Quality of Service and Asynchronous Transfer Mode in IP Internetworks

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Outline

Introduction

Previous and Related Work

Research Issues

Research Plan

Summary

Introduction

Asynchronous Transfer Mode (ATM)

- A new networking technology for integrated services networks

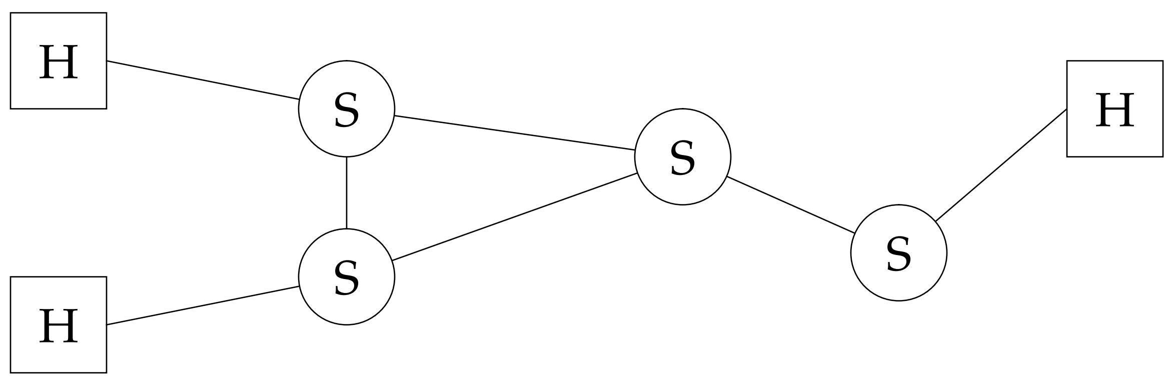
Internet Protocol (IP)

- Network layer protocol of the Internet
- Communication over heterogeneous internetworks

IP over ATM

- The use of an ATM network to transmit IP datagrams

Asynchronous Transfer Mode (ATM)



Point-to-point links between switches in a switching fabric

Connection-oriented network

Potential for quality-of-service guarantees

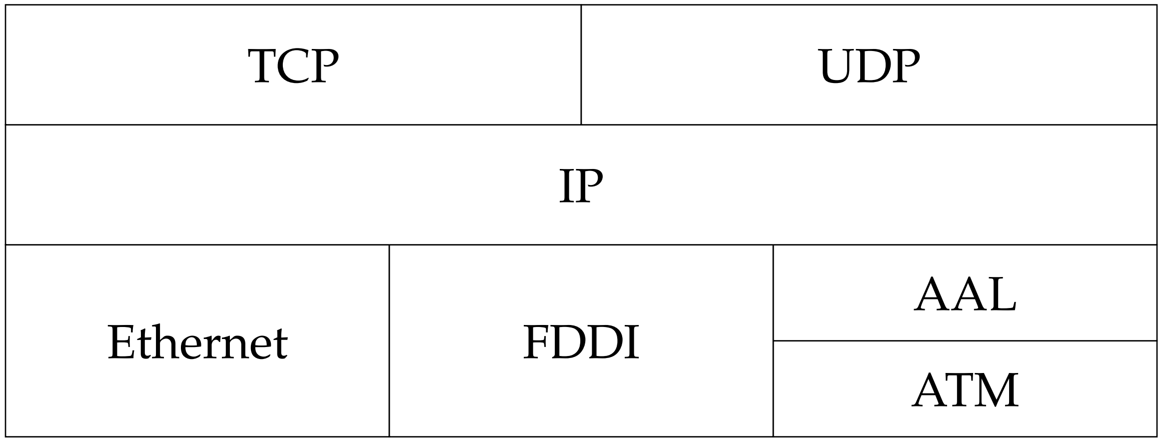
No specific QOS model implied or assumed

- Possible to specify general delay, bandwidth, and loss requirements
- Some number of service classes

The Need for Internetworking

- ATM is not (will not be?) ubiquitous and dominant
  - Time to deploy a new technology
  - Legacy networks (e.g. Ethernet)
  - New, non-ATM networks
- An internetworking solution is still required

The Internet Protocol (IP)

