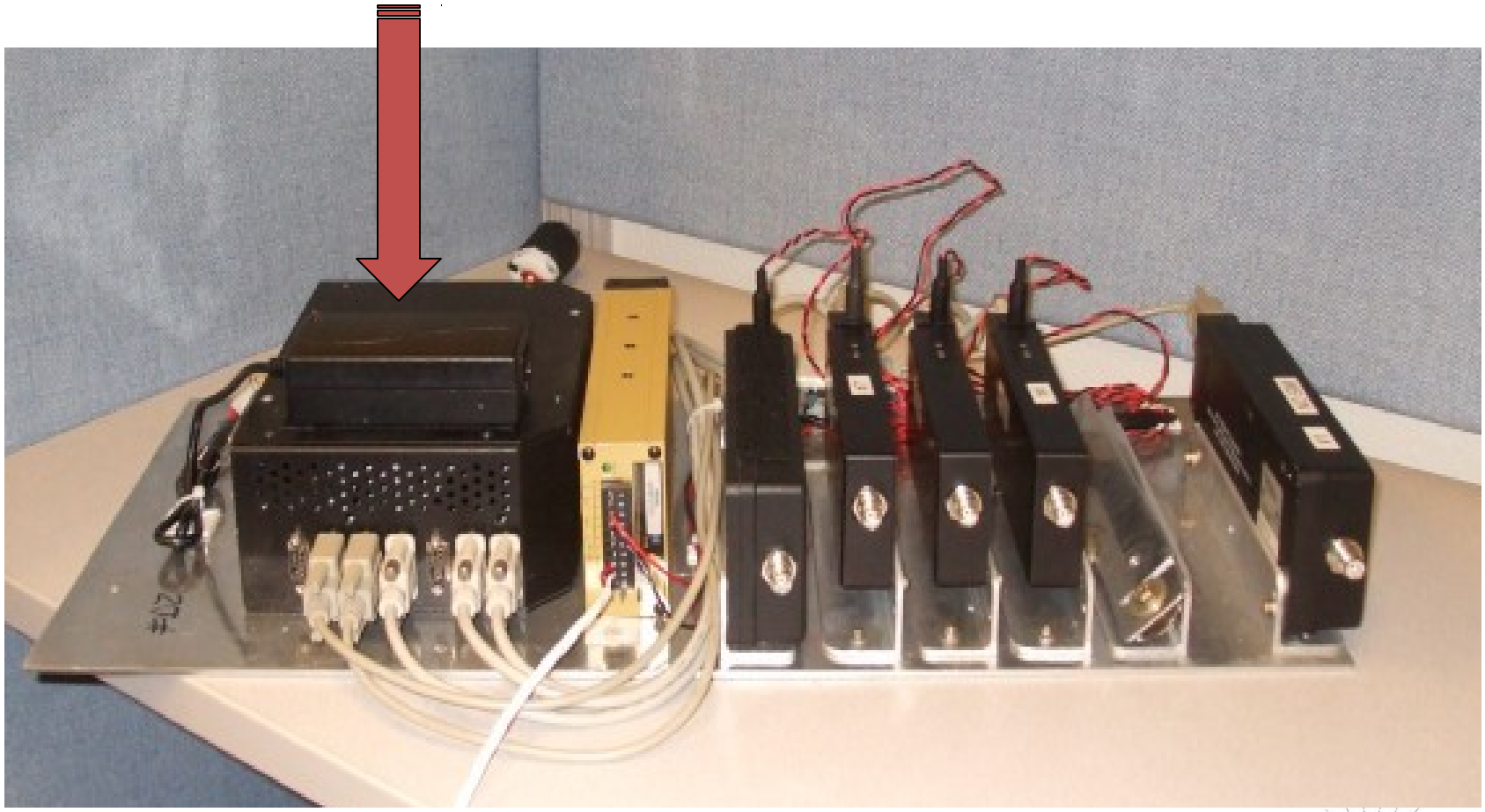
Solution

- MPTCP creates 4 subflows, one per channel
- Channels 1,3 and 4 get through even if modem 2 has drops.

