195
"Real-time Applications of the Internet,"
N. F. Maxemchuk,
Johns Hopkins University, April 8, 1999.

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TWO INTERNET SERVICES BEYOND THE WEB

PACKET PHONE:

- Right Now It's Free **AND**
  You Get What You Pay For

THE MBONE:

- Video and Audio Distribution To Home PC's
  Of Events With Limited Audiences

PROBLEM:

- *How Should Real Time Services*
  Be Provided By An IP Network ?

http://www.research.att.com/~nfm/

DIFFERENCE IN REQUIREMENTS

- **DATA:**
  - — Near Perfect
  - — Better Off Late Than Wrong

- **REAL-TIME AUDIO or VIDEO**
  - — News, Sporting Events, Conference Sessions, Courses
  - — Natural Redundancy Permits Intelligibility With Errors
  - — A Few Second Delay Is Permissible
    Even With Questions
  - — Lost Phrases Cannot Be Recovered

- **INTERACTIVE AUDIO or VIDEO**
  - — Short Delay To Maintain Conversation
  - — Garbled Phrases Or Lost Seconds Can Be Recovered
    What did you say?
    Preferable to Continuous Noise

PACKET VOICE

Define The Quality Of A Connection

The Loss Measures Used For Telephone Networks Are Not Appropriate For Packet Voice On The Internet

Determine The Effect Of

Receiver Delay And Packet Replacement Stratagies

Intrastate, Cross Country And International Connections

Take Different Views Of Data:

Average, Time Of Day, Specific Connections

An Observation On Internet Voice

THE MEASUREMENTS

Between

From Rutgers Univ. *To* Murray Hill, N.J.

From U.C. Berkeley *To* Murray Hill, N.J.

From GMD - Berlin *To* Murray Hill, N.J.

Measure The Delay Of

One Packet Every 20 msec.

For 10 Minutes Every Hour

For 14 Days

QUALITY OF A CONNECTION

The Fraction of the Time That A Receiver Obtains An Active Speech Interval Without Distortion.

— Distortion Is Caused By Missing Packets
Lost OR Late
That Are Not Replaced By Interpolation.

— Interaction between QOS, Receiver Delay, and Interpolation

Average Active Speech Interval = 1.3 seconds

T_{min} = Minimum Error Free Interval

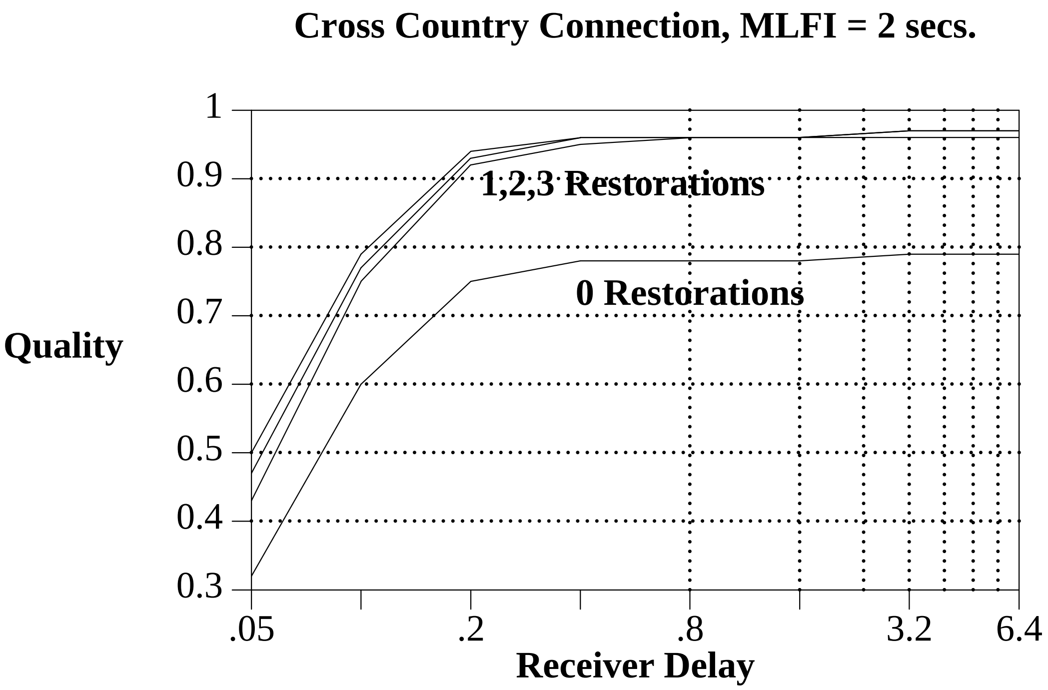
T_e = Time Between Successive Missing Packets