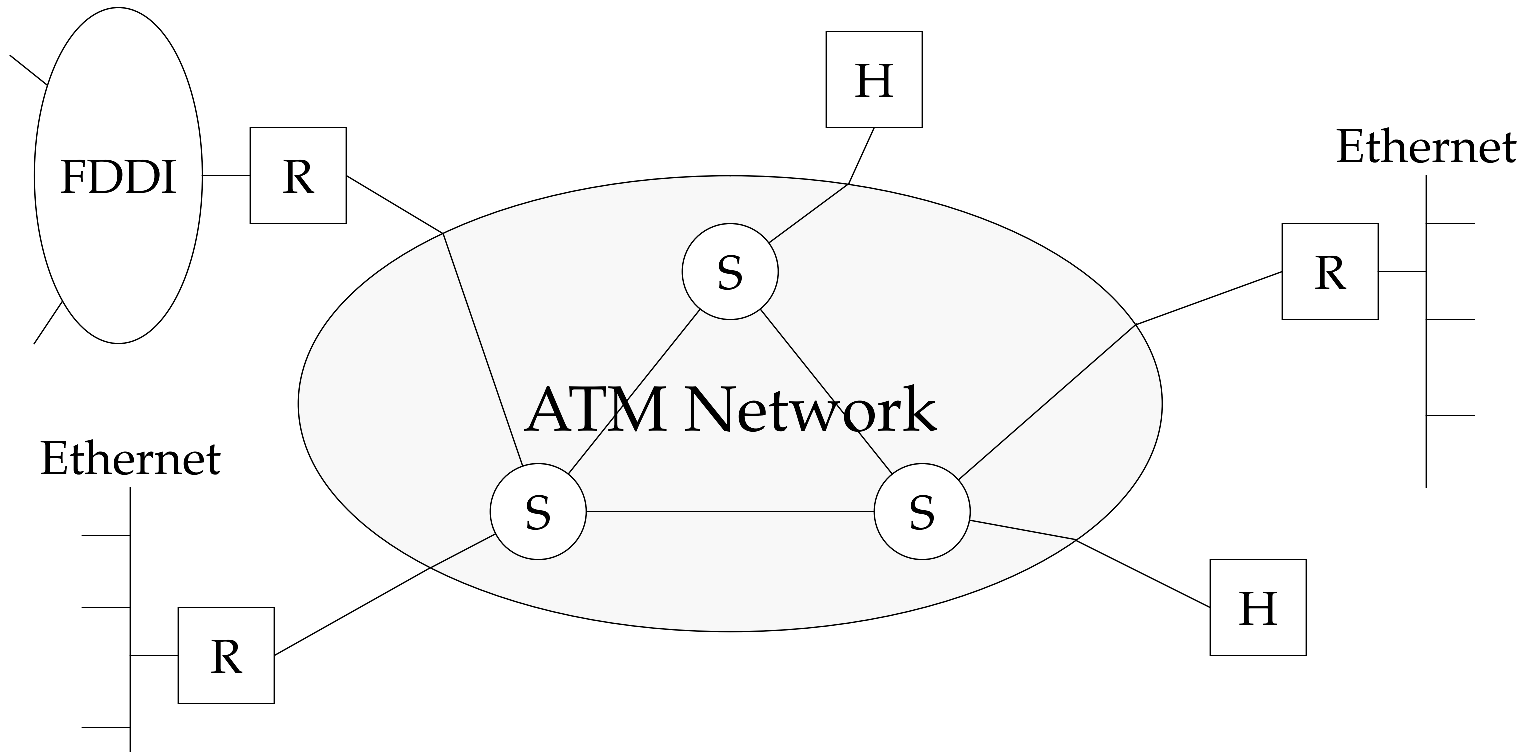


Supports heterogeneous internetworks

Datagram-oriented network-layer protocol

No performance guarantees or quality of service support

Environment



Conventional data (e.g. `ftp`, `telnet`) as well as multimedia traffic (e.g. `nv`, `vat`)

IP over ATM

Question: How can IP applications get the best performance out of an ATM subnet?

Idea: Use quality of service features of ATM to improve IP performance

Different types of virtual circuits to meet needs of different applications

- `telnet` ⇒ low latency bound
- Video playback ⇒ bandwidth guarantee

Related Work

Models for IP over ATM

- Conventional Model—RFC 1577 (1994)
- Subnet Model—R. Cole (1994)
- Connectionless Servers—D. Box, et al. (1993), D. Omundsen, et al. (1994)

Traffic Measurement and Analysis

- A. Schmidt and R. Campbell (1993)

Traffic Multiplexing

- R. Cáceres (1992)
- K. Claffy (1994)

Virtual Circuit Management

- C. Lund, et al. (1994)
- S. Keshav, et al. (1994)

Research Issues

The Use of ATM QOS for IP Conversations

- How to map a stream of IP datagrams onto a virtual circuit?
- What performance requirements do IP conversations have?