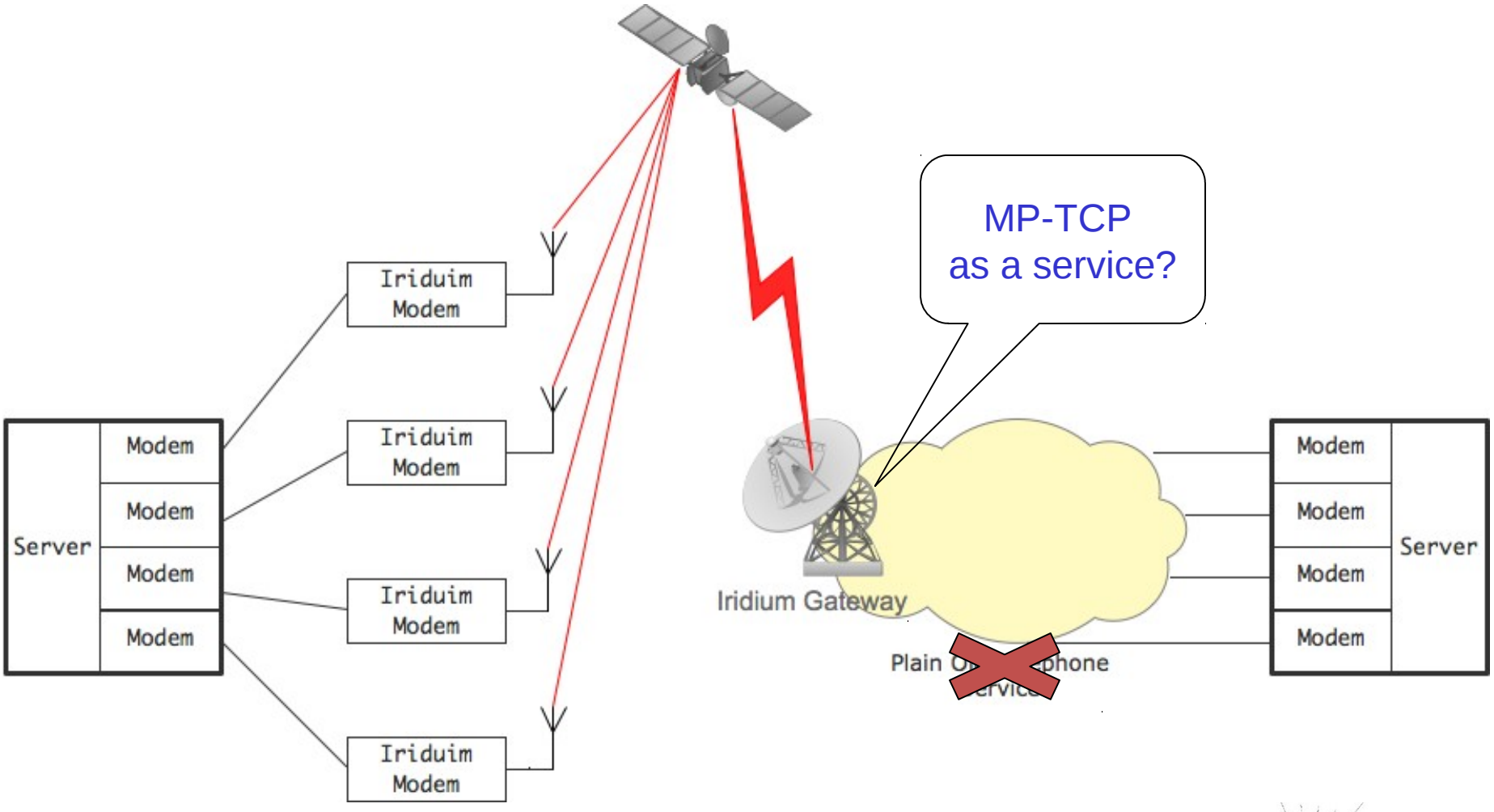


Channel Bonding 4 Iridium Modems

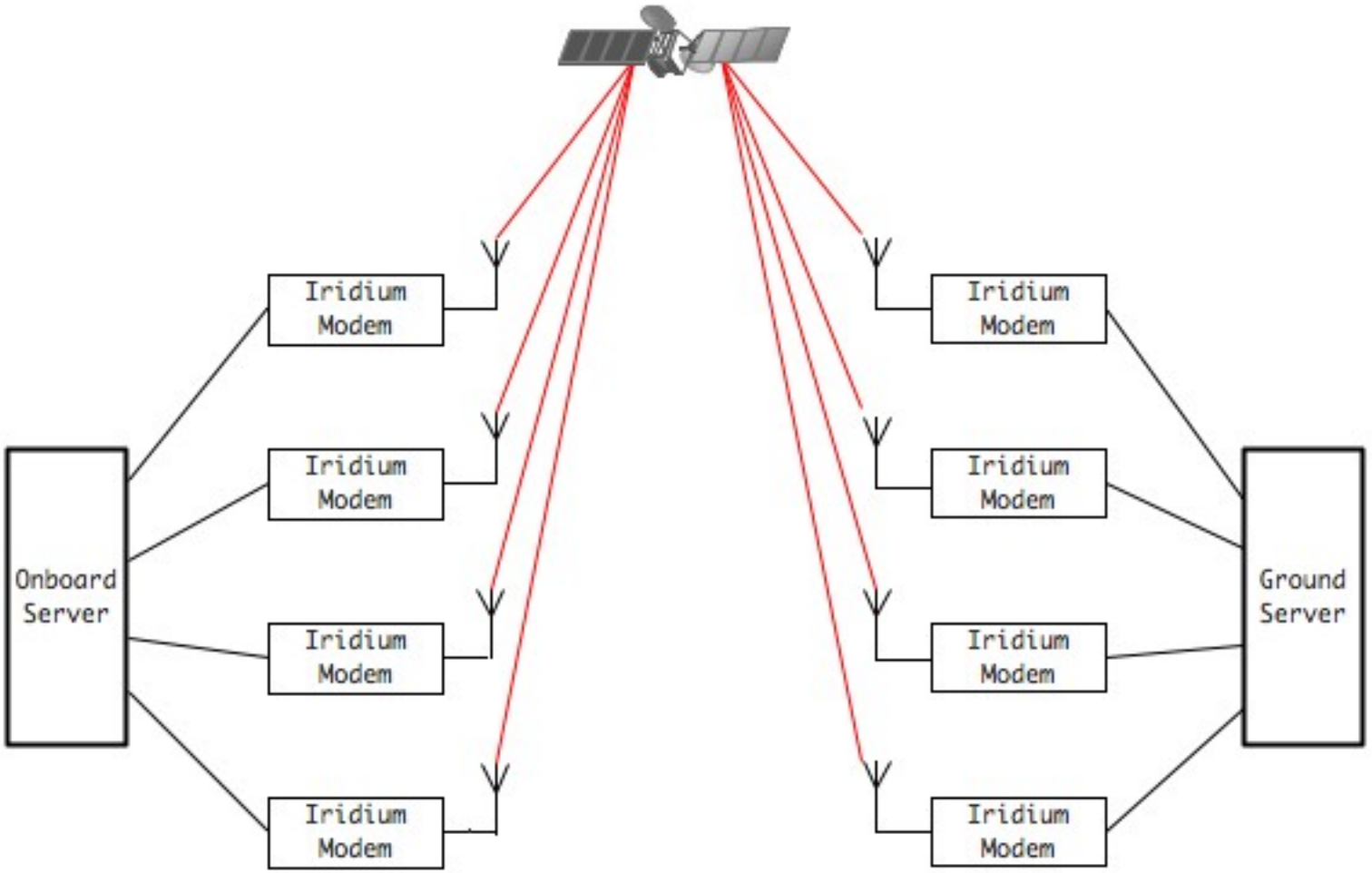
Change Software, not Hardware!



