Putting the "Ultra"in UltraGrid: Full rate Uncompressed HDTV Video Conferencing

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Outline

- The UltraGrid System

- Beyond 1 Gbps

- Experimentation

  - Lab Experiments
  - Network Experiments

- Summary

The UltraGrid System

- UltraGrid is ultra-high quality video conferencing tool
  - Supports uncompressed High Definition TV video formats
  - Video codecs: Digital Video (DV)
  - Incurs minimum latency
  - Adaptable to network conditions

- Not solely a video conferencing tool:
  - HDTV distribution system for editing purposes
  - A general purpose SMPTE292M-over-IP system
  - High-definition visualization and remote steering applications

Approach

- Build a system that can be replicated and built by other HDTV enthusiasts:
  - Use hardware that is commercially available
  - All audio and video codecs are open source
  - Use standard protocols:
    - Real-time Transport Protocol (RTP)
    - Custom payload formats and profiles where necessary
  - Software available for download

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Beyond 1 Gbps

- We have previously successfully demonstrated UltraGrid at ~1Gbps
  - Supercomputing 2002
  - Video is down sampled at the sender:
    - Color is down sampled from 10bits to 8bits
    - Auxiliary data removed

- Why < 1 Gbps limitation?
  - limitation is the Gigabit Ethernet NIC

- Solutions:
  1. 2 Gigabit Ethernet NICs
  2. 10 Gigabit Ethernet NIC

The (new) UltraGrid node

- 10 Gigabit Ethernet NIC:
  - T110 10GbE from Chelsio: http://www.chelsio.com/
  - 133Mhz/PCI-X

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- HDTV capture card:
  - Centaurus HDTV capture card from www.dvs.de
   - same SDK as HDstation
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- HDTV capture card:
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- Dual Xeon EM64T Power Station
  - SuperMicro mother board
  - 5 programmable PCI-X slots
  - 32bit Fedora Core3 - Linux 2.6 Kernel

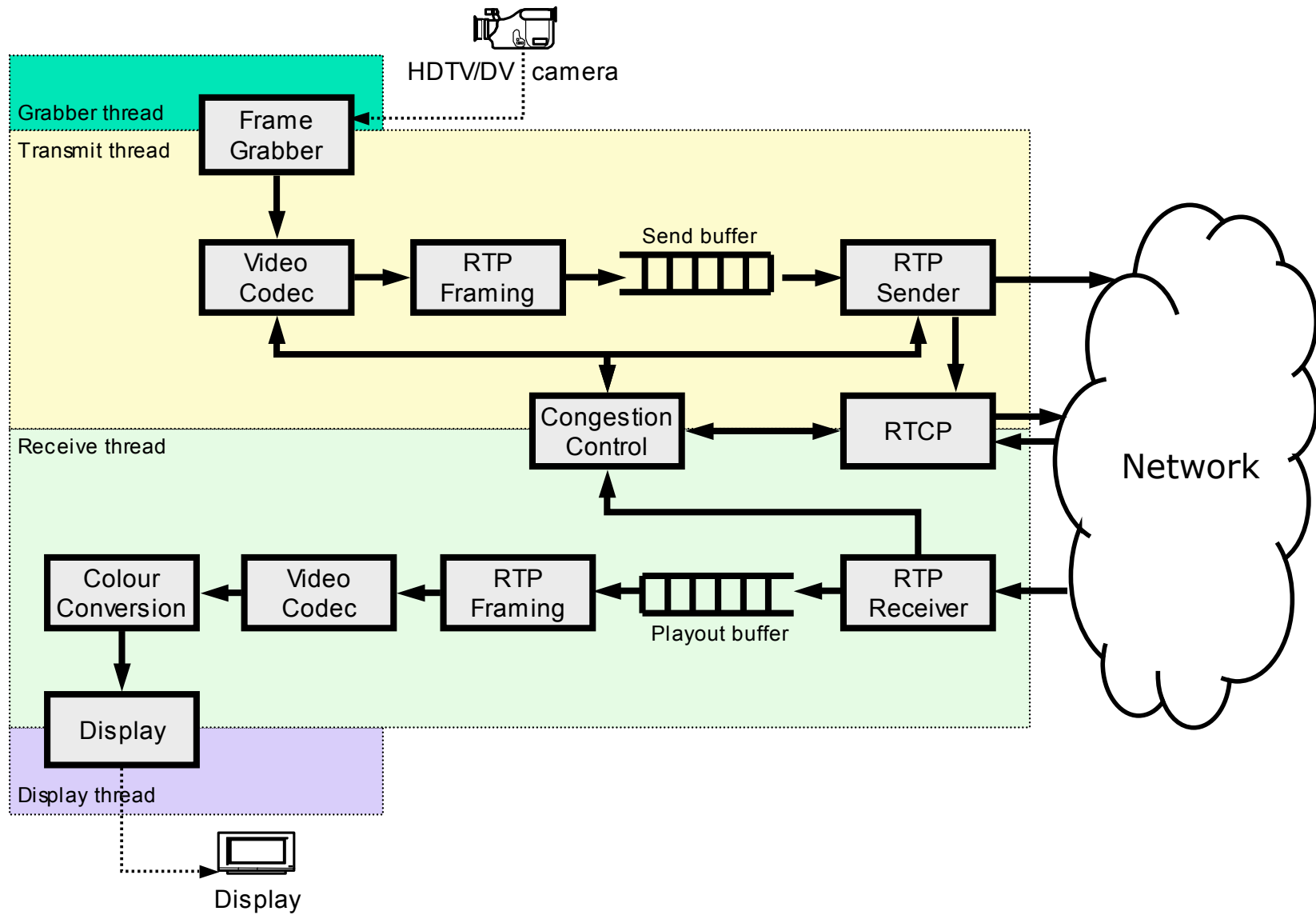# UltraGrid: Architectural Overview
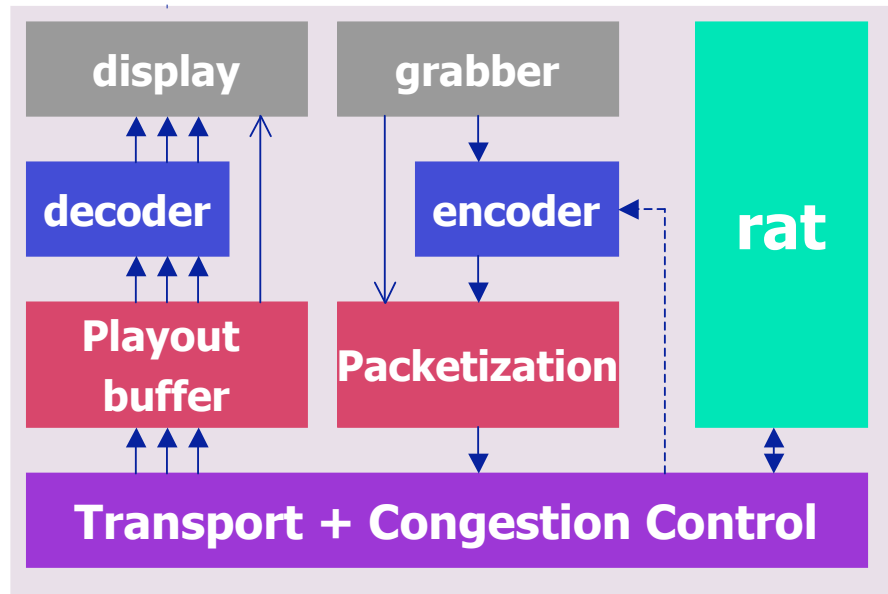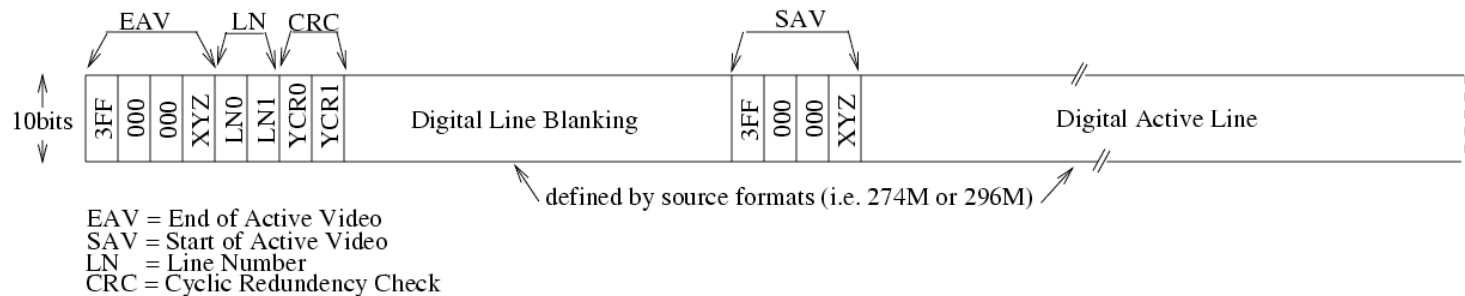

