HDTV over IP

University of Southern California
Information Sciences Institute

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About ISI

- Part of USC School of Engineering
- Main site in Marina del Rey, Los Angeles
- East coast site in Arlington, VA
- Approximately 300 staff
- Funding from DARPA, NSF, industry

- ISI East works on:
  - Internet core technology
    - Routing, DNS
  - High speed networking
    - TCP performance
    - Network monitoring
    - IP security
  - Networked multimedia
    - Digital Amphitheatre
    - HDTV over IP
  - Sensor networks and adaptive computing

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HDTV over IP

- Goal of our multimedia work is scaling:
  - To large group conferences
  - To very high quality
- Led us to choose delivery of uncompressed HDTV over IP as a target application
- Two directions:
  - Custom hardware solution in conjunction with Tektronix
  - PC-based solution developed at ISI
- Desire interactive real-time, so use RTP over UDP/IP
  - Work from standards for media streaming and teleconferencing
  - Evaluate their use at high rates
  - Design payload formats for HD
  - Proof of concept implementation

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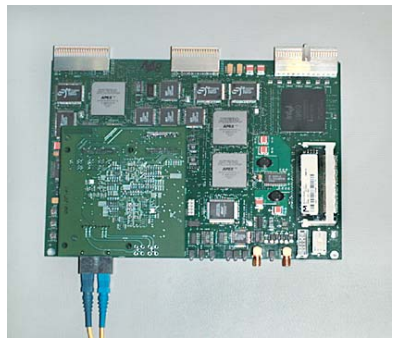
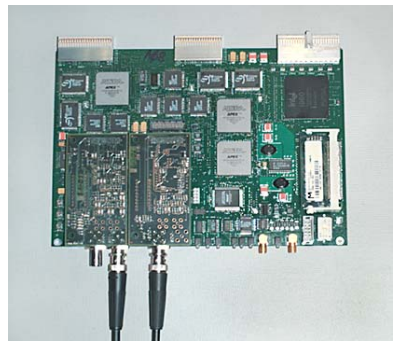
Custom Implementation

- RTP payload format designed by ISI and Tektronix
  - Designed to interoperate with existing equipment
  - Limited flexibility and robustness
    - Assumes a perfect network
- Implementation by Tektronix
  - One-off custom hardware
    - OC-48 network interface
    - SMPTE-292 HDTV interface
  - Full HDTV support @ 1.5 Gbps
- Tested across Internet2 between University of Washington and ISI East





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PC-based Implementation

- Transmitter and receiver on separate host PCs
  - Dell PowerEdge 2500 servers
  - 1.2GHz PIII Xeon/Dual 64 bit PCI
  - Linux 2.4
- Gigabit Ethernet
  - Sub-sampled colour ⇒ 850 Mbps
- HDTV video capture card and camera
  - DVS HDstation OEM card

- All hardware needed is commercially available
- Custom software client available for download from ISI East

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PC-based Implementation

- Application logic implemented in software
  - Fragmentation and reassembly
  - Network adaptation
- Does not assume the network is reliable
  - Standard IP service
  - No QoS/resource reservation
- Tolerant to jitter and packet reordering
- Tolerant to some loss
  - FEC desirable

- Status:
  - Prototype code is stable
  - Standard RTP payload format under development
  - Demonstrated at SC '01 and SC'02
- Ongoing development:
  - NSF support to continue development
  - Robustness and adaptability
  - Congestion control
  - Usability