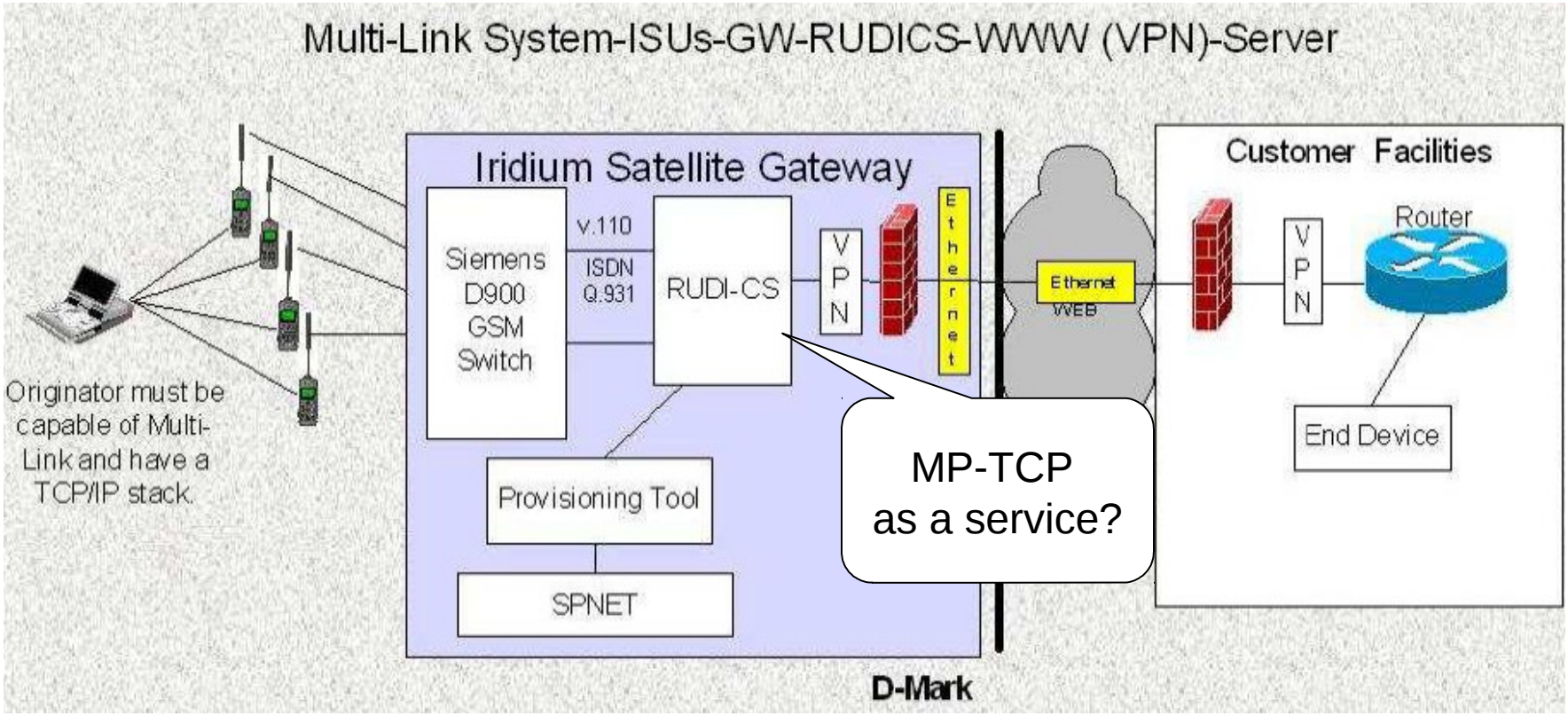
Iridium to Ground Station



Iridium to Iridium



RUDICS - Router-Based Unrestricted Digital Internetworking Connectivity Solutions