UltraGrid Node

An open and flexible architecture with "plug-in" support for codecs and transport protocols:

- Codec Support:
  - DV, RFC 3189
  - M-JPEG, RFC 2435
  - H.261, RFC 2032

- Transport protocols:
  - RTP/RTCP
  - RFC 3550

- Congestion Control:
  - TCP Friendly Rate Control (TFRC), RFC 3448

UltraGrid: Architectural Overview

Software modifications

EAV = End of Active Video
SAV = Start of Active Video
LN = Line Number
CRC = Cyclic Redundency Check

- Both capture cards operate in 10bit or 8bit mode

- Update code to operate in 10bit mode
  - packetization must operate in 10bit mode
  - packetization is based on draft-ietf-avt-uncomp-video-06.txt
    - Supports range of formats including standard & high definition video
    - Interlaced and progressive
    - RGB, RGBA, BGR, BGRA, YUV
    - Various color sub-sampling: 4:4:4, 4:2:2, 4:2:0, 4:1:1

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- **Beyond 1 Gbps**

- **Experimentation**

  → Lab Experiments

  → Network Experiments
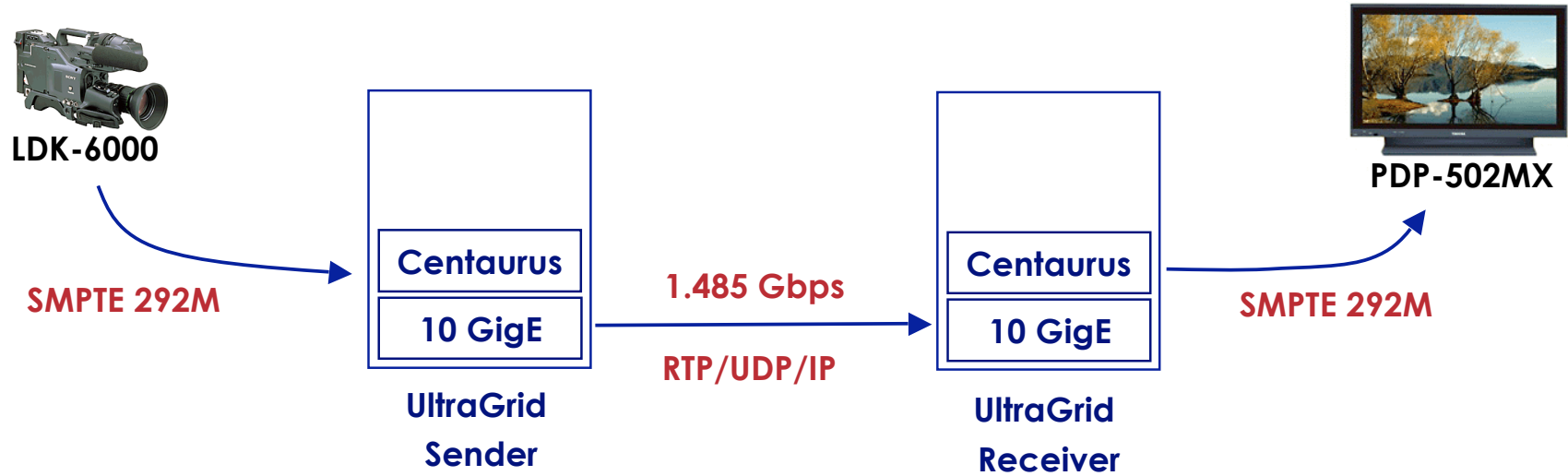
- **Summary**

Experimentation

1. Lab Tests
   - ➔ Back to back
2. Network Tests
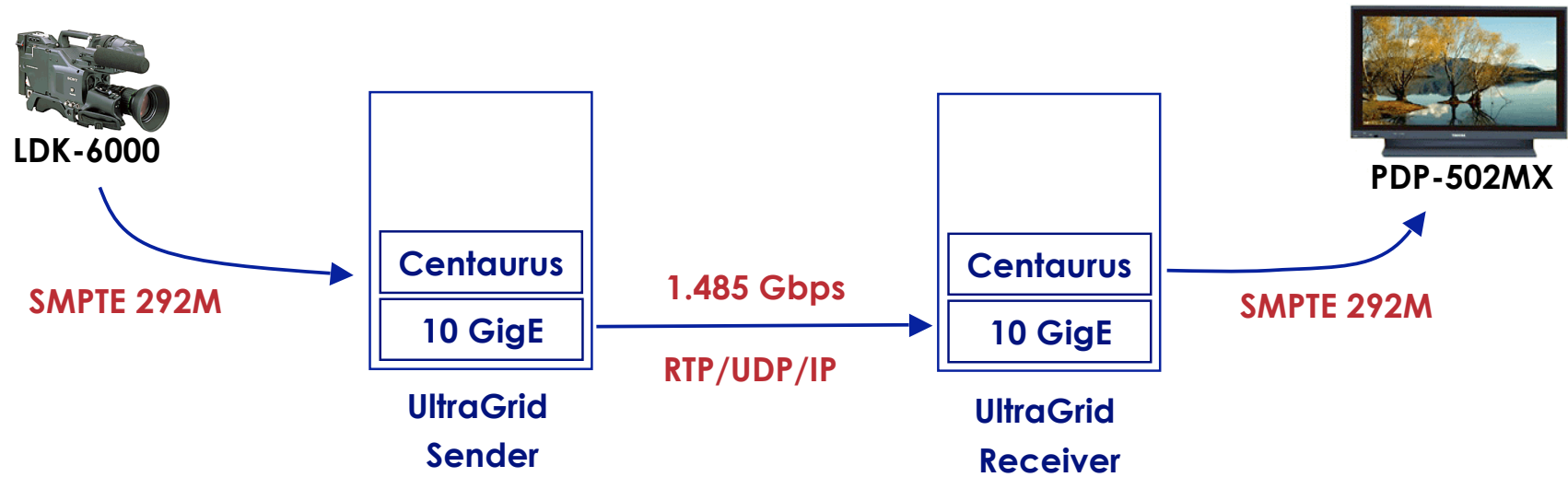   - ➔ The DRAGON Metropolitan Area Network

Measured:
- ➔ Throughput
- ➔ Packet loss and reordering
- ➔ Frame inter-display times
- ➔ Packet interarrival times at sender and receiver
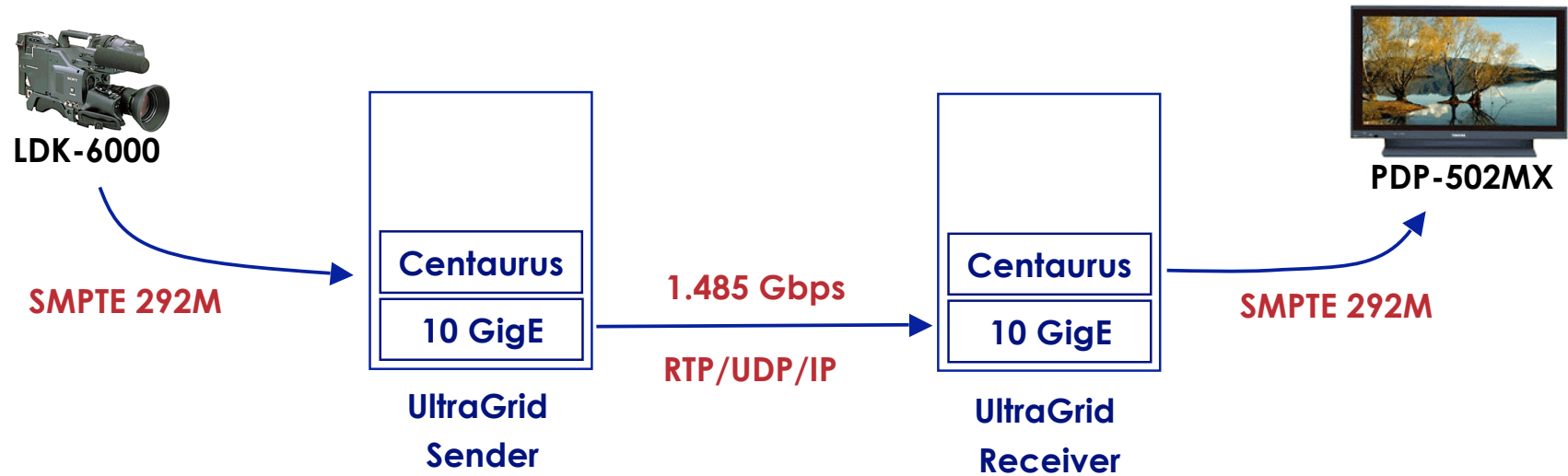 - ○ Measured on a subset of 50000 packets

Lab Tests

LDK-6000

Centaurus

10 GigE

UltraGrid Sender

SMPTE 292M

1.485 Gbps

RTP/UDP/IP

Centaurus

10 GigE

UltraGrid Receiver

PDP-502MX

SMPTE 292M

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Back-2-back tests:

→ Duration: 10 min

→ RTT: 70 µs

→ MTU: 8800 bytes

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Back-2-back tests:

➜ Duration: 10 min

➜ RTT: 70 µs

➜ MTU: 8800 bytes

Results:

➜ No loss or reordering

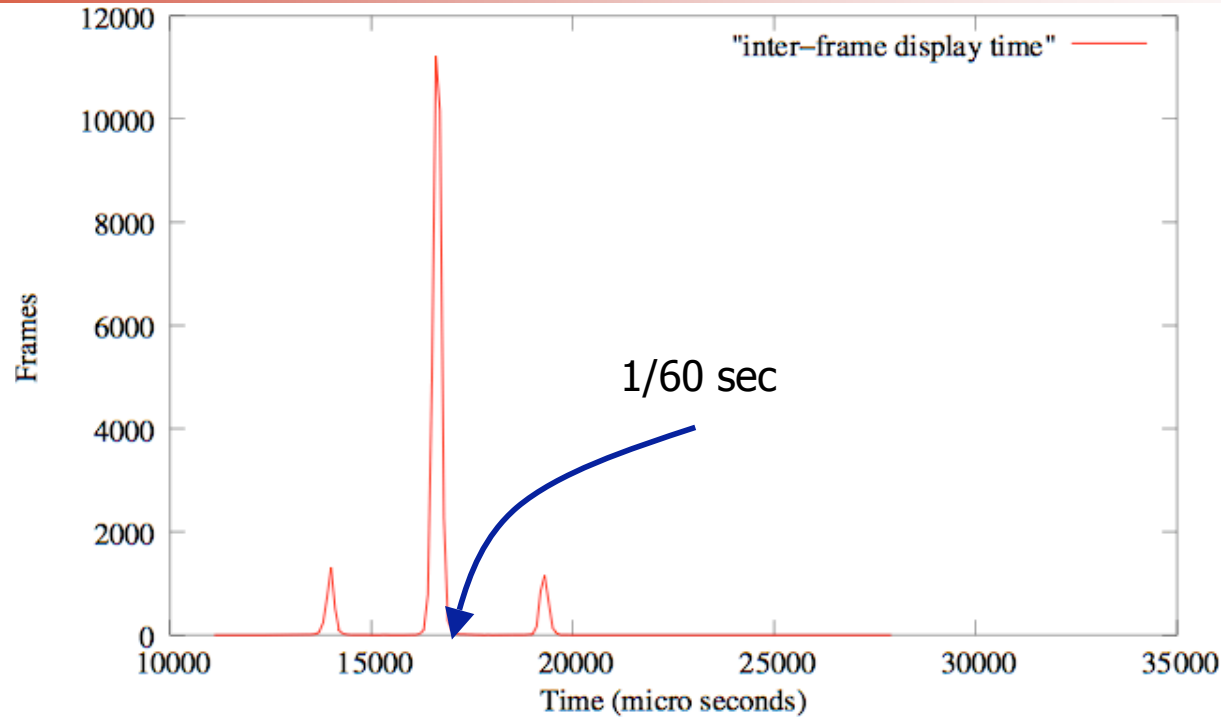➜ 1198.03 Mbps throughput

➜ Total 10,178,098 packets sent and received

Inter-packet Intervals: Sender vs. Receiver