Multiplexing

- How and when should multiple conversations share a virtual circuit?

Virtual Circuit Management

- When should virtual circuits be created?
- When should virtual circuits be torn down?

Mapping IP Datagrams onto a Virtual Circuit

"IP Conversation"

- A stream of related IP datagrams between common endpoints with some definable set of QOS parameters
- Hosts and routers place packets of IP conversations onto ATM VCs

Examples

- All datagrams for a given TCP connection
- All datagrams between a pair of UDP ports
- All datagrams on an IP multicast tunnel
- All ICMP datagrams between a host pair

Mapping IP Datagrams onto a Virtual Circuit

IP (and TCP, UDP, ICMP) headers to determine conversations

Version	Hdr Ln	Prec	TOS	Total Length			
ID				Flags	Fragment Offset		
TTL		Protocol		Header Checksum			
Source Address							
Destination Address							
Source Port				Destination Port			
TCP Sequence Number							
TCP Acknowledgment Number							
Hdr Ln	Rsrvd	Flags		Window Size			
TCP Checksum				Urgent Pointer			

Determination of Requirements

Goal is *not* end-to-end performance guarantees, but improved performance across ATM subnet

Well-known applications

- For applications whose needs and traffic characteristics are known
- Identified by fields in upper-layer protocol headers
- Example: `telnet`

Monitoring traffic

- Adaptive algorithm for determining bandwidth requirements
- Long-lived conversations only
- Example: Video transmission with user adjustments