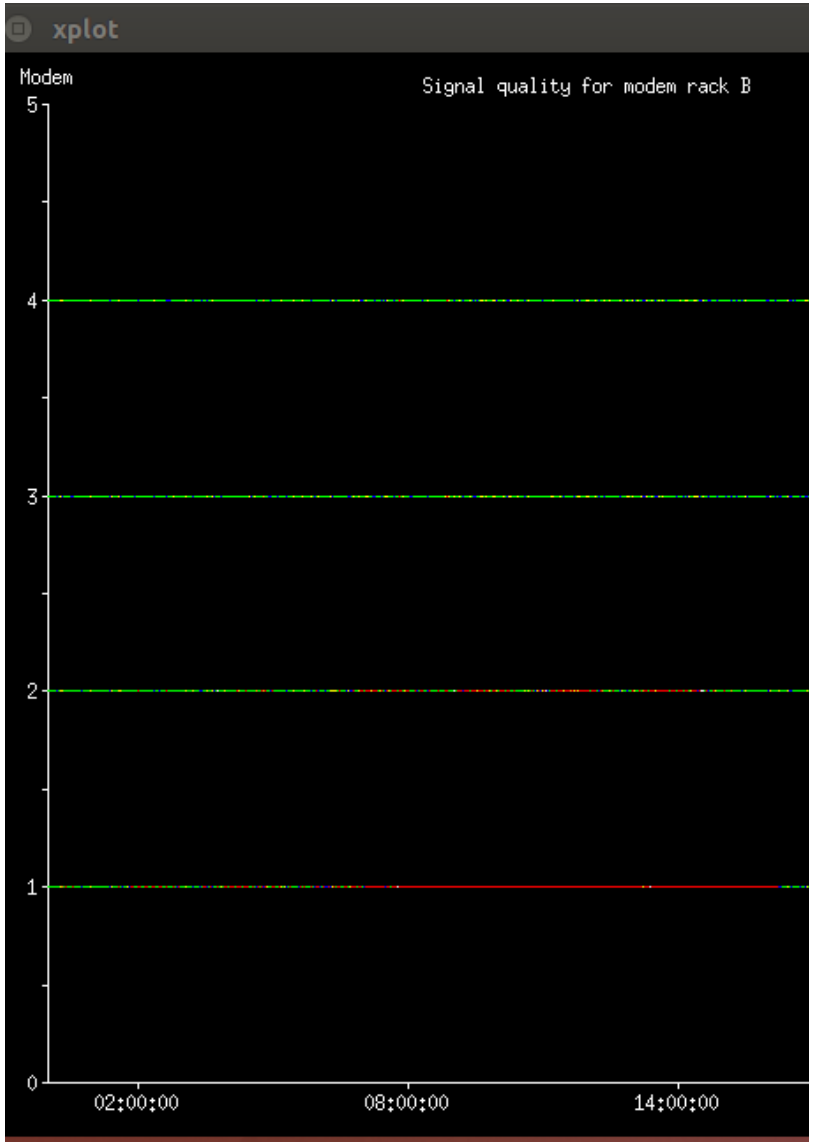
Engineering Testbed

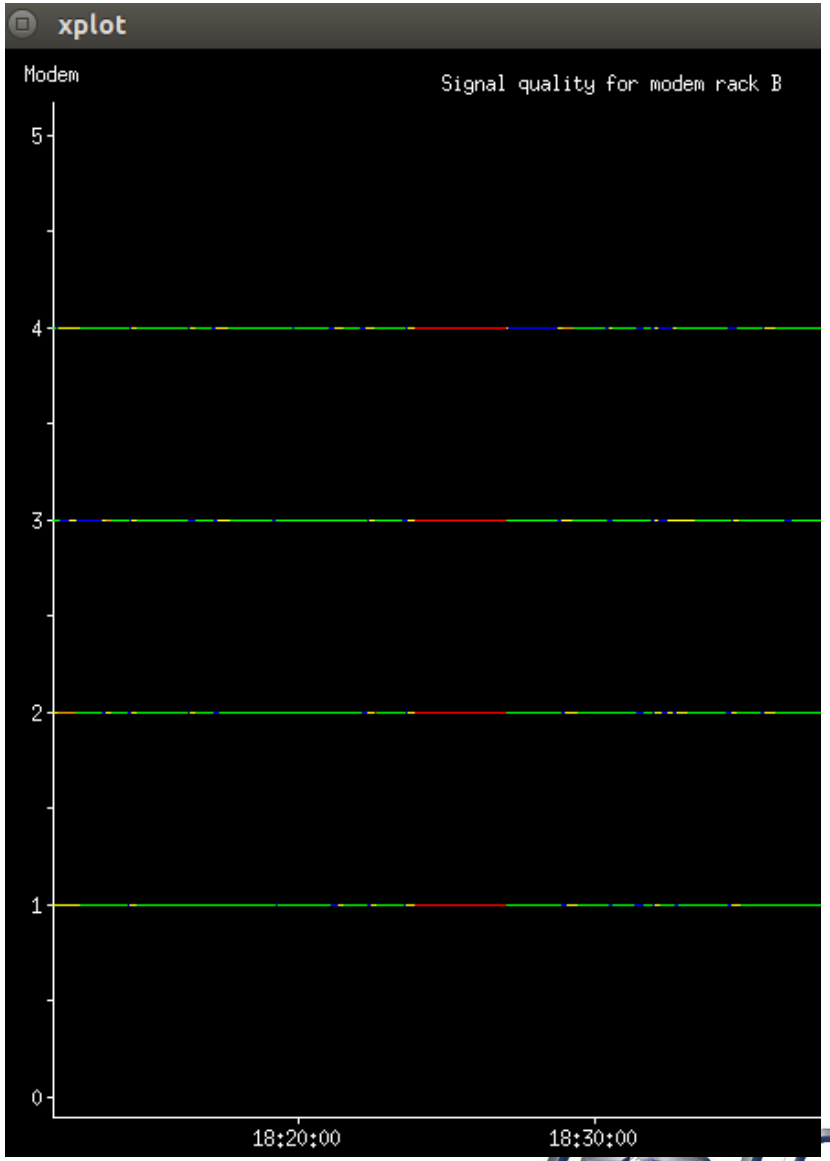
Antennas

Indoor Unit

Modem Performance

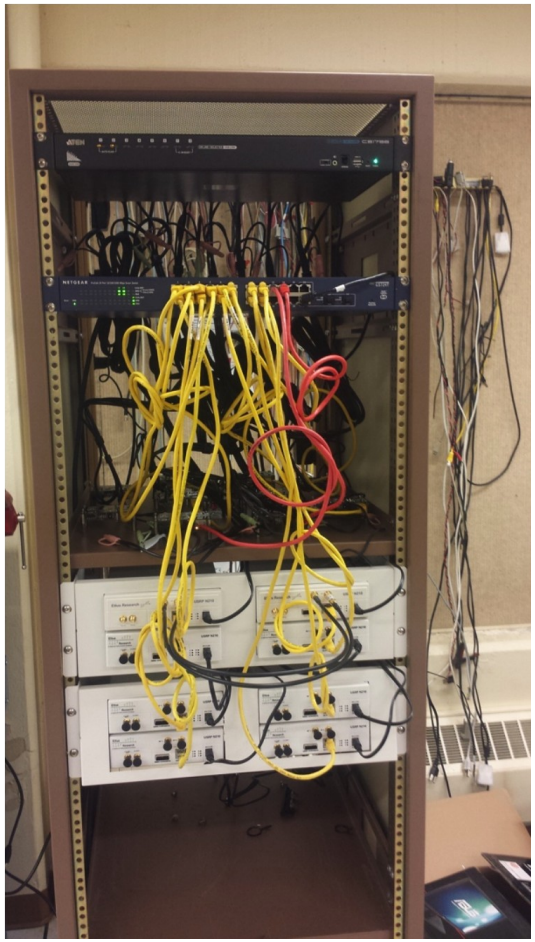
(Green is good, Red is bad)





MP-TCP and TCP Observations
(Data taken on Research Testbed)

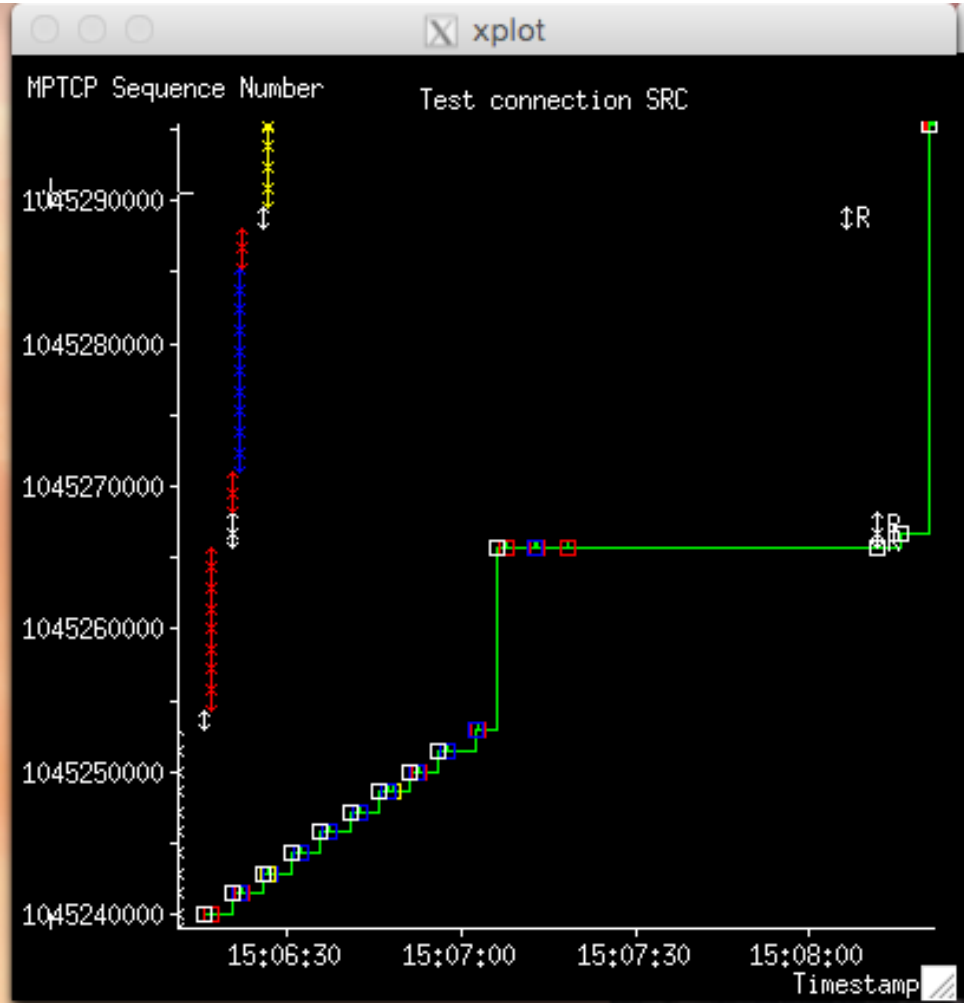
- Smaller MTUs result in smaller queues, greater likelihood of packet getting over radio, smaller RTTs and smaller RTO.
- For V0_87, at low-rates, noticed TCP periodically gets in a situation were Acks not returned for a number of packets at which point RTO can get large which becomes a problem if a packet is lost.
  - Is this bug in TCP implementation?
  - ARM vs Intel architecture build?
  - Related to congestion control algorithms?
- Problem resolved with V0_90 using Balias.