$$Fraction = \frac{\sum (T_e > T_{\mathrm{min}})}{Time\ of\ Connection}$$

Conclusion: T_{min} isn't Critical

Set at T_{min} = 2 seconds

RESTORING LOST PACKETS



Conclusion: Restore Single Lost Cells

When there is more than one lost cell it is likely that there are too many to restore accurately

Observation: 2 Loss Mechanisms

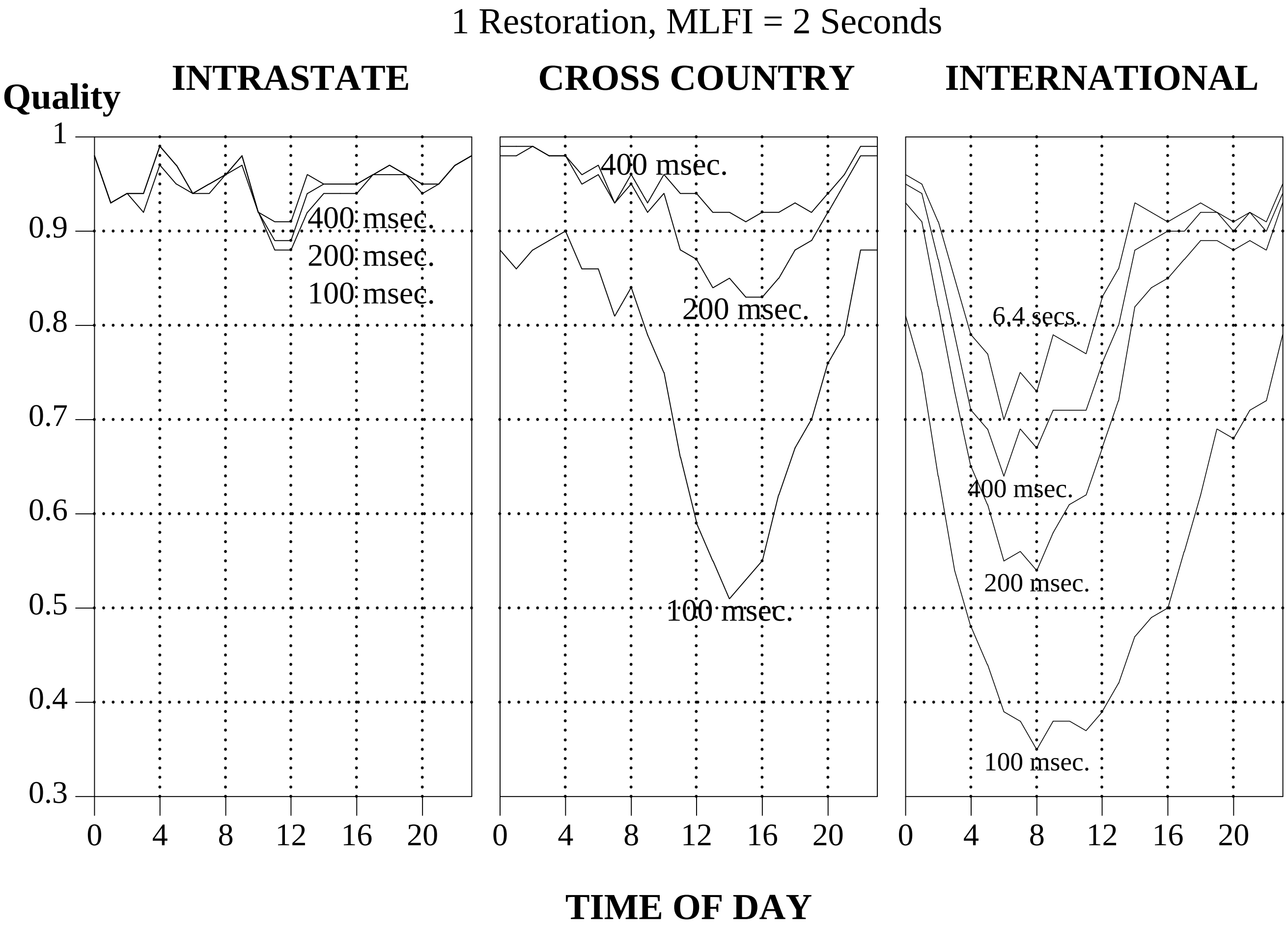
Random Losses -> *Single Lost Cells*
Bad States -> *Burst of Lost Cells*