Determination of Requirements

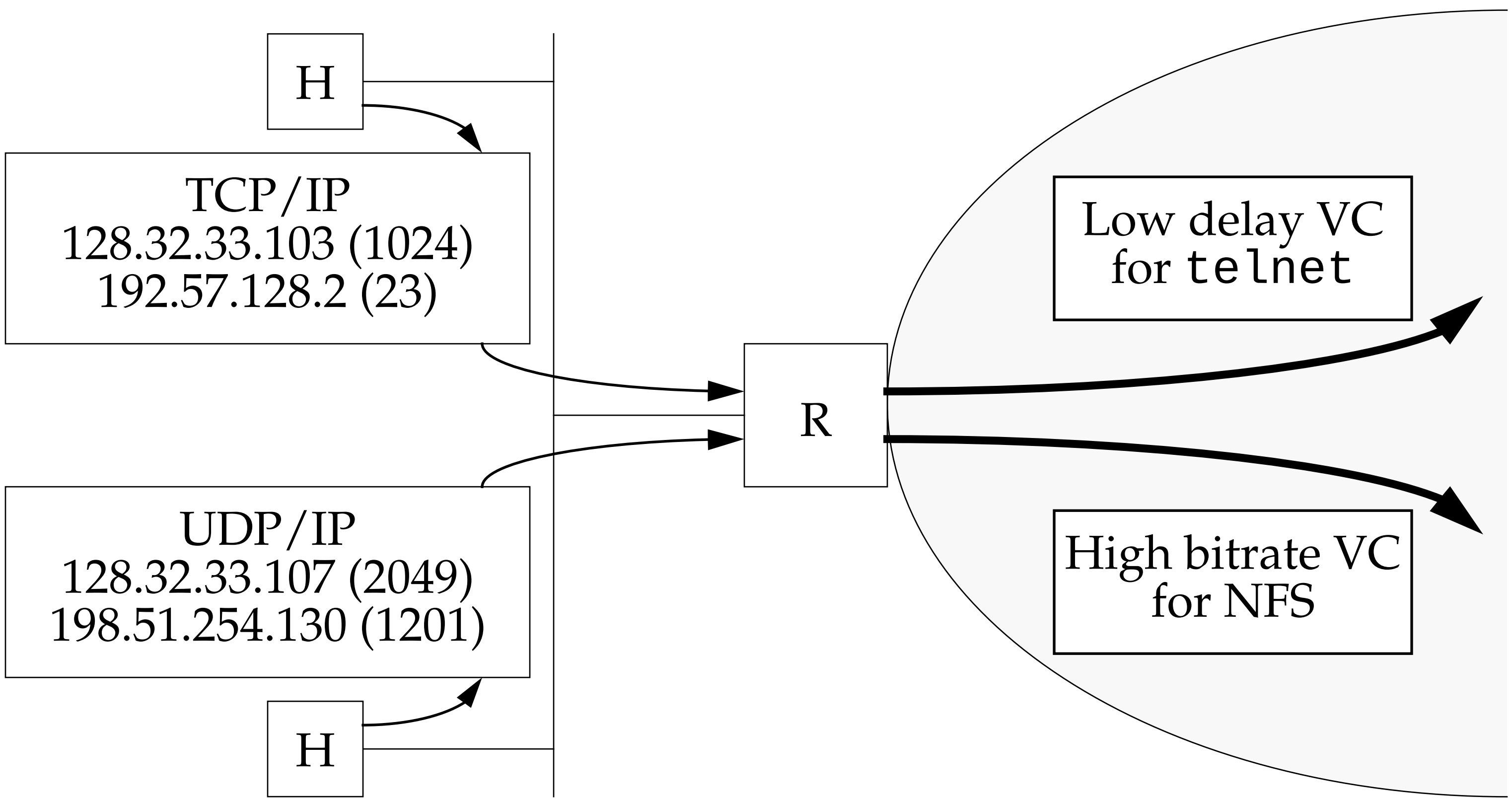
Explicit signalling

- Disadvantage: needs support by application
- In-band (e.g. IP TOS/Precedence, IP options)
- Out-of-band with a signalling protocol (e.g. RCAP, RSVP)

Default requirements

- For traffic not cover ed by other means
- "Best effort"?

Datagram to Virtual Circuit and QOS Mapping



Multiplexing with QOS Considerations

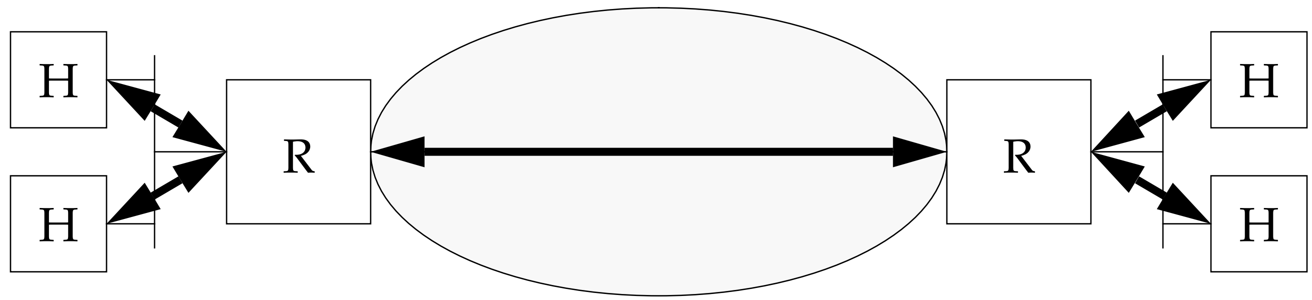
Tradeoff

- Protection of individual IP conversations
- Increased utilization of reserved resources due to statistical multiplexing

Levels of Multiplexing

- Virtual circuit per router pair—Most commer cial ATM LANs
- Virtual circuit per host pair
- Virtual circuit per application per host pair—R. Cácer es (1992)
- Virtual circuit per IP conversation
- Combinations

Virtual Circuit Per Router Pair



All traffic between a pair of routers routed over same virtual circuit

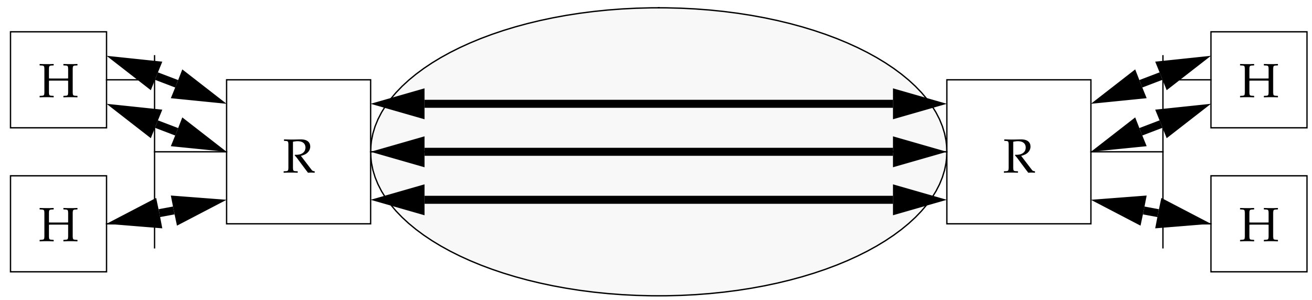
Statistical multiplexing of conversations over virtual circuit