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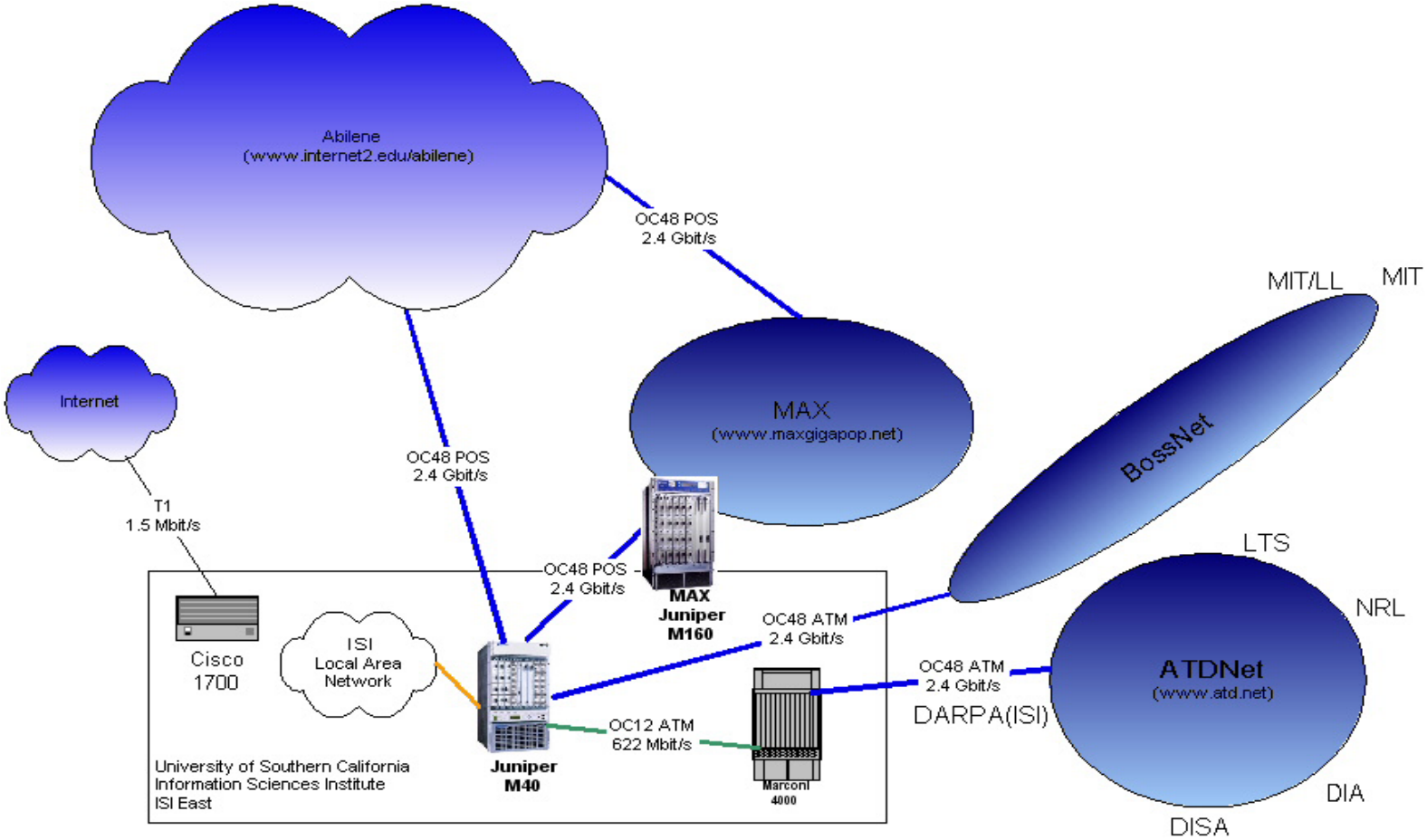
Wide area tests



-**BossNet** Optically Transparent Long-Haul network. WDM network with one lambda for OC48.
-**ATDNet** High performance networking testbed in the Washington D.C. area which is a collaboration between DARPA, DISA, DIA, NRL, NASA, and LTS. Dark fiber WDM network with one lambda for OC48 ATM.
-**MAX**. Washington area gigapop founded by University of Maryland, Georgetown University, George Washington University, and Virginia Polytechnic Institute and State University.
-**Abilene**. Internet2 high speed backbone for connecting Internet2 Universities.