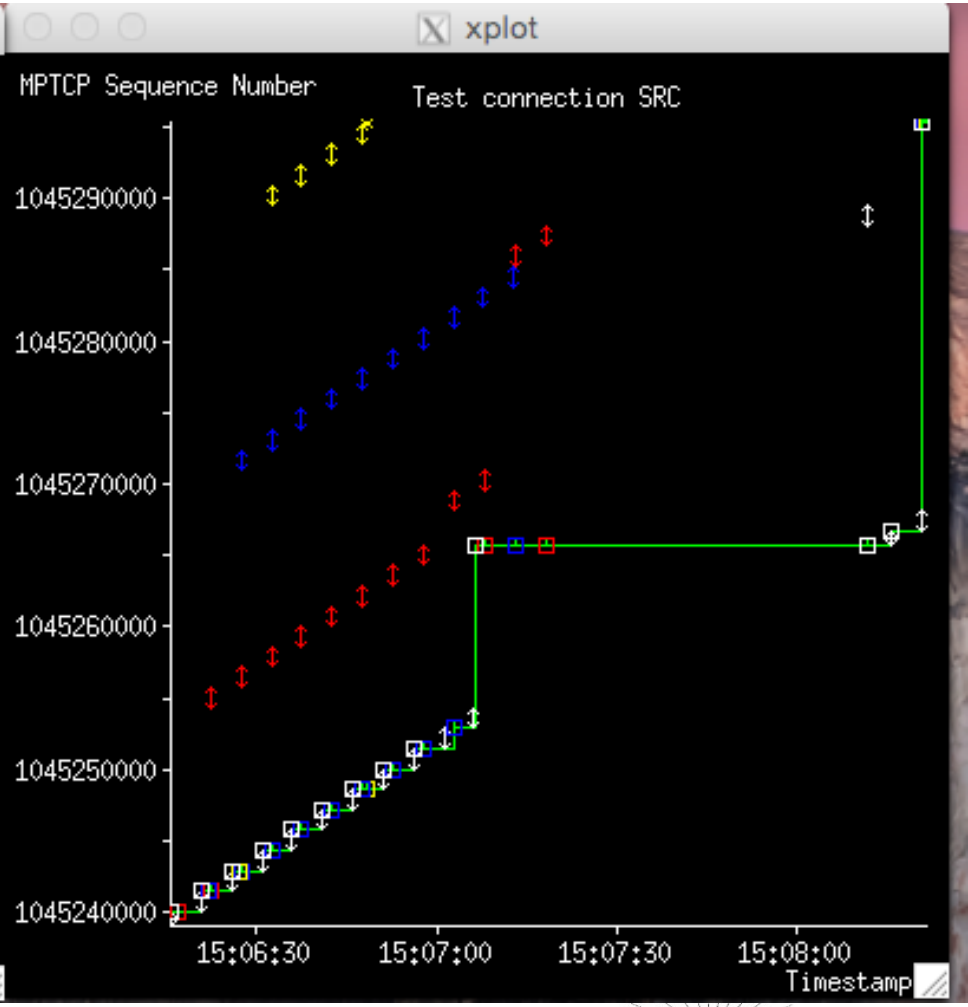
TCP Performance

(v0_87 CUBIC, 4 links, initial window size = 10)