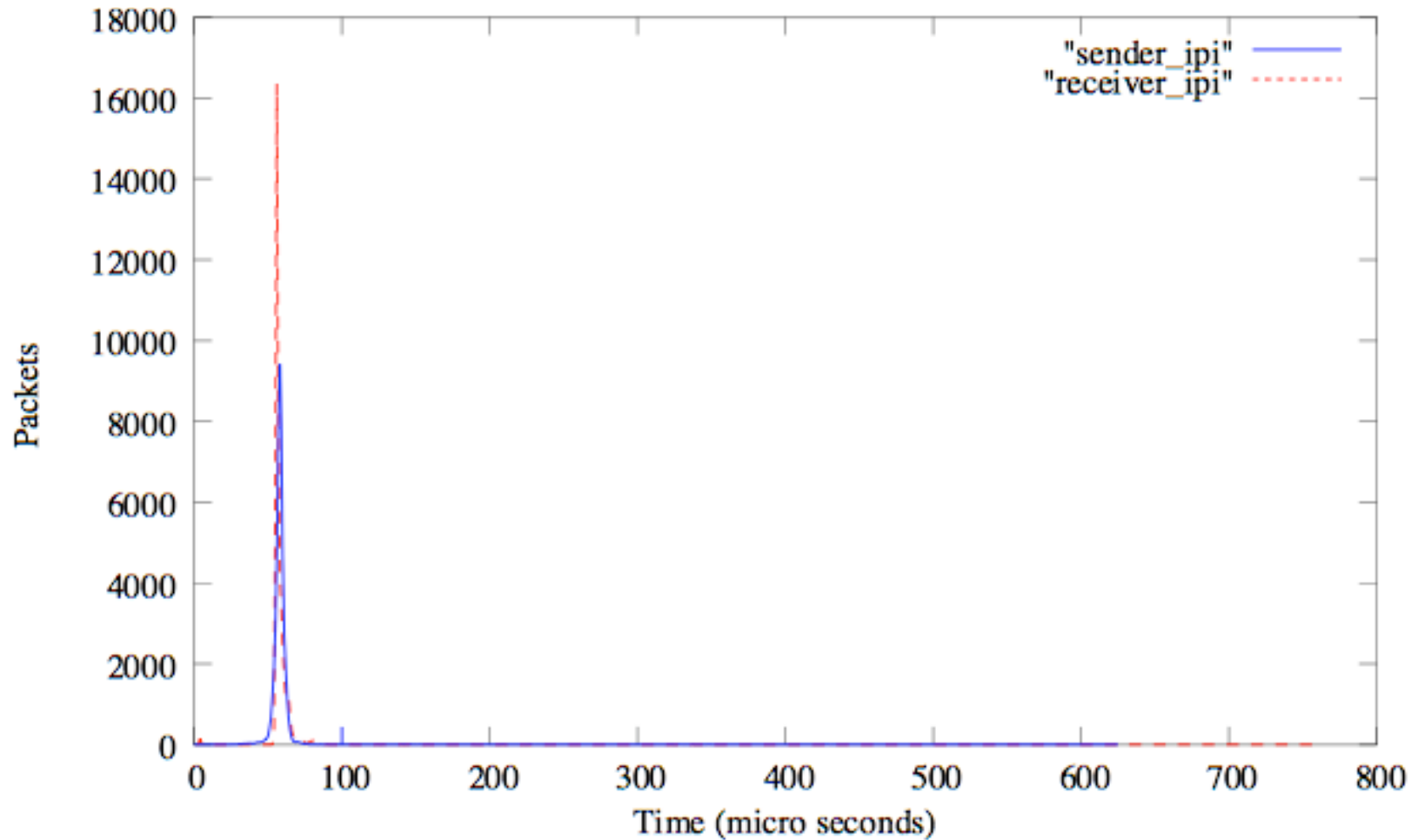
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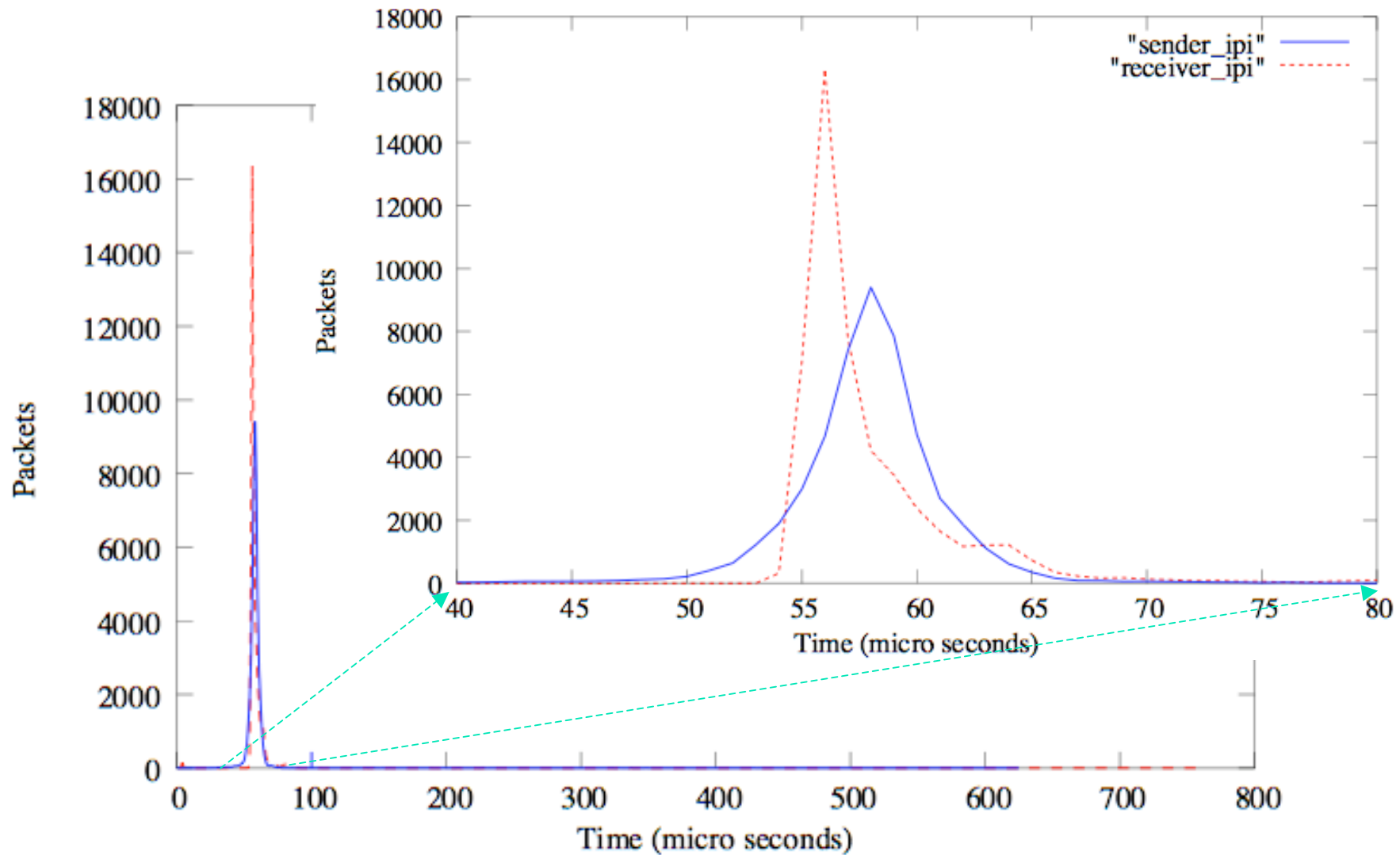
Frame inter-display times