No protection among conversations sharing a router pair

Uses:

- Low-bitrate or bursty traffic (ICMP)
- Background best-effort traffic (electronic mail)

Virtual Circuit Per Conversation



Each IP conversation seen by a router uses a separate virtual circuit

IP conversations protected from each other over ATM subnet

No statistical multiplexing gain within virtual circuit

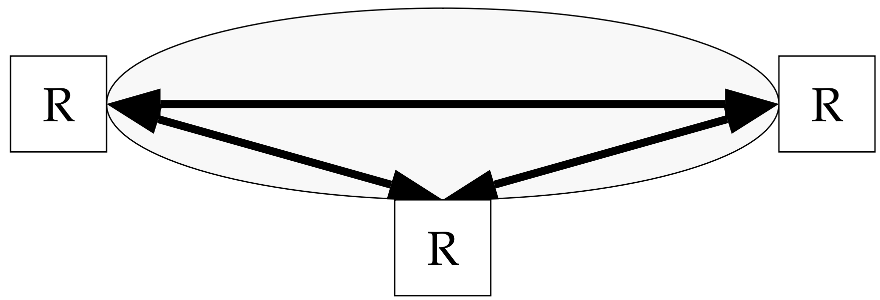
Uses:

- Real-time video
- Interactive file transfer

Virtual Circuit Management with QOS Considerations

- Paradigm shift: ATM connections vs. IP datagrams
  - When to set up and tear down connections for datagrams?
- Tradeoff
  - Resource reservation for QOS-guaranteed virtual circuits
  - Connection setup latency
- Alternatives
  - Permanent Virtual Circuits (PVCs)
  - Switched Virtual Circuits (SVCs)
  - Switched Virtual Circuits with connection caching
  - Combinations

