

Internet HDTV and the ResearchTV Project

Terry Gray

University of Washington

Objectives for this talk

- Briefly describe the ResearchTV project
- Focus on UW's Internet HDTV experiments
- Credits
 - Corbató/ Zekauskas talk at I2/NLANR/JT
 - Richardson talk at CANARIE workshop
 - Philipson notes on ResearchTV

The ResearchChannel

- Formerly known as ResearchTV
- Distribution of HQ R&E videos
- Nationwide broadcast via Echostar
- Network distribution via Internet2
 - On-demand and scheduled
 - Interested in HD and multicast
 - Good QoS case study candidate!
- i2ResearchTV wg at March I2 mtg
- Participation and content welcome!

UW Network Environment

- Pacific/NorthWest Gigapop
 - vBNS OC3
 - Abilene OC12 (soon OC48)
 - HSCC OC48
 - Commodity 4x DS3
- Campus: separate GE R&D backbone
- Frame-based; no ATM

UW's Internet HDTV Project

- How would world change if it worked?
 - Support ResearchChannel objectives
 - Support Internet2 objectives
 - Support our normal urge to push limits
- Interdisciplinary team from UW central computing organization
- Major assistance from Sony, lots of others
- Focus on studio quality HDTV and broadcast industry standards...

Chronology

- **Feb 99:** Abilene roll-out (6 Mbps SDTV)
- **Jul 99:** HD/IP project kickoff
- **Oct 99:** I2 (Stanford to Seattle via Abilene)
- **Nov 99:** SC99 (Seattle to Portland via NTON)
- **Feb 00:** ISIE-UW (DC to Seattle via HSCC)

HDTV Basics

- Movie-like images
 - 16x9 aspect ratio, all digital, rich color sampling
- Many different flavors
 - p vs. i, lines of resolution, sampling depth, etc.
- “1080i” = 1920x1080 @ 60 interlaced fields/sec
- Quality levels:
 - consumer = 19.2Mbps
 - contributor = 40Mbps
 - studio = 200Mbps
 - raw = 1.5Gbps

Video Data Rates

1.5Gbps Raw HDTV

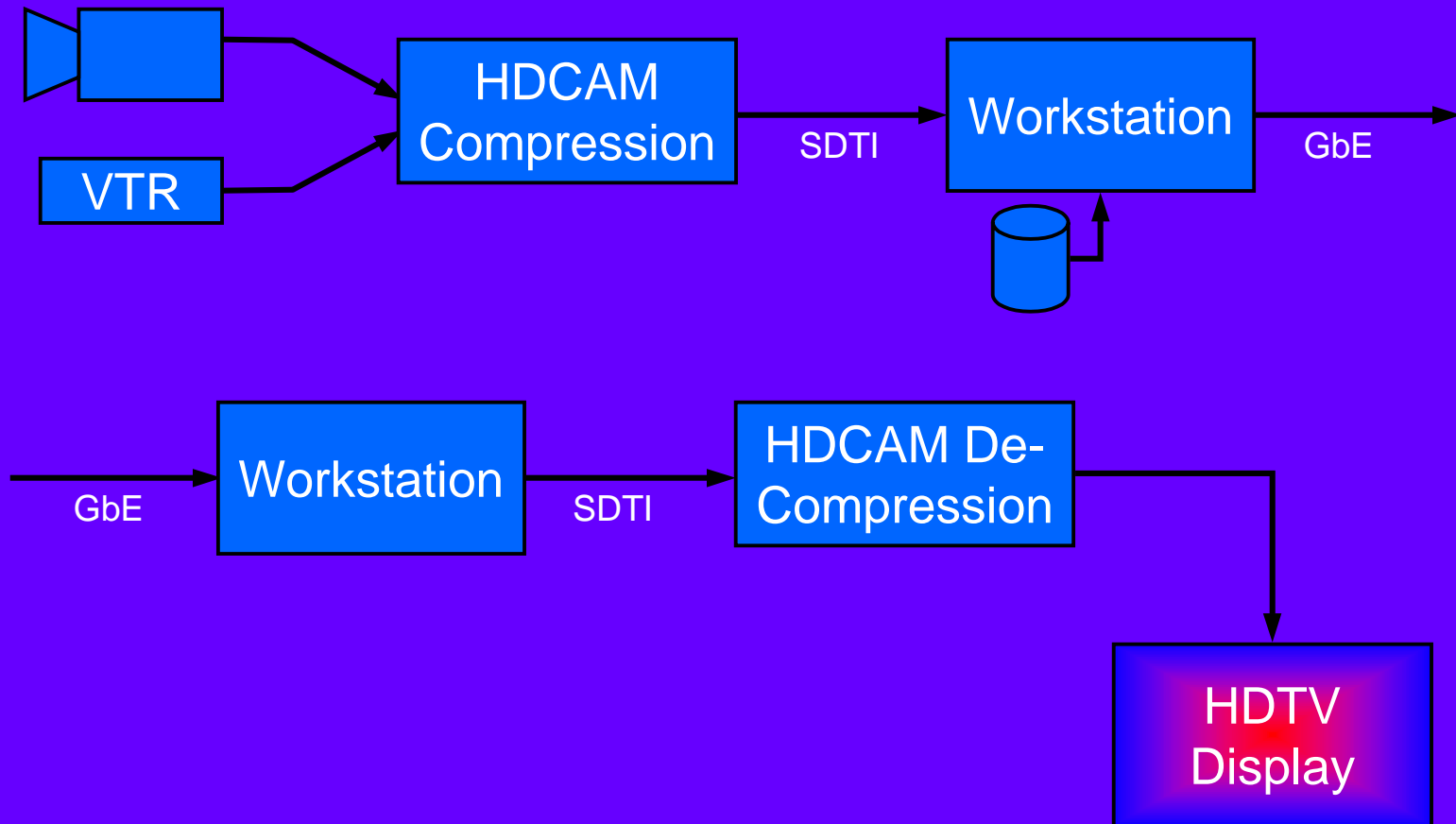
270Mbps Uncompressed SDTV (SDI)