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Packet Loss

- When the path is adequately provisioned, loss is rare
  - Numbers below are for a *bad* day
    - Typically zero packet loss in the core at 850Mbps
  - FEC can correct these errors with minimal overheads
- We believe this is typical for major ISP backbone networks
  - Problems due to access networks/interconnects/hosts
  - Difficulty will be getting a commitment to quality

Loss event duration	Frequency
No loss	24697400
Single packet	85797
Two consecutive packets	587
Three consecutive packets	7
Four or more packets	0

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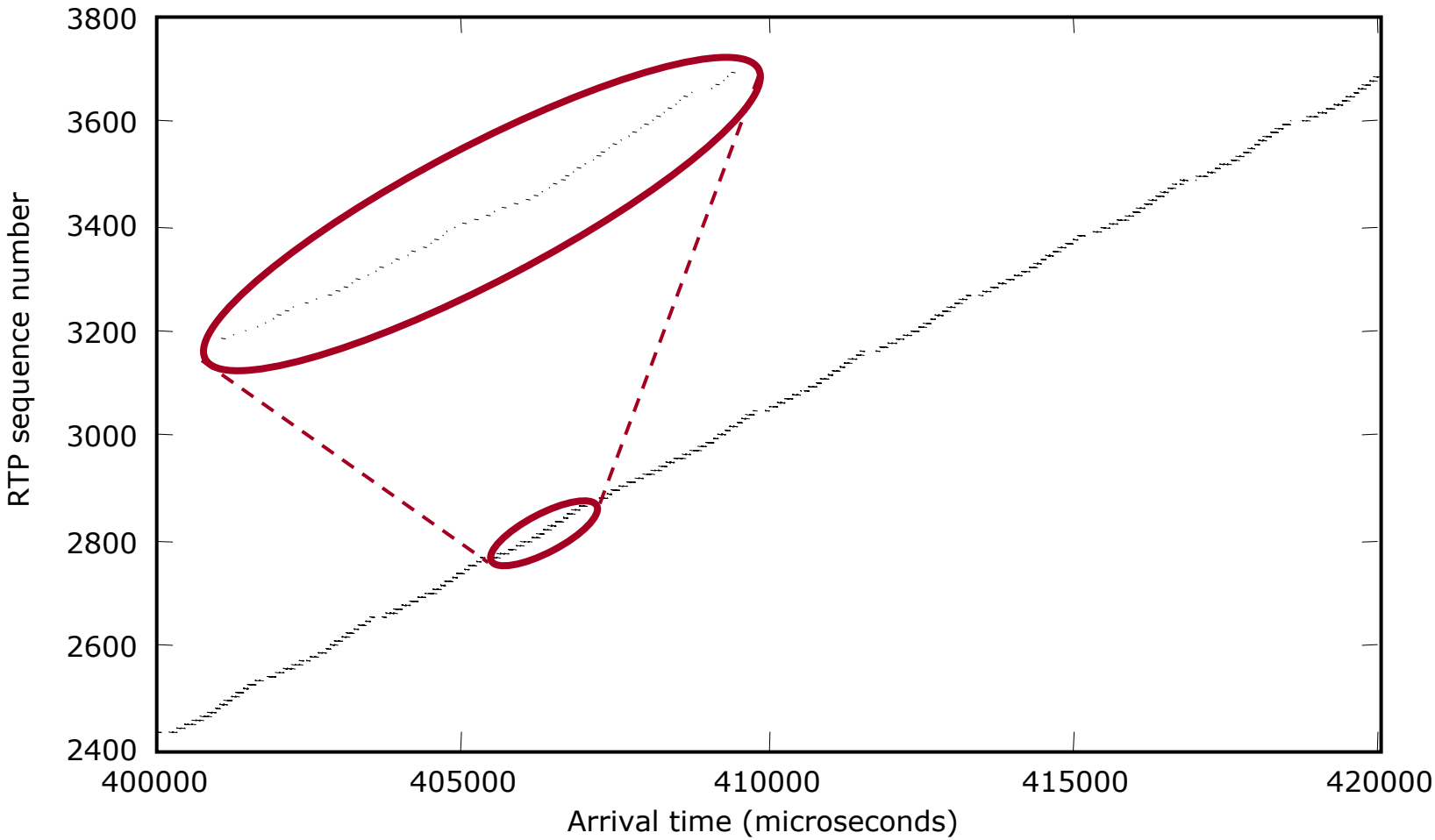
Packet Timing Variation