Permanent Virtual Circuits

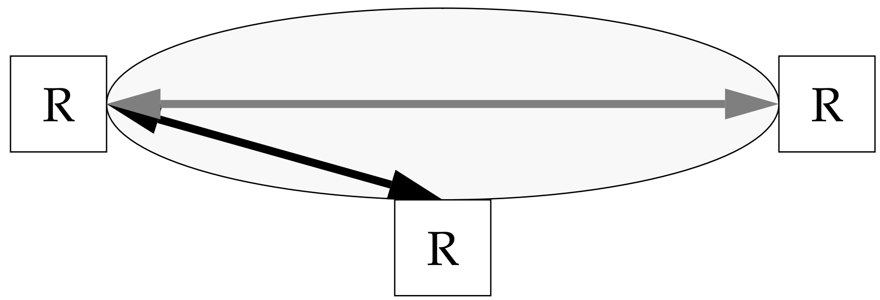


No connection setup latency

Resources always reserved

Scalability a problem: $O(n^2)$ connections

Switched Virtual Circuits



Determine start and end of IP conversations

- First packet $\Rightarrow$ start
- Timeout $\Rightarrow$ end

Connection setup latency incurred

- For first packet of conversation
- For other packets if SVC closed too early

Enhancement: connection caching for other IP conversations

Research Plan

Approach

Evaluate IP over ATM with QOS policies in an actual ATM network

Completed Work

Packet classifier for XUNET II

MBONE Measurements

Future Work

IP over QOS-guaranteed virtual circuits on XUNET

Evaluation of policies

Research Plan—Appr oach

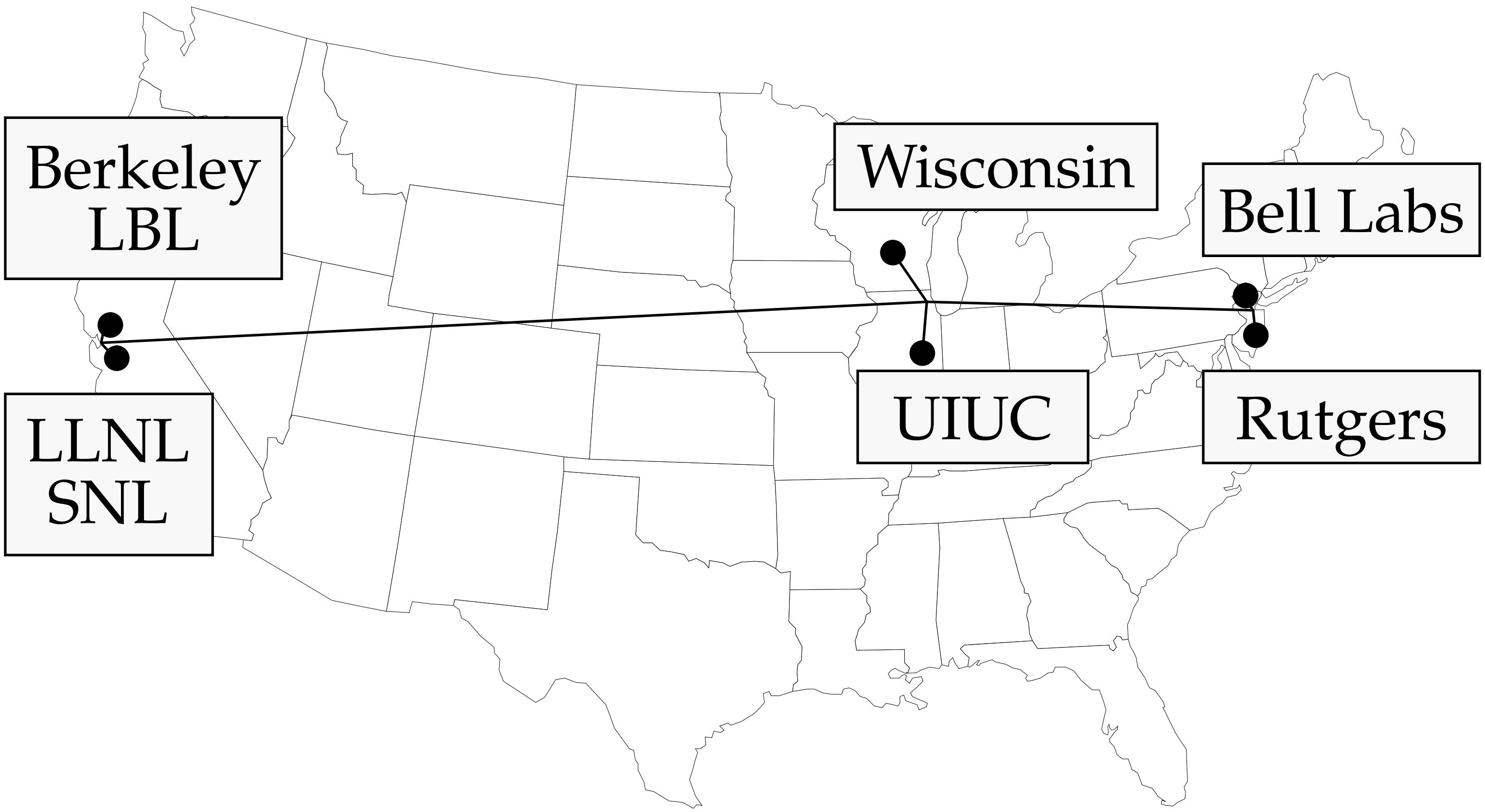
Evaluate policies in an actual wide-area ATM network