Sender



Receiver



TCP Performance

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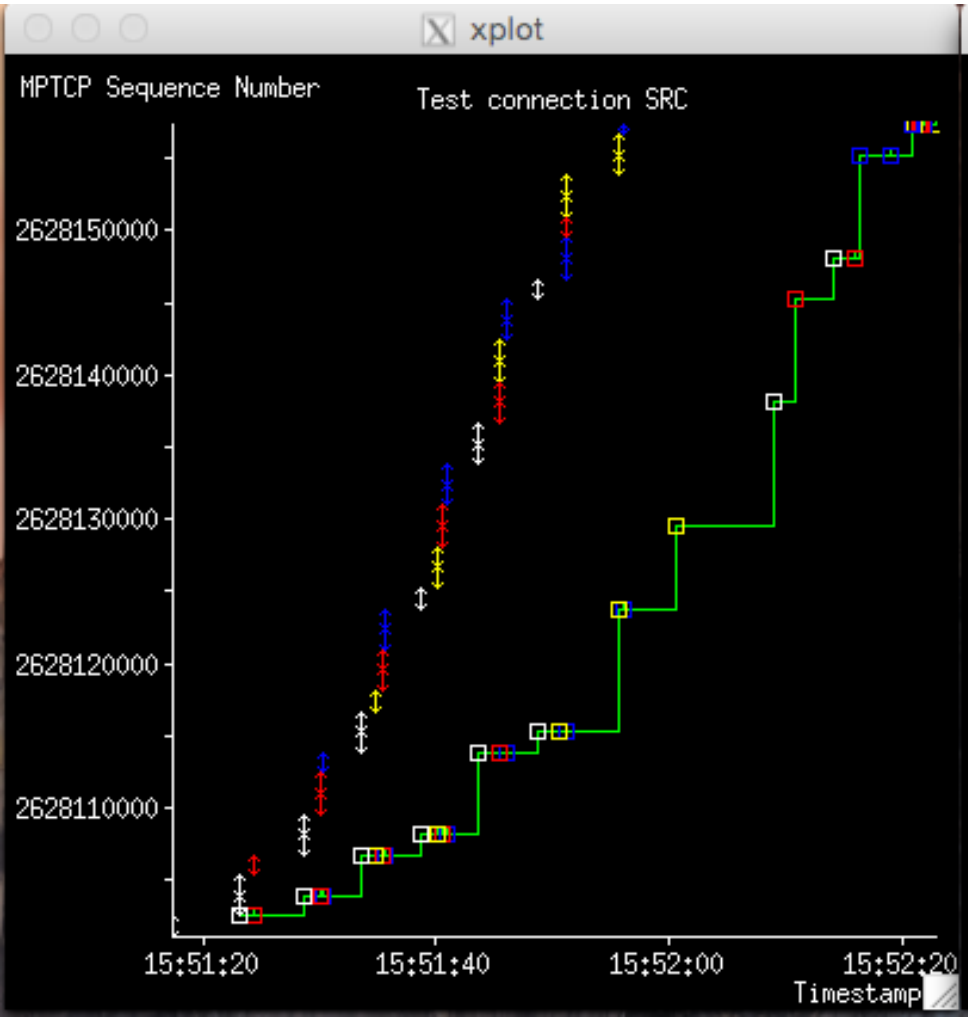
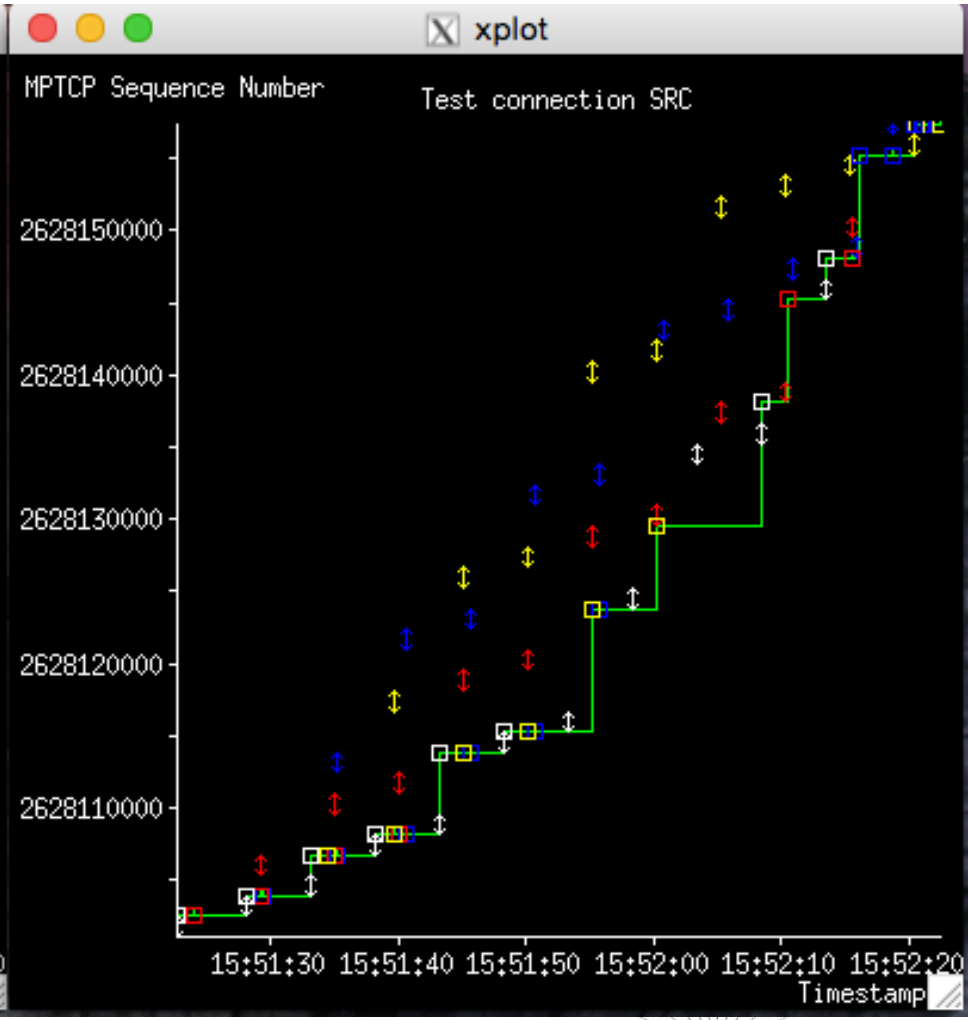
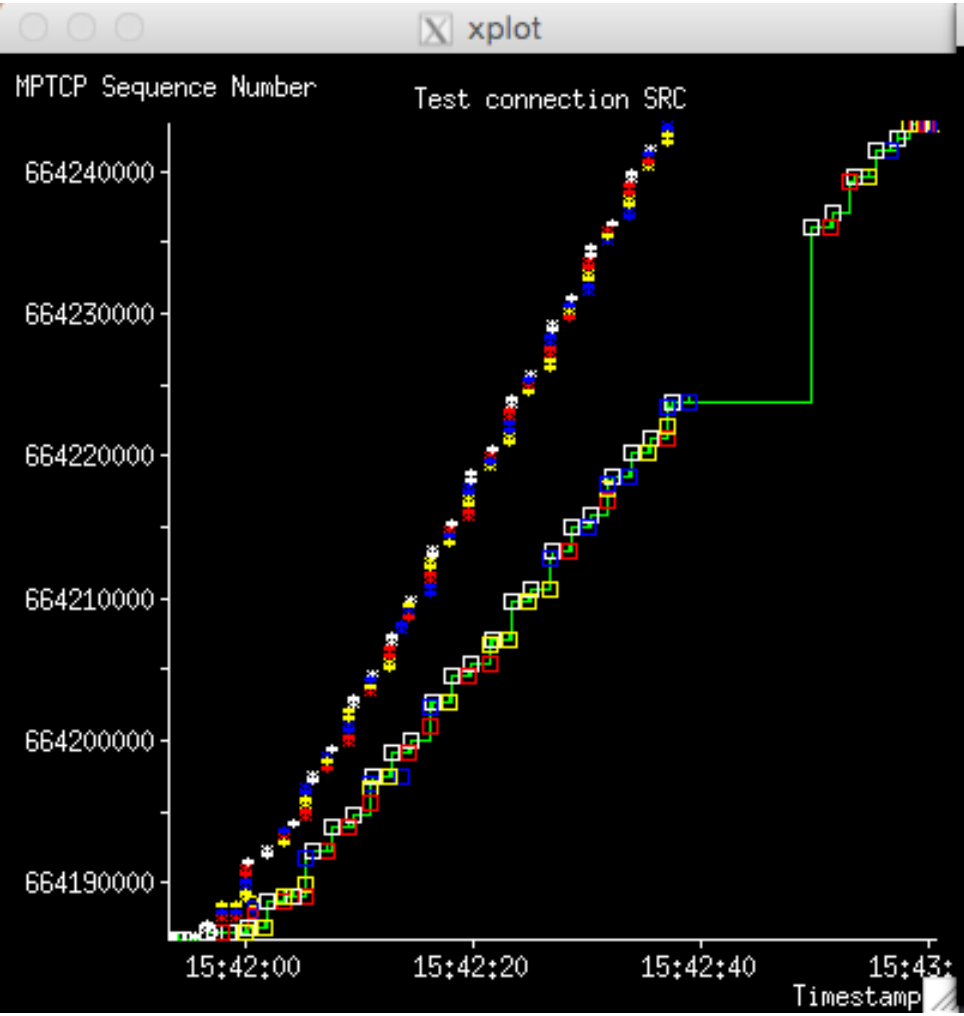