- At 60 fps frames are displayed with an inter-display time of 16666 μs
- The Linux scheduler interferes with timing in some instances:
  - This is an OS scheduling issue
 - One solution is to change granularity of scheduler to 1 ms

Network Tests

- Network tests were conducted over a metropolitan network in the Washington D.C. area, known as the DRAGON network.

- DRAGON is a GMPLS based multiservice WDM network and provides transport at multiple network layers including layer3, layer2 and below.

- DRAGON allows the dynamic creation of "Application Specific Topologies" in direct response to application requirements.

- Our Ultragrid testing was conducted over the DRAGON metropolitan ethernet service connecting:
  - University of Southern California Information Sciences Institute (USC/ISI) East (Arlington, Virginia); and
  - University of Maryland (UMD) Mid-Atlantic Crossroads (MAX) in College Park, Maryland.
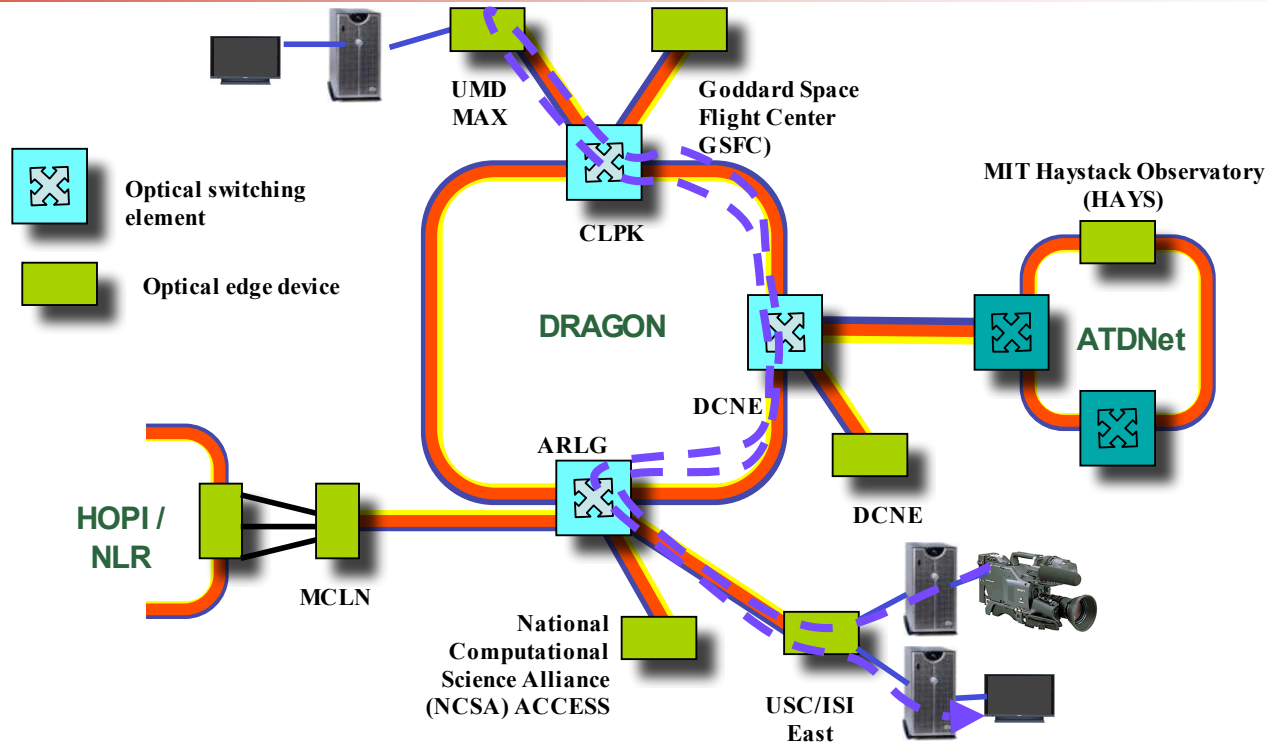
UltraGrid over DRAGON Network
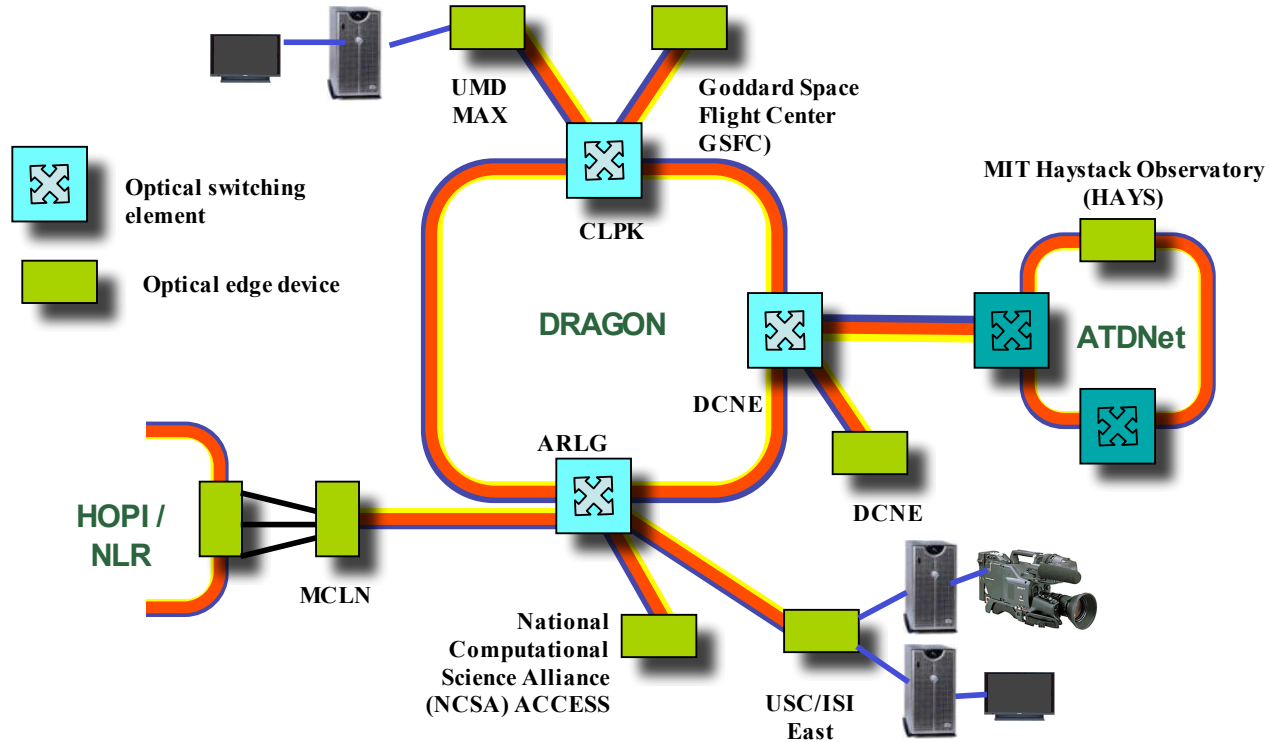
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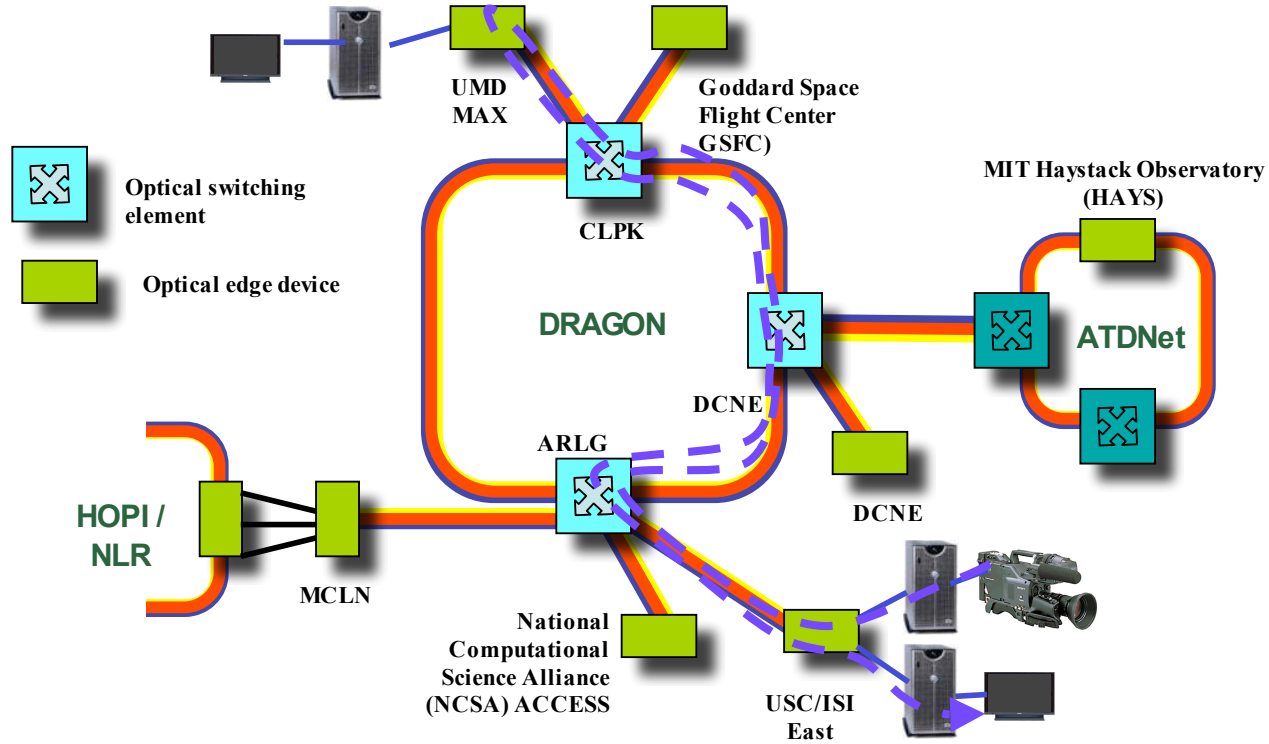
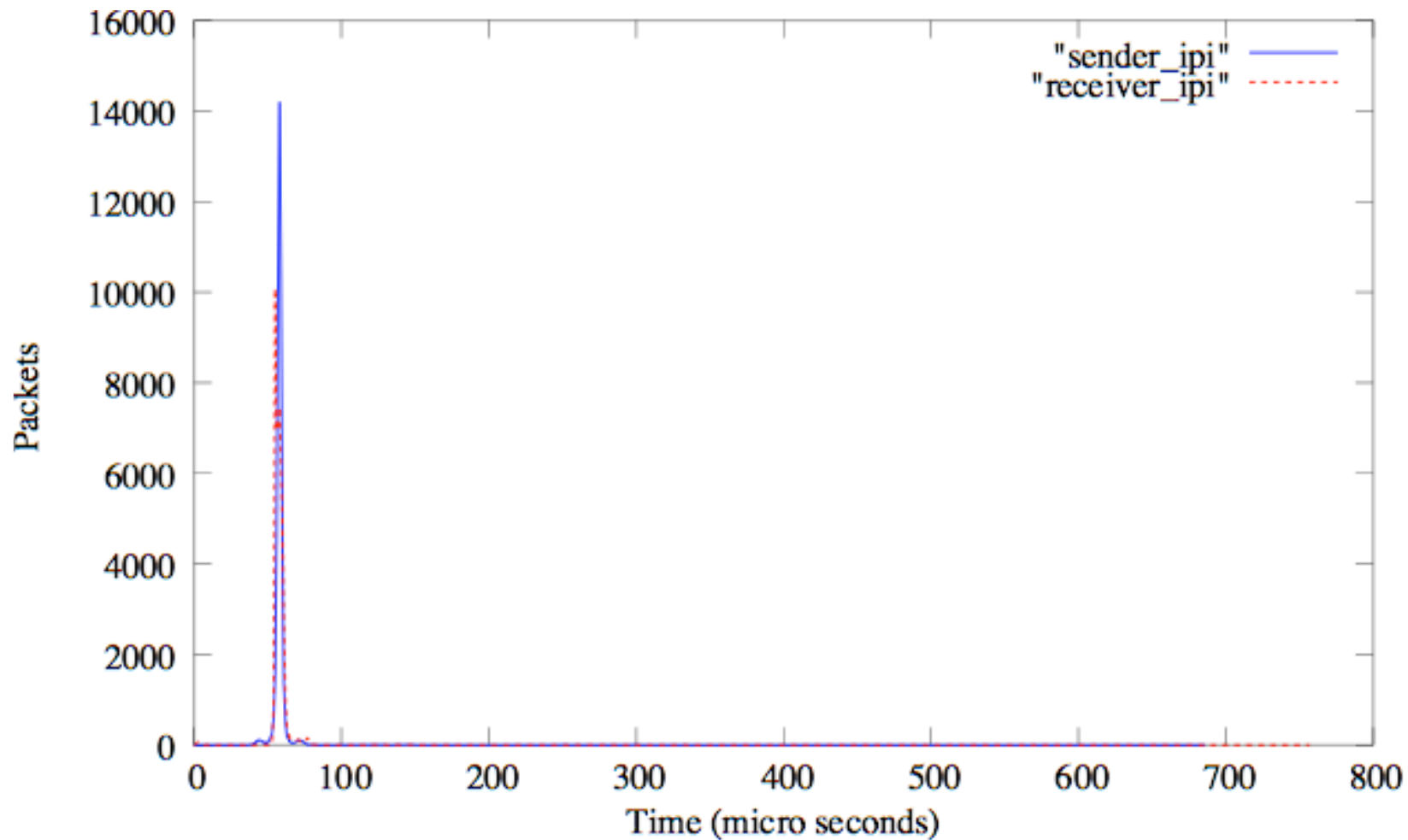# UltraGrid over DRAGON Network