- Inter-arrival times not significantly affected by the network
- Observed >99.9% of packets in order, with negligible jitter

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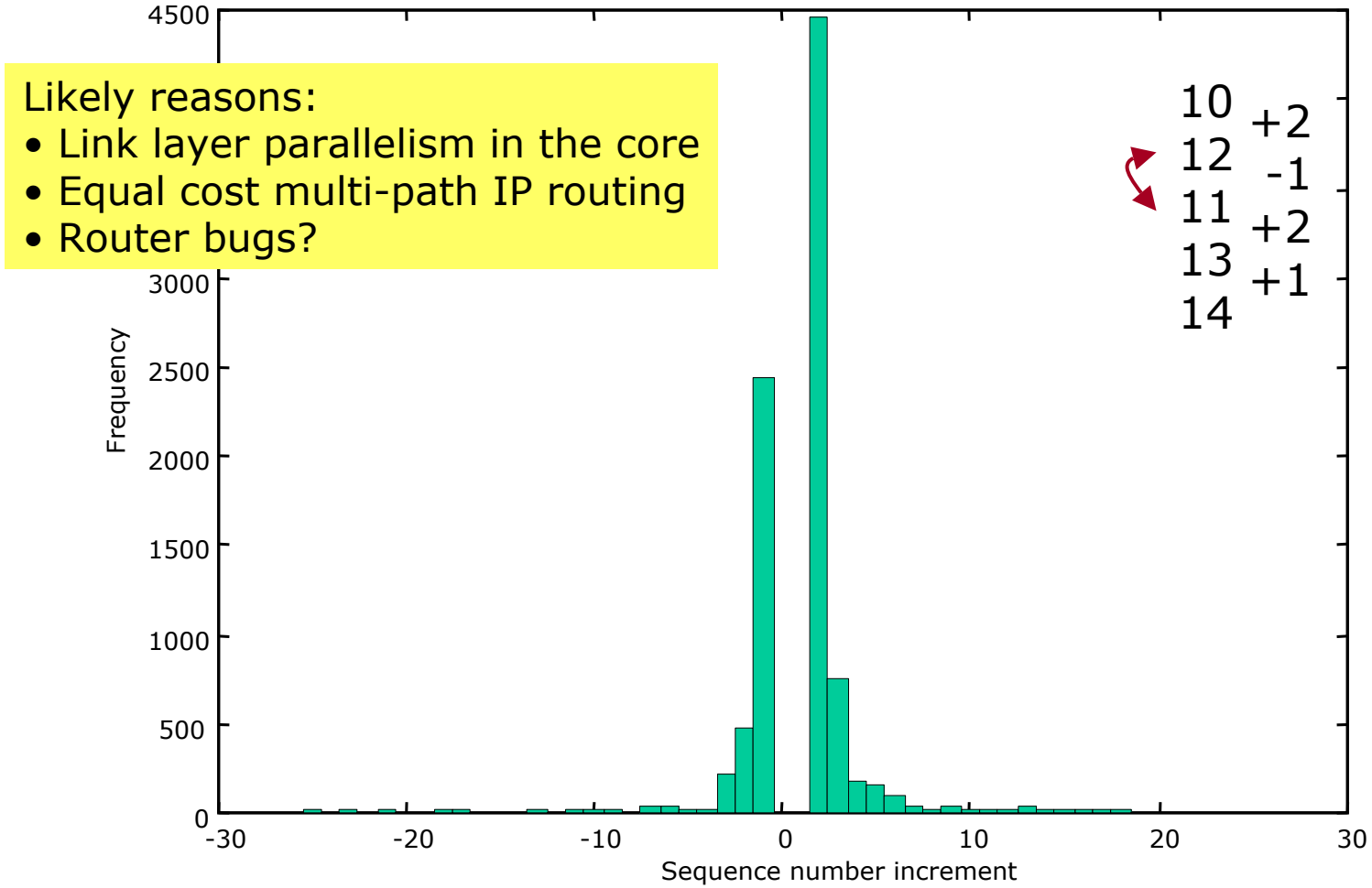
Packet Reordering