Same Results For:

Intrastate, Cross Country and International Circuits
MLFI = .5, 1.0, and 2.0 seconds

SETTING THE RECEIVER DELAY

Packet Delay - Min. Packet Delay



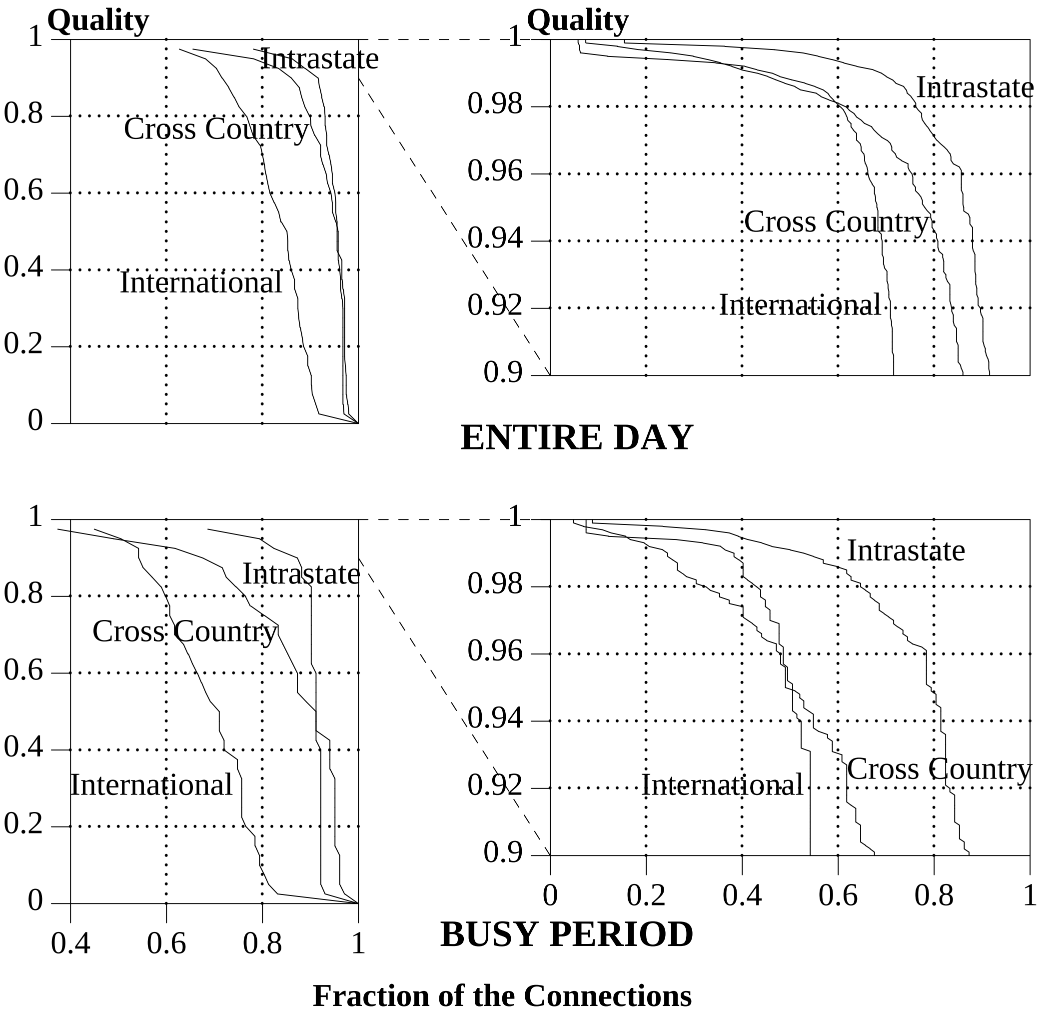
Observations:

— The Further You Go,
The More Chances for Delay Variation

— On Intrastate: Dependence on Time of Day
Is Less Than I Would Expect
Effect of Using Internet at Home?

THE CONNECTIONS THAT EXCEED A QUALITY

1 Restoration, MLFI = 2 Seconds
Receiver Delay= 100 msec.*(Intrastate)*; 200 msec.*(Cross Country)*;
400 msec.*(International)*



International Connections: *During The Busy Hour*

— On 20% of the Connections,
  Almost *NO* Speech Intervals get Through

— On 50% of the Conections,
  Almost *ALL* Speech Intervals get Through

AN ANTISOCIAL OBSERVATION

If We Suppress Packet Xmission During Silent Intervals
The Fraction Of Active Intervals With Loss Increases

If We Double Packet Xmissions During Silent Intervals
The Fraction Of Active Intervals With Loss Decreases

Good Engineering Doesn't Pay ?

THE PROBLEM WITH TCP

TCP Flow Control Depends Upon Cooperation
The Internet Is Now Competitive

Evolution:

Reno, Taho, Multicast

Aggressive TCP

Competitive Advantage:

Perverse Proxies

An Open Problem:

Policing and Penalty Boxes

Freezes TCP in the Network

California Congestion Control:

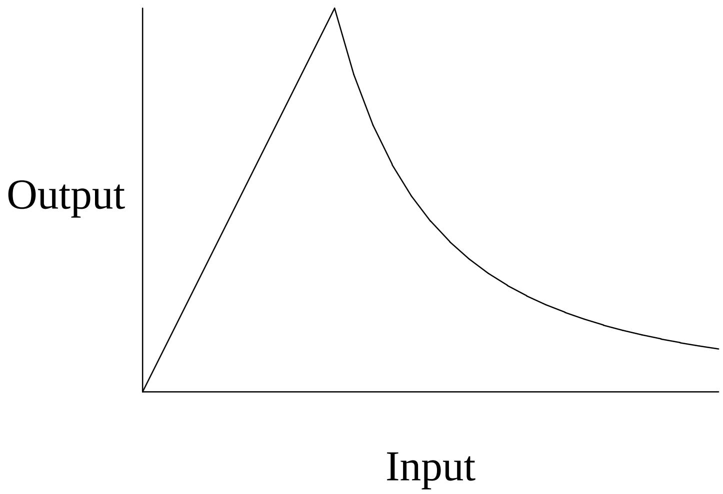
Right Direction *BUT* ...