200Mbps HDCAM Compressed HDTV

40Mbps MPEG2 HDTV Contribution

19.2Mbps HDTV Broadcast

HD/IP Block Diagram

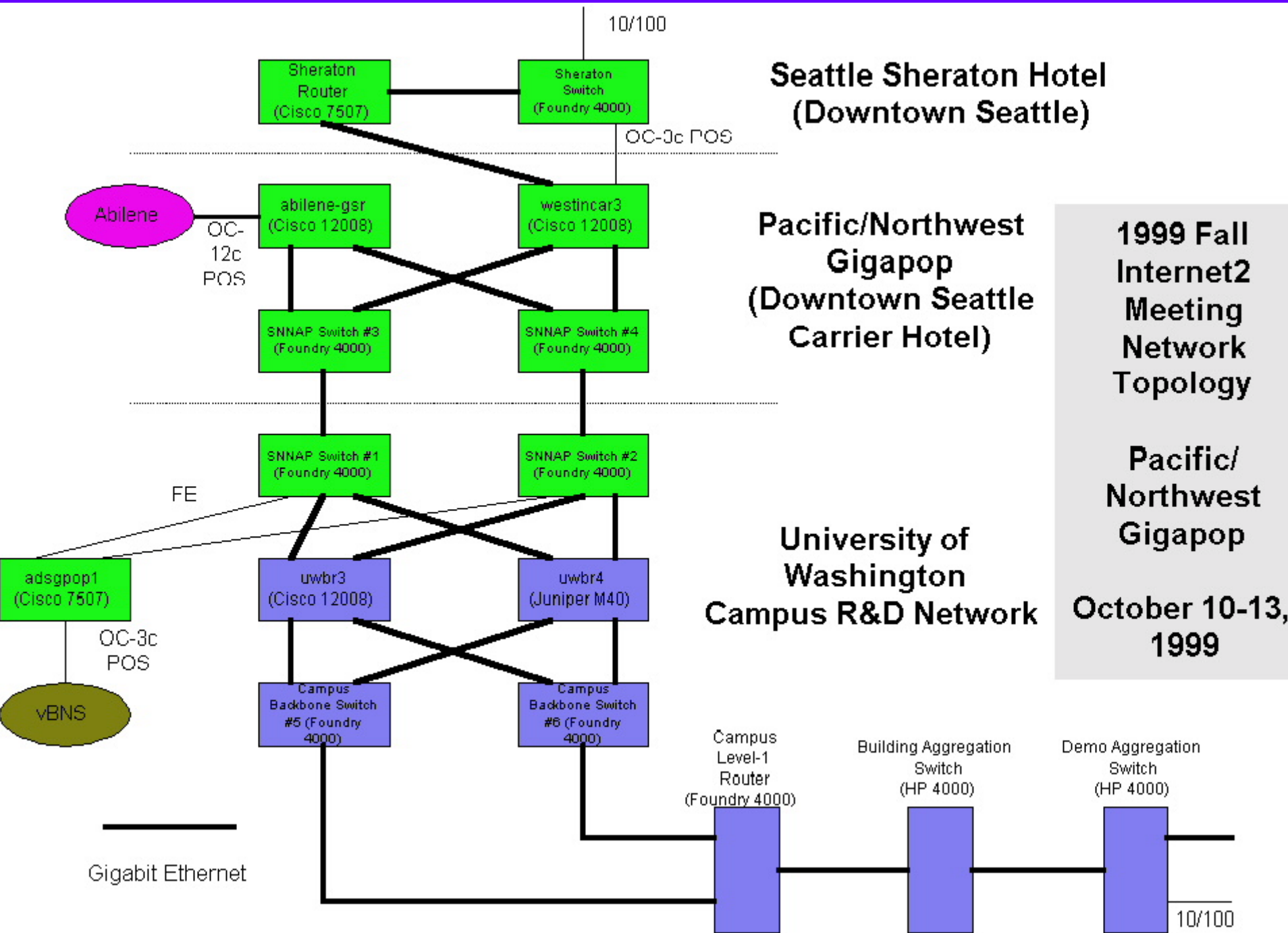


UW's HD/IP Software

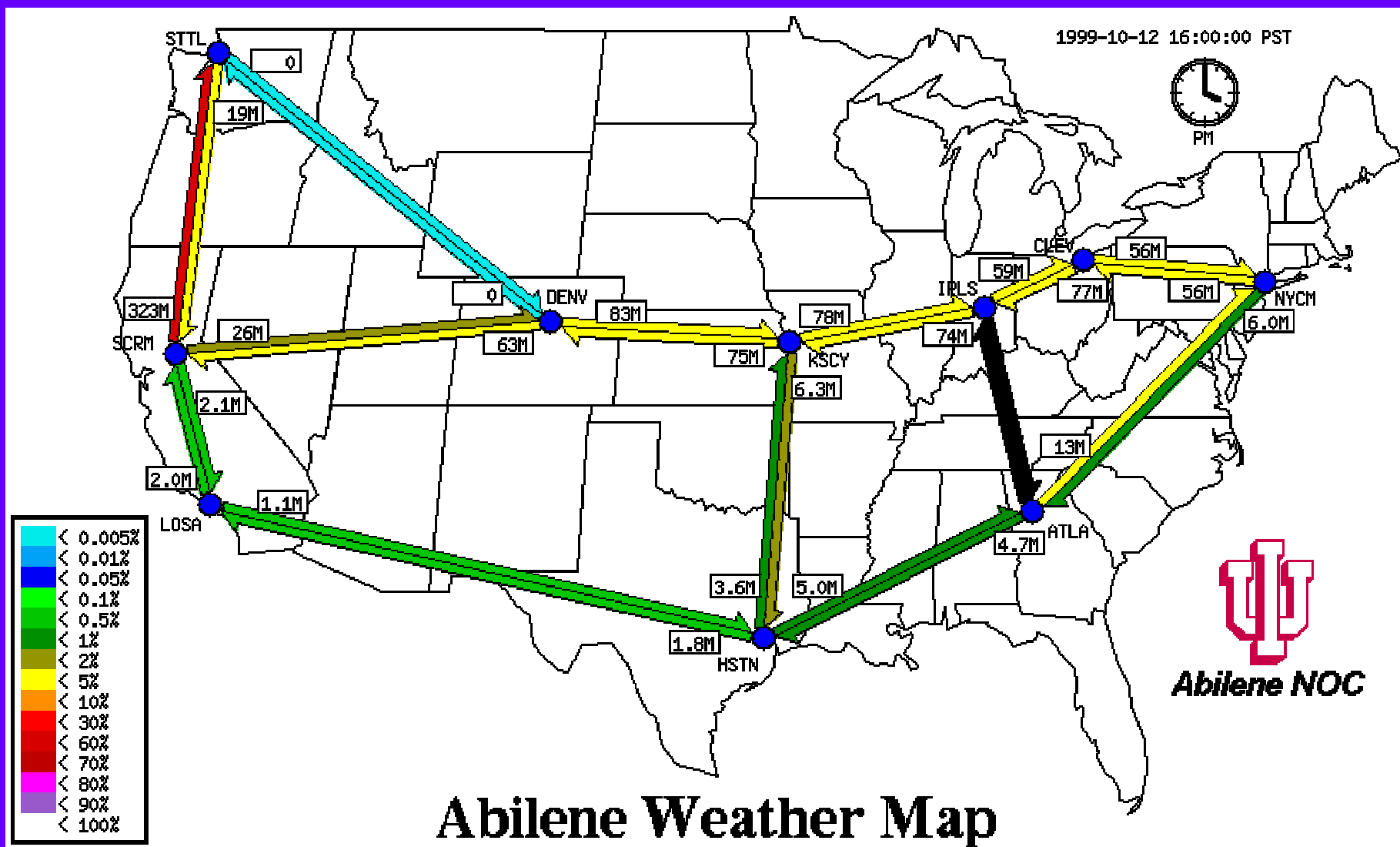
- Two different projects:
 - **40Mbps MPEG2-DVBASI**
 - ~900B UDP datagrams
 - RAID-style FEC; low latency
 - Loss tolerance depends on decoder (5-10%)
 - **200Mbps HDCAM-SDTI**
 - 1472B UDP datagrams
 - retransmit and buffering; 4 sec latency
 - Loss tolerance: 10-15%
- Using standard 1500 byte GigE MTU
- Not using RTP