Receiver

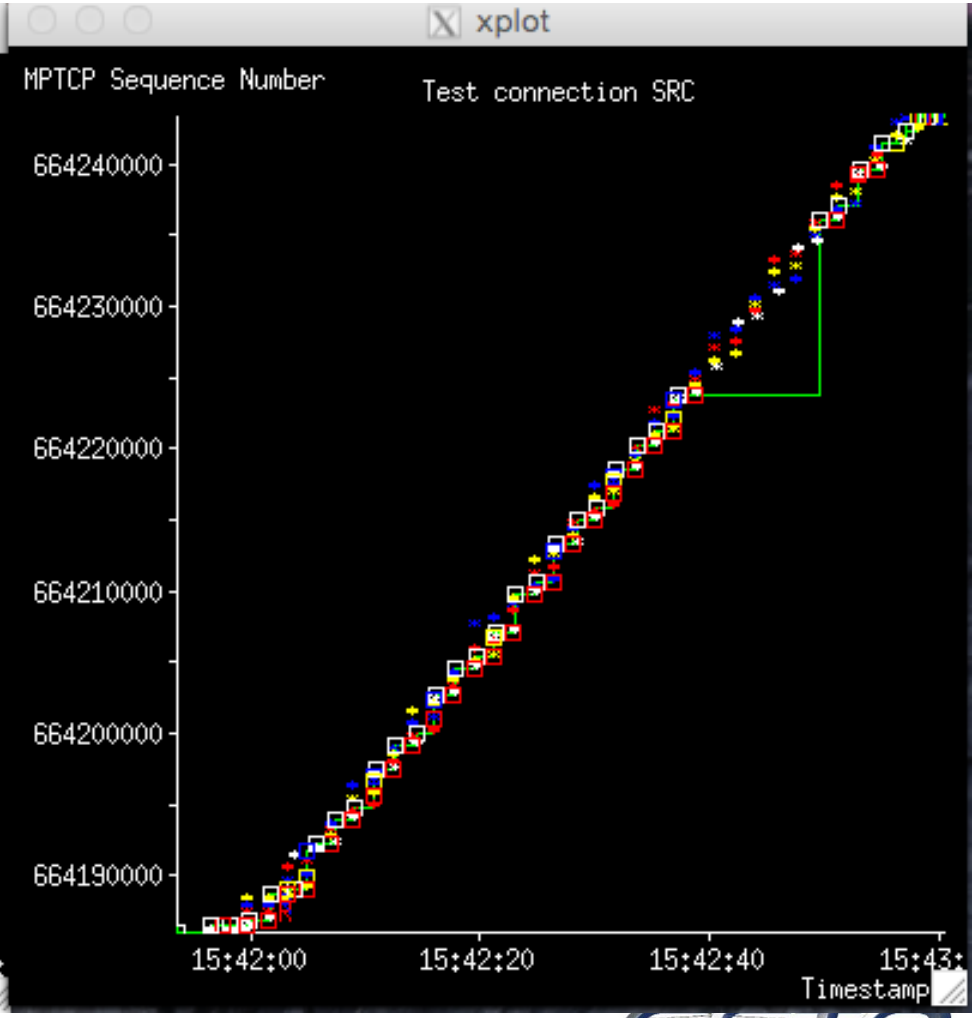


TCP Performance
(v0_90 CUBIC, 4 links, MTU=512)