- Quality of service mapping
- Multiplexing
- Virtual circuit management

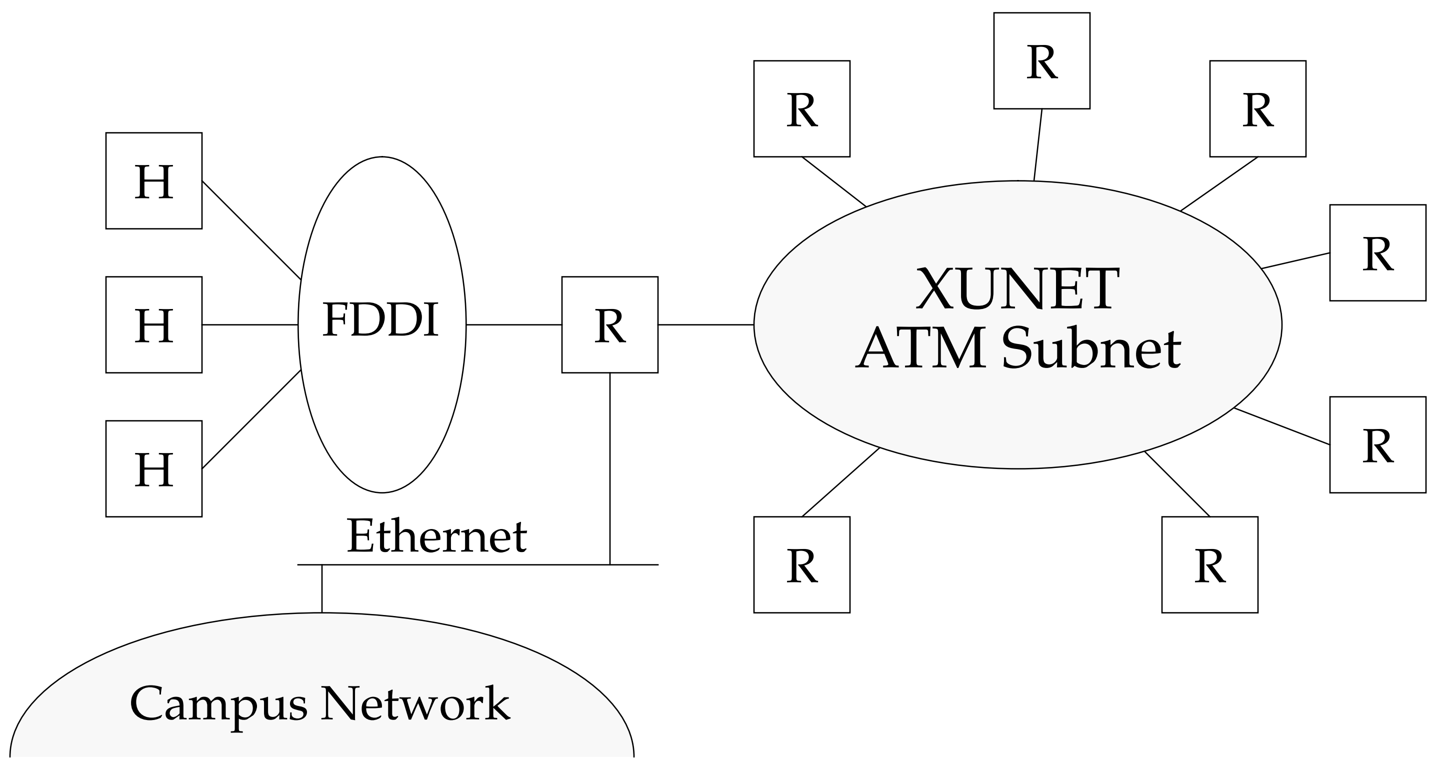
Implementation and Evaluation: XUNET II

- A wide-area ATM backbone network
- ATM/DS3 connecting FDDI LANs
- IP over ATM service in place now (PVCs only)

XUNET II Geographic Topology



XUNET II Logical Topology (IP Layer)



Completed Work—Packet Classifier

XUNET IP driver modified to discriminate among IP conversations

- All TCP connections map to unique virtual circuits
- All UDP streams map to unique virtual circuits
- Aggregation of conversations possible
- No performance degradation observed

XUNET IP over ATM service enhanced to use SVCs

- Virtual circuits created on demand
- Static timeout (15 seconds for initial testing)