- Packets are occasionally reordered in the network
  - (above data is from a 10 million packet trace)

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Summary of Network Performance

- Backbone networks can support high rate UDP streams
  - Our data is from Qwest and Internet2
  - Have seen similar numbers from AT&T and Sprint
- Need a somewhat smart application
  - Some tolerance to loss, jitter and reordering
- Difficult problems are:
  - Engineering the edge network and interconnects
  - Persuading the ISP to give service guarantees

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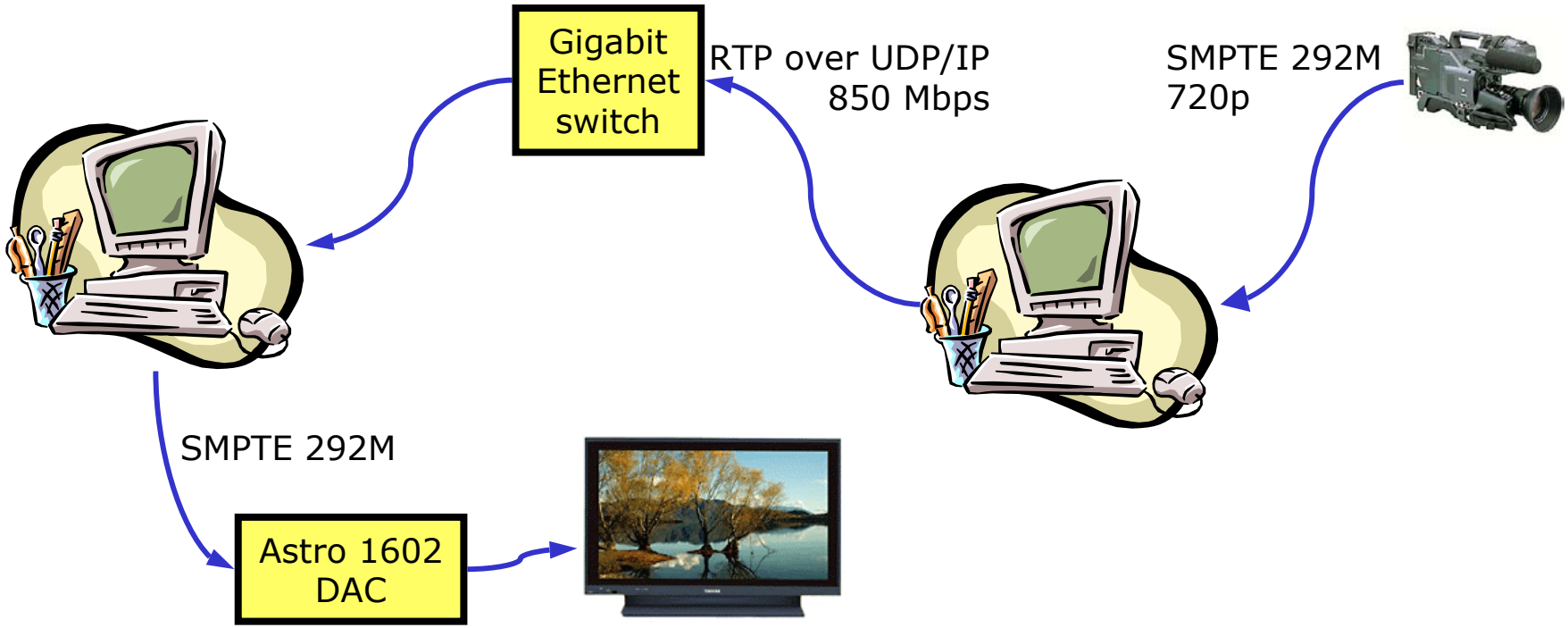
Today's Demonstration



- Local area test running at 850 Mbps
- PCs are dual-processor Dell PowerEdge 2500 servers with gigabit Ethernet and HDstation OEM capture/display cards
- SMPTE-292M input and output

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