Sender



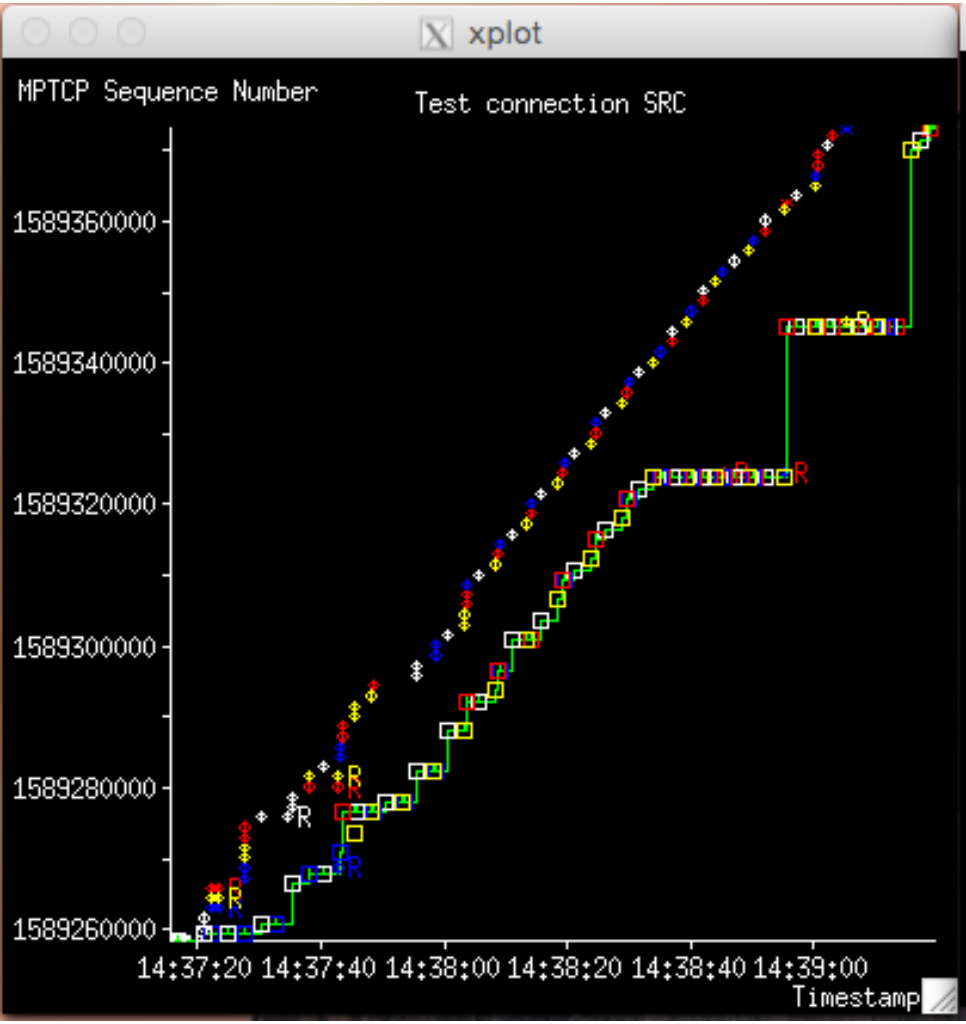
Receiver



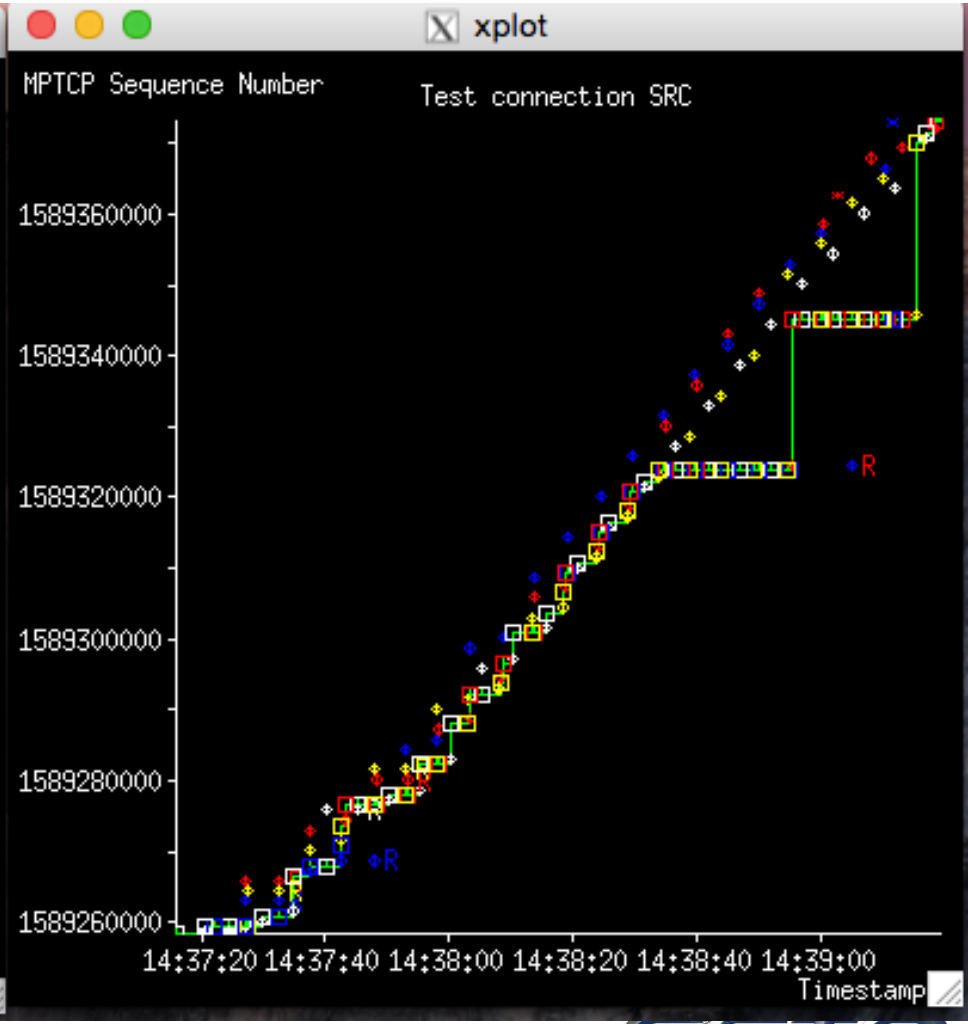
TCP Performance

(v0_90, Balia, 4 links, MTU=1500)

Sender



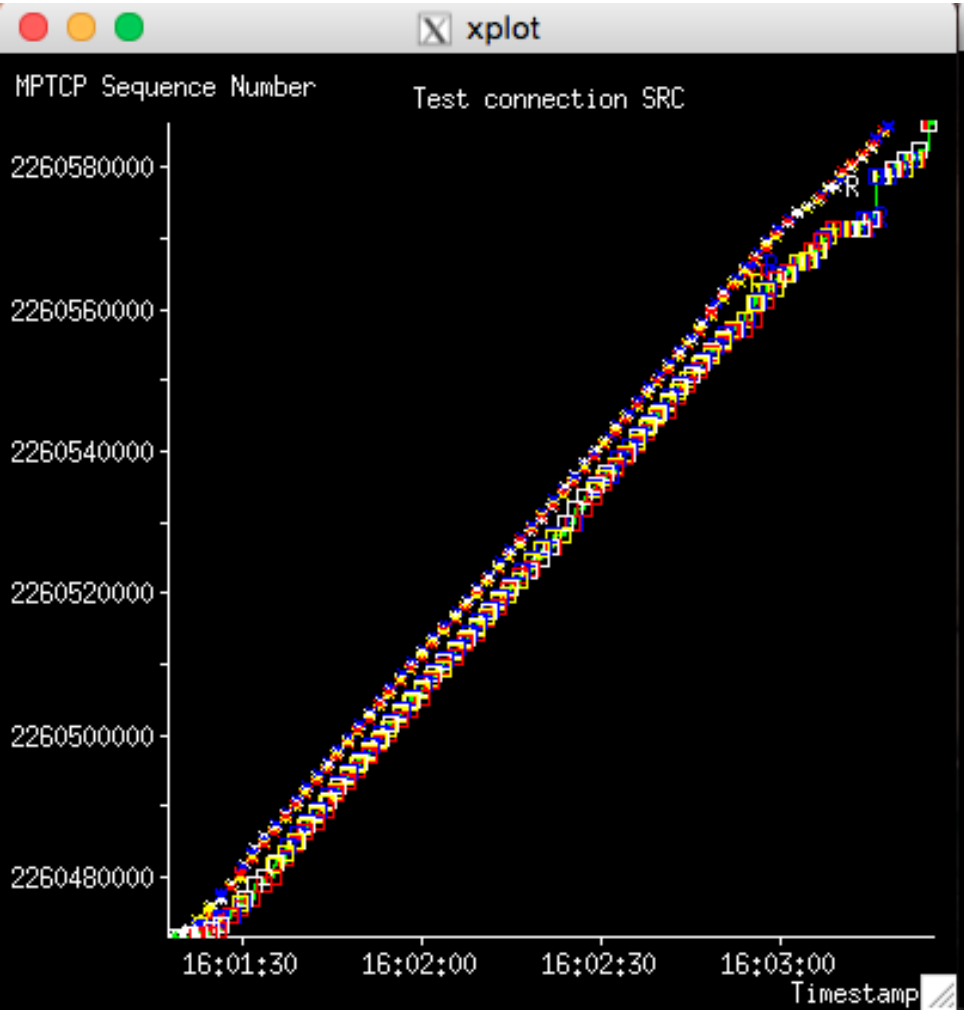
Receiver



TCP Performance

(v0_90, Balia, 4 links, MTU=512)

Sender



Receiver