CCC With An Arrival Dependent Penalty Box

Can't Adjust Rate or Window for an RTD

IT’S TIME TO STOP FREE WHEELING

Match An Objective Function



— Try Solutions With Different Amounts of Work

— Cost Associated With Network Resources Wasted By Failed Packets

— A Different Definition of Fairness

A MULTICAST PROTOCOL
FOR REAL TIME VIDEO OR AUDIO

1. OBSERVATION

— Mbone Video Retransmission Is Within The Speed And Memory Capabilities of Current PC's

— Transmission Rate = 128 Kbps
128 KBytes of Memory = 8 Seconds
Enough for 2 or 3 Retrys, Most of the Time

2. DIFFERENCES BETWEEN VIDEO OR AUDIO AND DATA

— Continuous Transmission *VRS* Stop And Wait
NACK Instead of ACK

— Inherent Redundancy Makes Imperfection Acceptable
Stop Retrying After Small Number of Attempts
Retransmit Server and Source Not Colocated

DESCRIPTION OF THE PROTOCOL

THE PLAYERS

1. **THE SOURCE**
   — Multicast Packets (*Including Sequence Numbers* - *RTP*)

2. **THE RETRANSMIT SERVER** *(Near the Source)*
   — Receives Multicast Packets From The Source
   More Than Distant Receiver
   — Retransmits Packets When A NACK Is Received

3. **THE RETRANSMIT CLIENT**
   — Receives Multicast Packets From The Source
   — Requests Missing Packets From The Retransmit Server
   Based on Sequence Numbers
   — Multicasts Repaired Sequence
   After K Seconds

4. **THE RECEIVERS** *(Near the Retransmit Client)*
   — Non-Participants - Receive Multicast From The Source
   — Participants - Receive Repaired Multicast

UNIQUE CHARACTERISTICS

— Implemented Without The Cooperation of the Source or Receivers
Improve the Quality of Existing Mbone Broadcasts

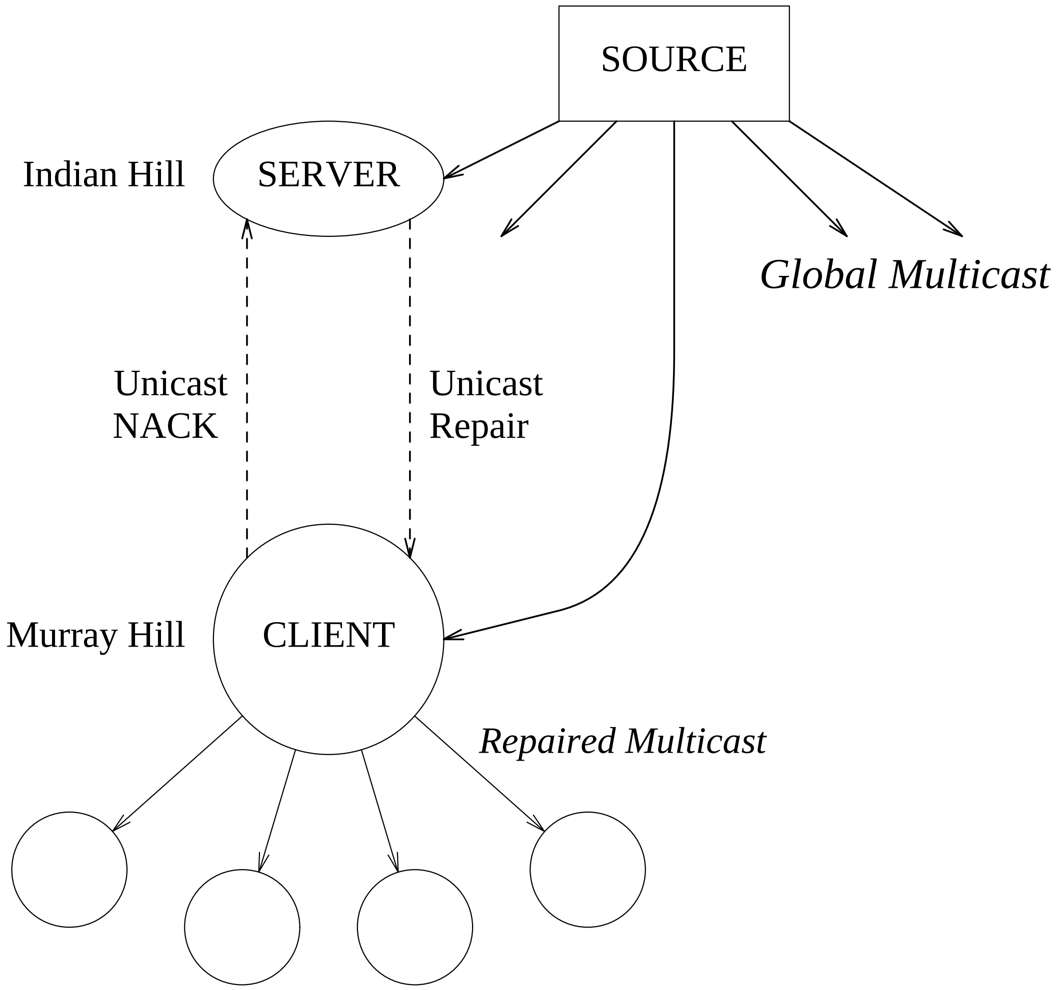
— Improves Quality For Some, Not All, Receivers
Provides a Service That An ISP Can Sell