Experiment 1: Fall I2 Mtg

- Stanford to UW/Seattle via Abilene OC12
 - 40Mbps MPEG2-DVBASI stream
 - 200Mbps HDCAM-SDTI stream
- Approximately 12 network hops
 - Stanford, CALREN, Abilene, P/NWGP, UW
- Sony provided an HDTV ‘movie projector’
- Jay Leno, *Secret Adventures of Jules Verne*



Abilene - afternoon of UW event (2 hour average)



Line Utilization

Experiment 2: SC99 GNAP Demo

- UW/Seattle to Portland via NTON OC48
- Five concurrent 200Mbit streams \Rightarrow 1+ Gbps
 - 4 streams sourced from disk arrays
 - 1 stream sourced from Sony HDTV system (live and tape)
 - All streams displayed concurrently at SC99
- Link shared with MSR desktop Gbps TCP demo
- 2.4Gbps sustained; 54.7 Terabytes in 90 hours!
- Overall packet loss observed: 10^{-4} - 10^{-5}
 - predominantly at application and system layers

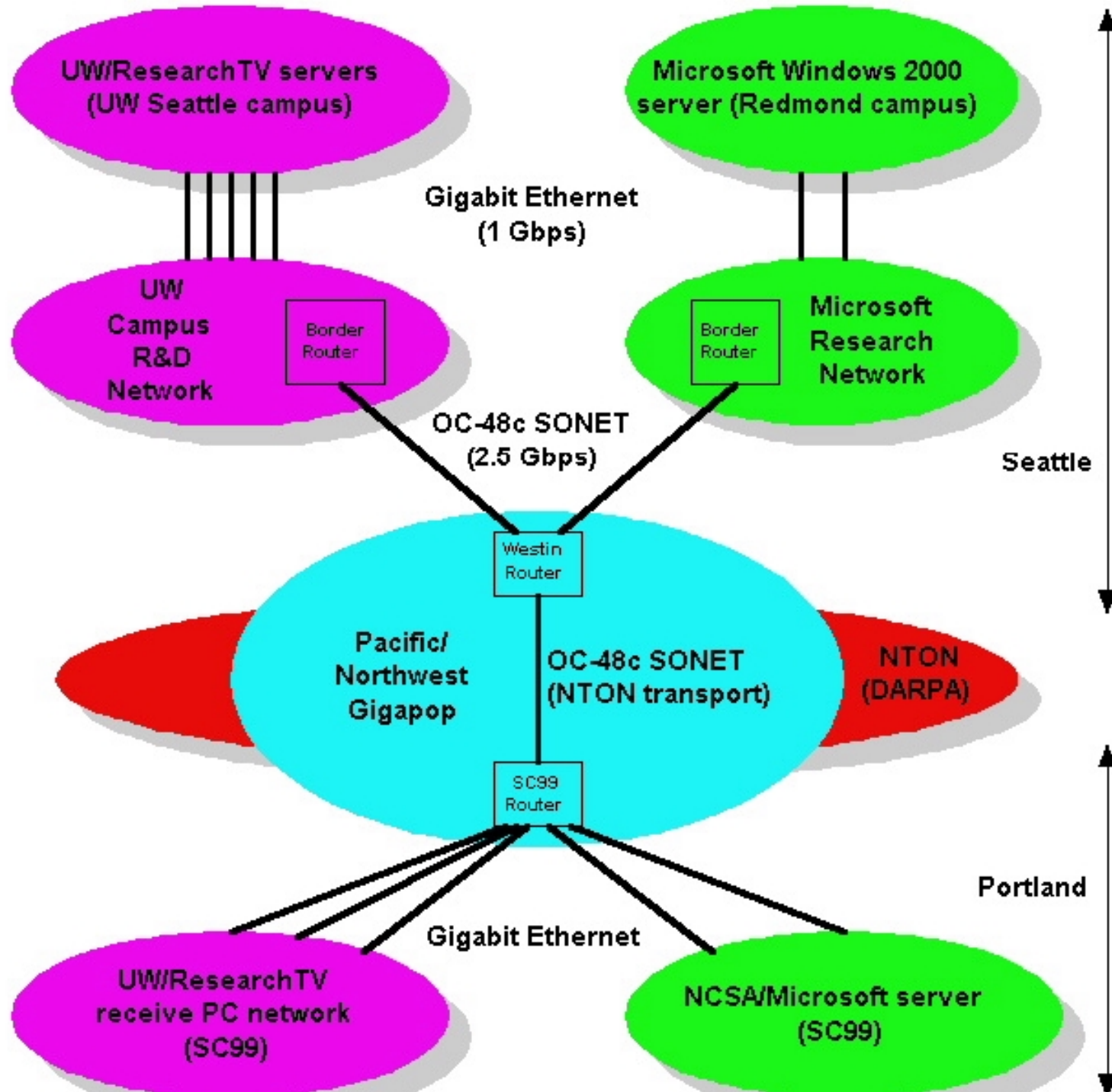


SC99 GNAP Booth

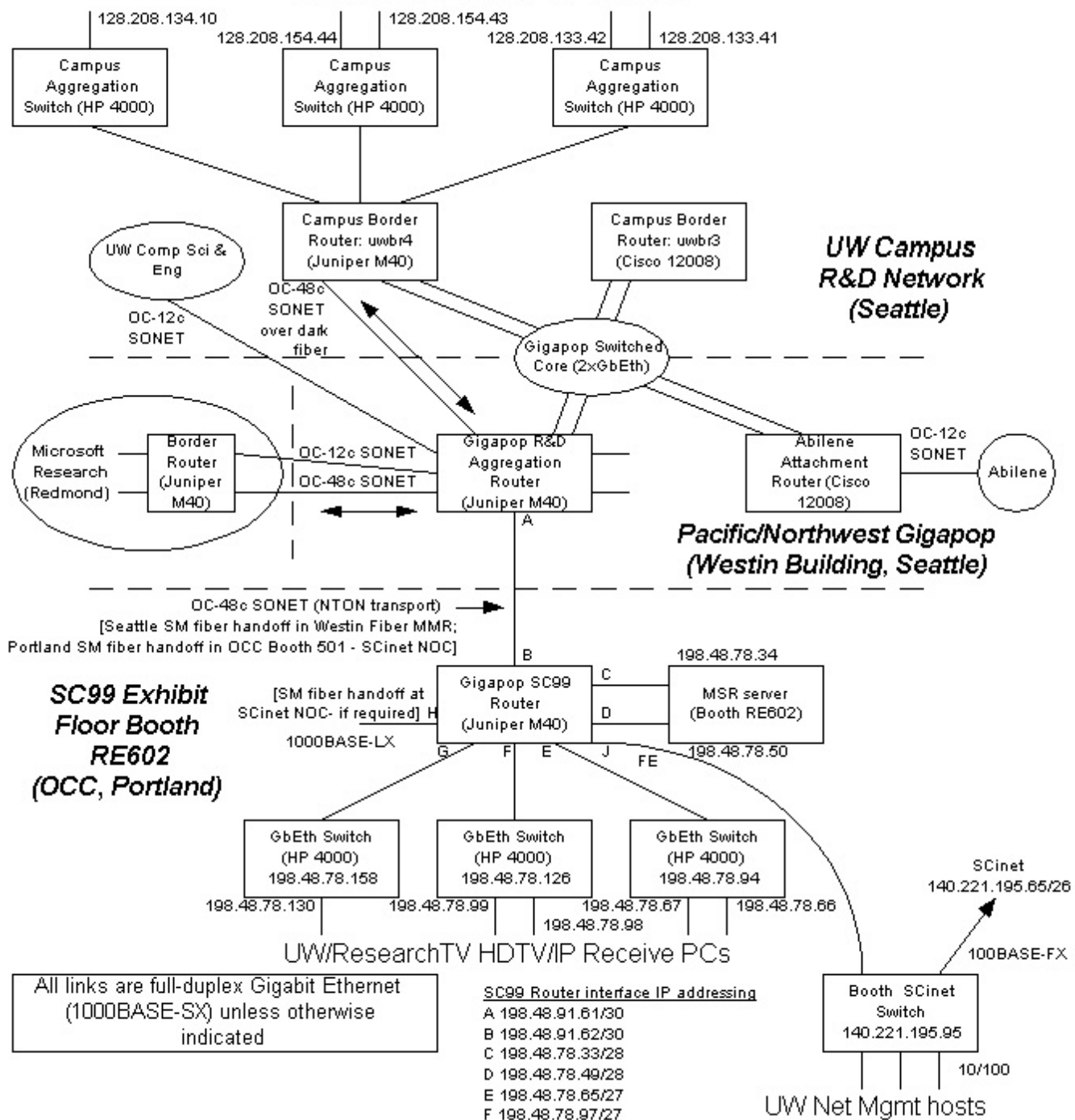
15-18 November, 1999

Portland, Oregon



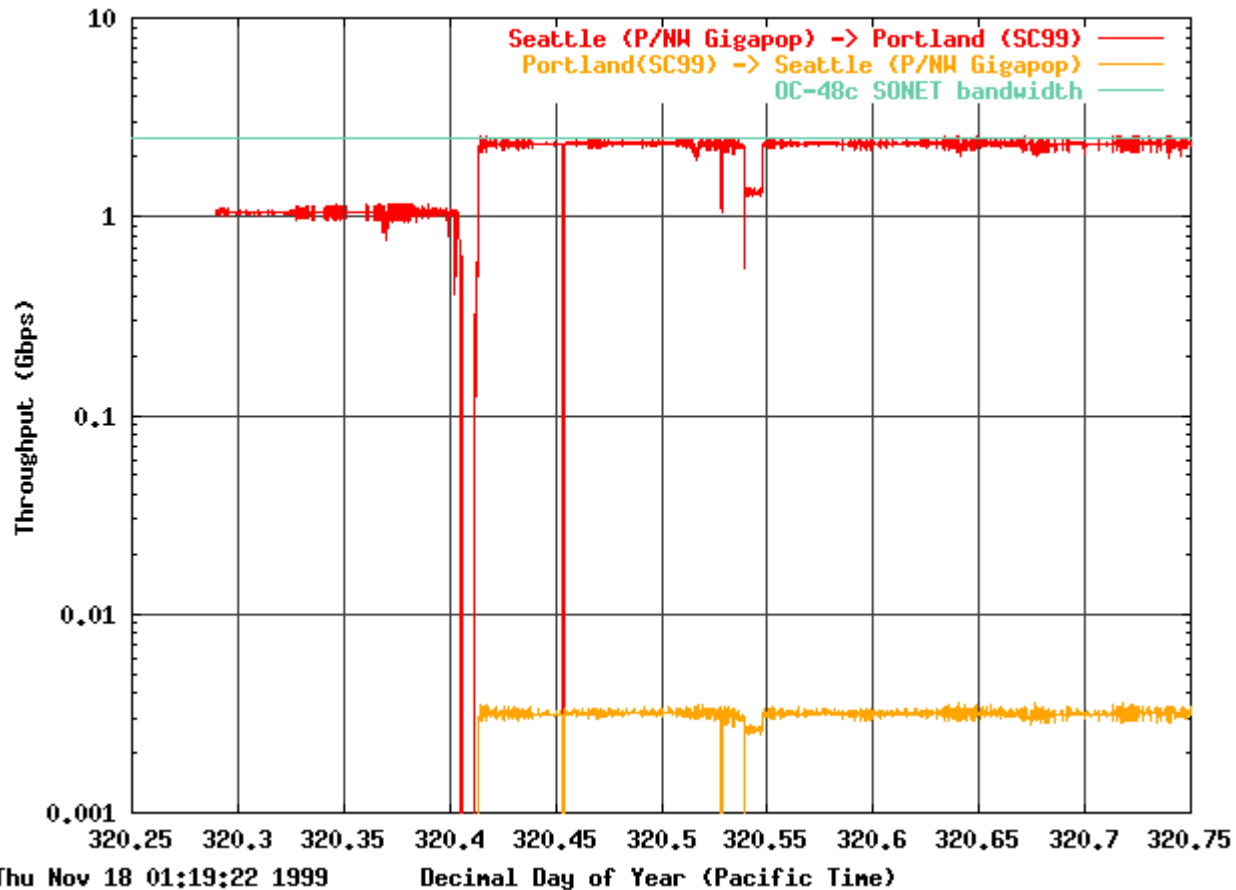


UW/Research TV HDTV/IP Servers



SC99 Flows

Gigabit Networking and Applications Partnership demo - SC99 - Tuesday 11/16/1999 (10s poll)



Experiment 3: ISIE/UW

- ISI/DC to UW/Seattle via HSCC OC48
- Single GE router attachment
- 200mbps HD + 700mbps chaff = 900 total
- >700 chaff: high LOCAL loss
- <700 chaff: low loss (.0005%)
- Soon: 5x200 HD/IP via two GE ports

HSCC iperf UDP tests

- UW->ISLe:
 - 100-475 Mbps consistent 0.03% loss