Network tests:

➔ Duration: 10 min
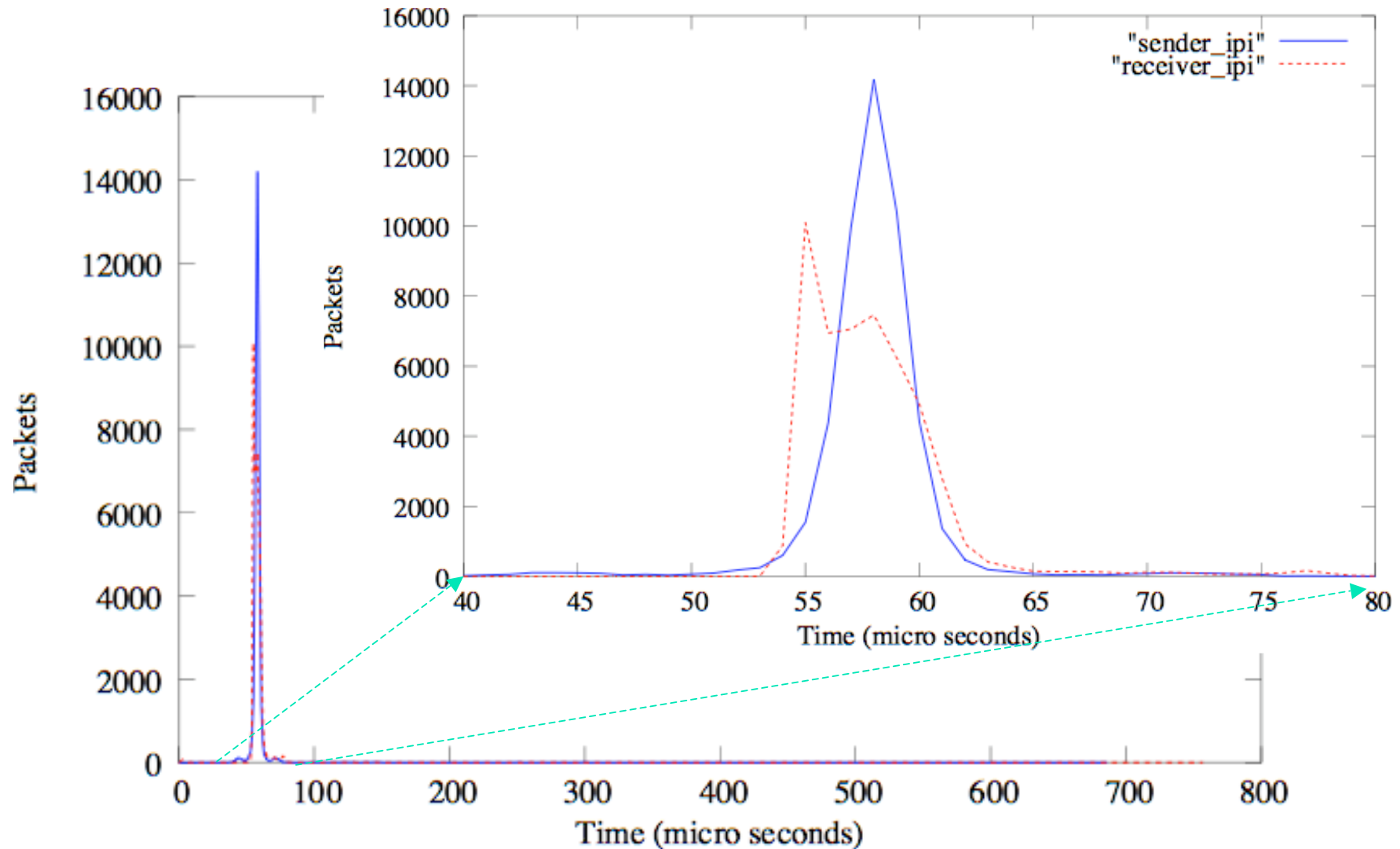
➔ RTT: 570 µs

➔ MTU: 8800 bytes

Results:

➔ No loss or reordering

➔ 1198.03 Mbps throughput
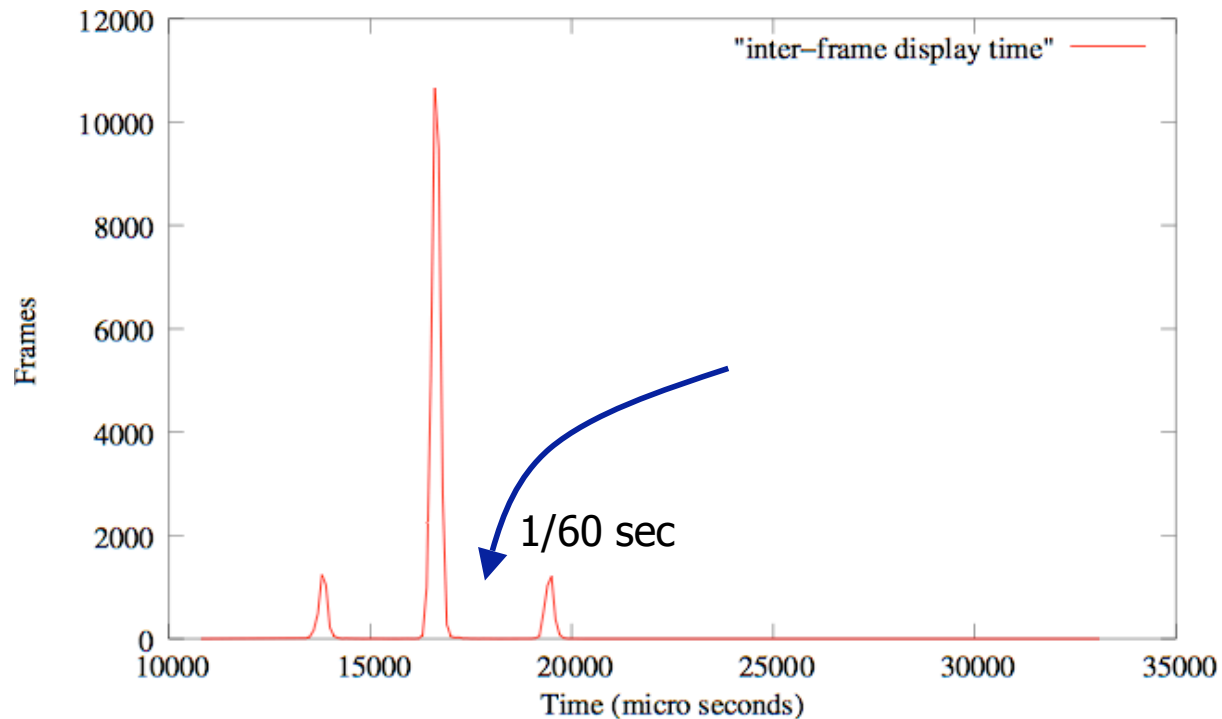
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Frame inter-display times

- In the network tests we see the same interference from the Linux scheduler in the inter-display times of frames:
  - This is an OS scheduling issue
  - Solution: change granularity of scheduler to 1 ms/1000 Hz

Summary

- Full rate uncompressed HDTV video conferencing is available today, with current network and end-system technologies.

- Approximate cost UltraGrid nodes are:
    - Hardware: ~$18000
    - Software: open source code

- It is paramount to be able to adapt to differing network technologies and conditions:
    - Full rate 1.2Gbps flows on dedicated networks
    - Network friendly flows on IP best effort networks

Further Information...

- UltraGrid project web-site: http://ultragrid.east.isi.edu/
  - Latest UltraGrid release available for download
  - UltraGrid-users mailing list subscription information

- Congestion control for media: http://macc.east.isi.edu/
  - Version of Iperf+TFRC for UDP flows, available for download

- DRAGON network : http://dragon.east.isi.edu/