— Fewer Active Participants
Simpler Than Most Reliable Multicast Protocols

— Network Variables Are Learned Rather Than Predicted
It Is Almost As Good to Be Right From Now On
As To Have Always Been Right

EXPERIMENTAL CONFIGURATION

Server and Source on the Same LAN

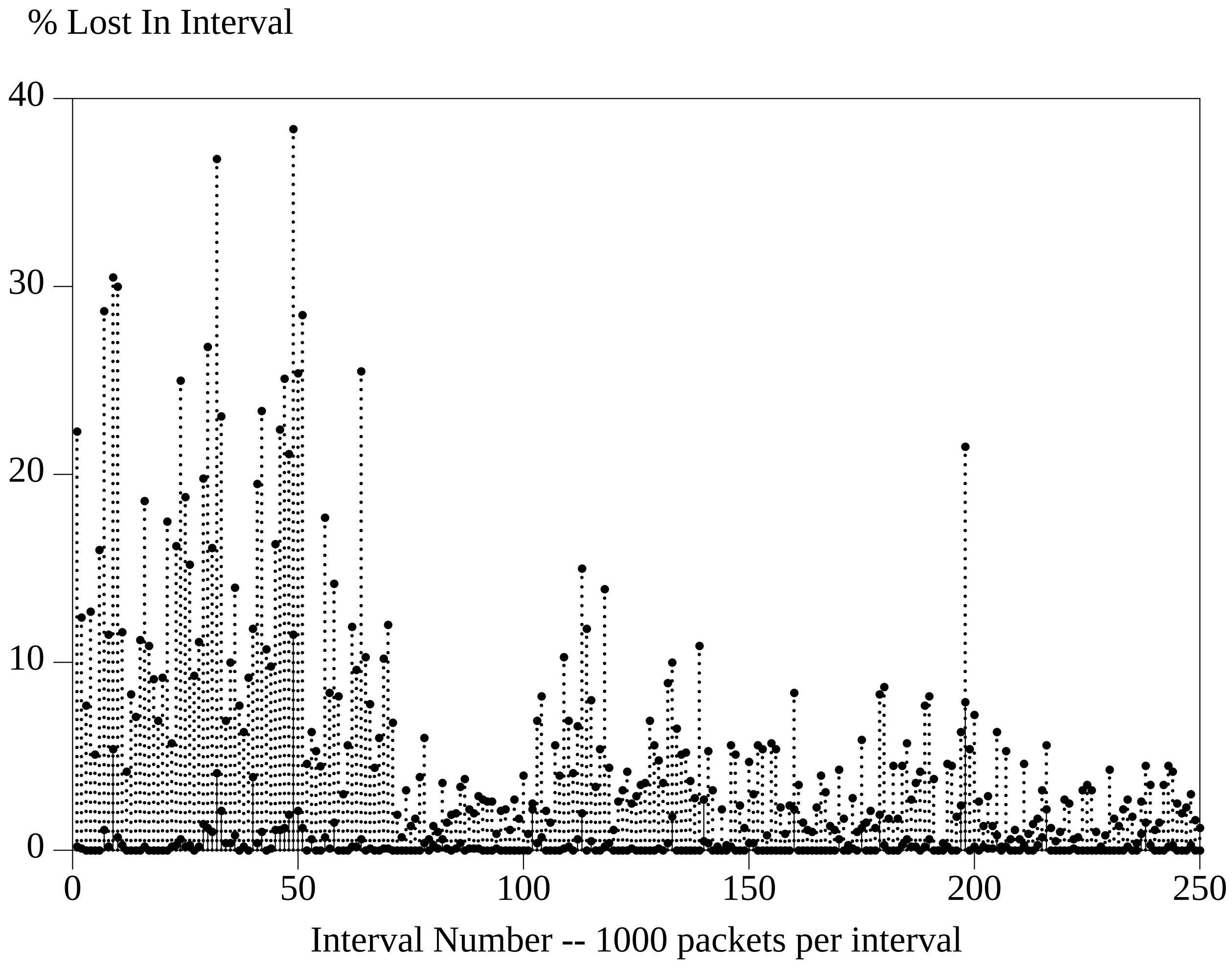


TYPICAL SESSION

2 ADJACENT RECEIVERS

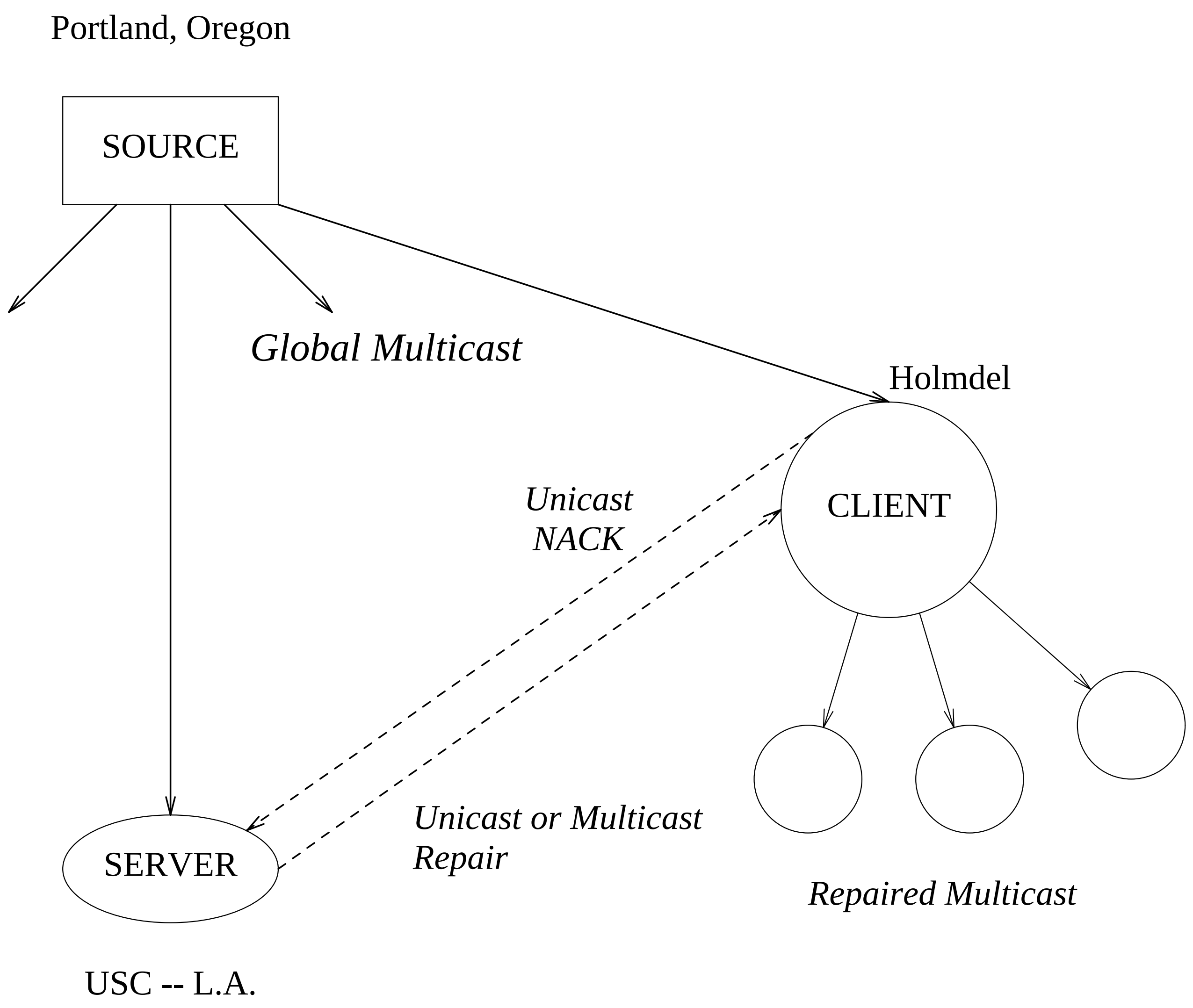
"." Receives Raw Multicast

"." Receives Corrected Multicast



EXPERIMENTAL CONFIGURATION

Server and Source Far Apart



REPAIR STRUCTURES

Objective: To Define a Recovery Graph That Recovers *Most* of the Available Messages While Using The *Least* Network Resources

-*An Apples And Oranges Cost Function*

Importance: A New Repair Graph For Each Source

Observations: On A Multicast From Berkeley

Losses Are Correlated In Time

- The Quality Of The Multicast At Each Site Changes
- *The Strategy Should Be Adaptive*

Losses Are Correlated In Position

- Most Server's In Europe Miss The Same Messages.
- *One European Server Recovers From The US and Supplies The Others*