Completed Work—MBONE Measur ements

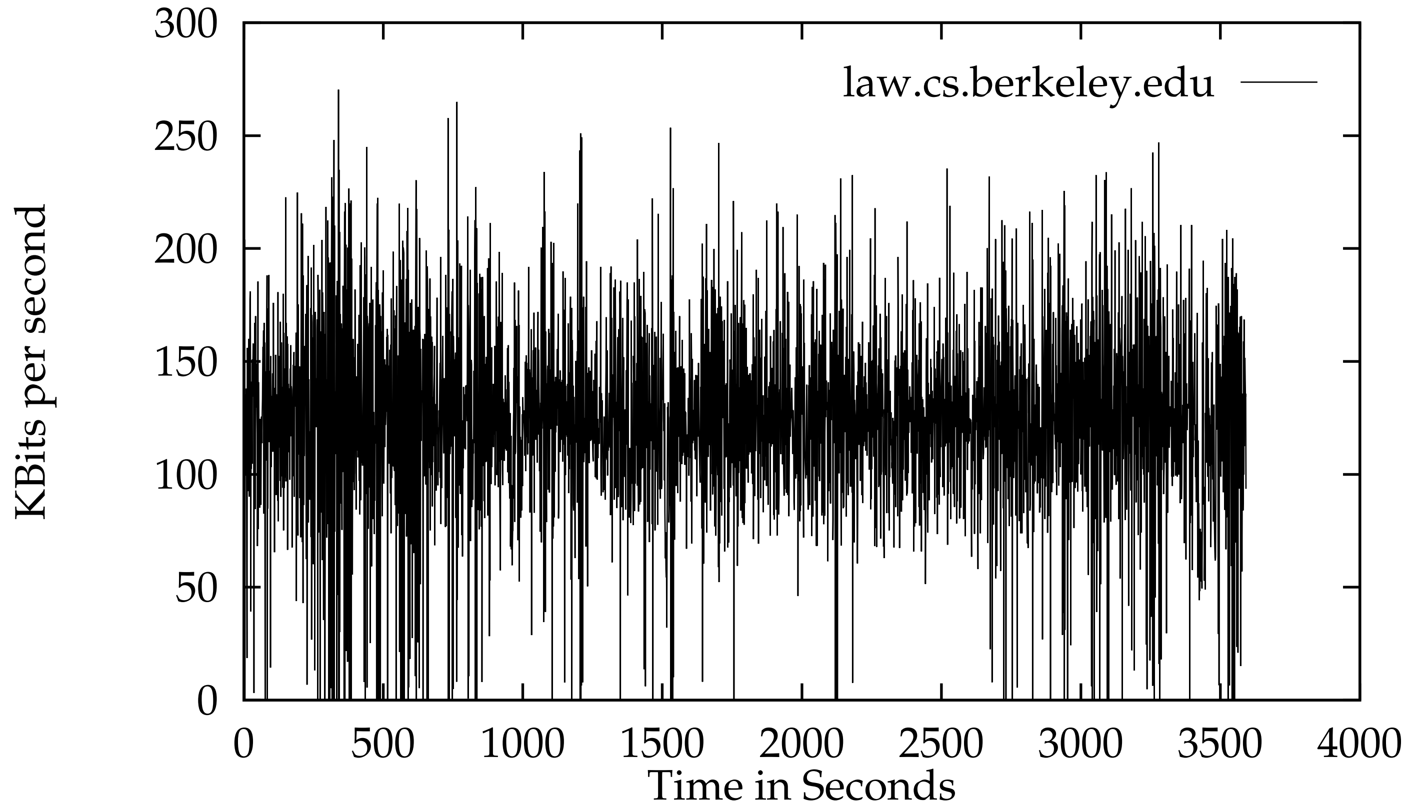
Traditional data applications (`ftp`, `telnet`) well-studied

Little published about audio and video on Internet

Traces taken of MBONE conversations

- Video—`nv`
- Audio—`vat`
- Image distribution—`imm`

Video Bitrate (nv 128 Kbps)



Peak bitrate (one-second samples) 270 Kbps

Future Work

- Obtain QOS-guaranteed virtual circuits over XUNET
  - Scheduling disciplines—H. Saran, et al. (1993)
  - Signalling support—S. Keshav (1994)
- Formulate IP over ATM policies
  - Mapping from IP conversation(s) to QOS-guaranteed virtual circuit
  - Multiplexing policy
  - Virtual circuit setup and teardown policy

Future Work

- Experimental setup
  - Transmit IP traffic from applications
  - Vary intensity and type of cross traffic
  - Measure performance as seen by applications
- Evaluate performance for IP conversations with respect to:
  - End-to-end latency
  - Throughput
  - Setup latency
- Evaluate overall network performance with respect to:
  - Utilization
  - Efficiency and overhead
  - Best-effort performance

Contributions

- Policies and subpolicies for the transmission of IP datagrams over QOS-guaranteed ATM virtual circuits
  - QOS mapping
  - Multiplexing
  - Virtual circuit management
- Criteria and a methodology for evaluating IP over ATM policies
- A working implementation of both a set of IP over ATM policies and any necessary underlying framework
- An evaluation of policies on a wide-area ATM network

Summary

ATM will be incorporated into IP internetworks

Issue: Can the use of QOS guarantees within an ATM subnet be beneficial to IP applications?

- Use of virtual circuits with QOS parameters to carry IP data
- Multiplexing
- Virtual circuit use and management

Evaluate policies on XUNET II, an experimental wide-area ATM network

- Performance of individual conversations
- Performance of network as a whole