- ISLe->UW:
 - 100 Mbps <0.003%
 - 200 Mbps 0.03%
 - 400 Mbps 0.2%
 - 600 Mbps 0.2%

Next Steps

- **Pushing the system:** uncompressed HDTV, multi-stream servers
- **Studying the system:** understanding the bottlenecks, exploring latency vs. quality
- **Scaling the system:** QoS, multicast, different data rates, VBR encoding
- **Using the system:** TV production, visualization, medicine, teleconferencing

QoS Issues

- Limits of application error correction
- TCP v. UDP issues
- Impact of CBR vs. VBR encoding
- Impact of DiffServ
- Impact of MPLS and DWDM
- Impact of Multicast

Conclusions

- **Studio HDTV to your home is *NOT* imminent**
- **Studio HD/IP is viable, without dedicated links**
- **Gbps flows are sustainable in the I2/NGI space**
- **Gigabit networking and e2e performance are *NOT* solved problems (especially for TCP)**
- **Network ops: Be very afraid & go to SNMPv3**
 - SNMPv1 counters wrap every 13seconds at OC-48c

References

- ResearchTV/ResearchChannel
www.washington.edu/researchtv
- Internet HDTV project
www.washington.edu/hdtv
- Enterprise QoS Survival Guide
staff.washington.edu/gray/papers
- Gigabit Networking & Applications Partnership - GNAP:
UW, Sony, ResearchTV, P/NW Gigapop, Microsoft,
NCSA/Alliance/NLANR, NTONC, DARPA
- Additional help from: Stanford U, Juniper Networks, Qwest, U S WEST,
Nortel, GST, Alcatel/Packet Engines, Alteon, SysKonnnect, SC99, Oregon
State U, Sandia-Livermore, ISiE, UCAID