Multicast And Rexmit Losses Are Correlated

- A Server In NJ Recovered More Packets From A Server At USC Than A Server At San Jose, Even Though The Server At San Jose Had More Of The Missing Messages.
- *Separate Rexmit Graph And Multicast Tree*

A PRACTICAL SOLUTION

Objective: Design A Recovery Graph That Can Recover Most Messages While Using The Least Network Resources

Static Component - *Dependent On Network Cost*

Rexmit Cluster - 2 or 3 Nodes With Most Received Messages
- Fully Connected

2 or 3 MST's From Cluster To Other Nodes
- *Work In Progress*
- Link Disjoint
- Survive Failed Nodes

Adaptive Component - *Dependent On Current Losses*

Sequentially Request Missing Messages From Nodes On The Recovery Graph

Order Depends On Recent Successes

Missing: Information About The Multicast Tree

THE IMPORTANCE OF REAL TIME, IP TRAFFIC IS INCREASING

The WEB is Bringing Real Time Traffic To The Masses:

Real Audio, Real Video, ... Victoria's Secret

Phone Companies Are Committing To IP

Separate Services and Xmission, As On The Internet

— Services No Longer Dependent on 64kbps

Vertical Integration vrs Layered Architecture

— Competition In Local Distribution

DSL, CATV, ...

— Bundled Services

TV, Internet, Telephone

— Introduce New Services Quickly

HOW WILL THE NET SUPPORT REAL TIME TRAFFIC ?

Yet Another Unanswered Question

It May Vary With Distance

QOS On the Private Line From a User To An ISP Can Be Guaranteed By Controlling The Sources.

Priorities Can Provide QOS In A Region Where High Priority Traffic Does Not Saturate The Links
- CISCO - Cooperative Again?

Tokens - Work Best Over Small Number of Hops
- Over The MAN to Gain Access to the WAN

Reserved Resources: Circuits or Shared Bandwidth
- Simplest for Small Number of Aggregated Users
- Large Aggregation Most Likely On the Long Haul

It May Vary With Time

ie: Reserved Resources

Short Term: Dedicated Circuit Per User

Medium Term: Aggregate Traffic So That N Similar Users Share K (<N) Circuits

Long Term: Reservations For Part Of The Shared Bandwidth
- Movable Boundary System