

# Providing End-to-end QoS for Real-Time Applications over the Internet

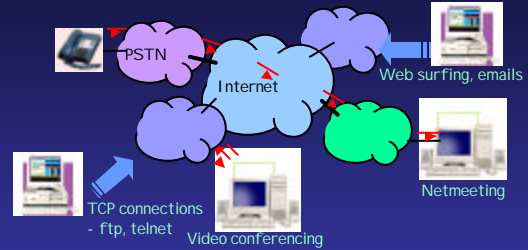
Chen-Nee Chuah

Networking Seminar  
April 6, 2000

ICEBERG Research Group  
Department of Electrical Engineering and Computer Science  
University of California, Berkeley

1

## Problem Statement



- How to support QoS for real-time applications over IP-networks?

2

## Motivation

- Future network architecture: a single "IP-based core" network for wireless, data & voice
  - computer telephony -integration
- Desktop Multimedia applications
  - video conferencing, video on demand, distance learning, electronic classroom

3

## Outline

- **Introduction**
  - Related work
  - Remaining Challenges
- Resource Provisioning via a Clearing House Architecture
- Workload Modeling
- Future Work
- Summary

4

## Why is it hard?

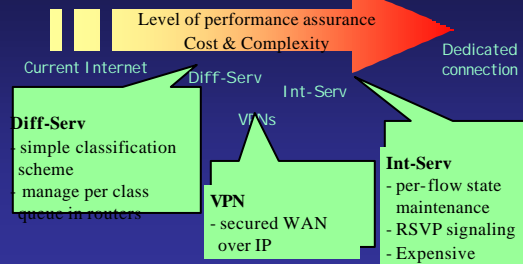
*Goal: Deliver statistical QoS to real-time applications*

- Unpredictable loss and delay in IP-networks
  - impair perceived quality
- Lack of performance assurance in current IP-networks
  - SLAs are vague
- Limited resources in shared access networks
  - switching bandwidth, buffer queues
- Scalability

5

## High-Layer Overview of Related Work

- Network-Layer QoS



6

## Missing Pieces

Limited understanding on

- Control plane/policy framework
  - How to regulate resource provisioning across multiple domains?
  - A Clearing House Architecture: coordinate aggregate resource reservations
- Characteristics of new workloads
  - Traffic characteristics of packet audio in several multimedia applications

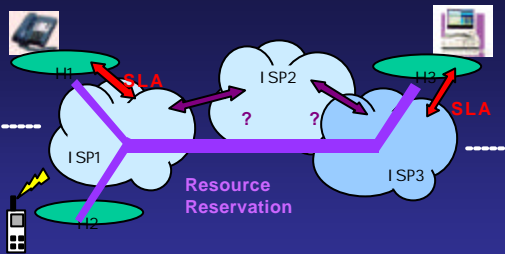
7

## Outline

- Introduction
- Resource Provisioning via a Clearing House Architecture
  - Clearing House Infrastructure
  - Predictor-based Advanced Reservations
- Workload Modeling
- Future Work
- Summary

8

## Present Scenario



- SLA: Agreements that describe the volume of traffic exchanged, bandwidth reserved and price

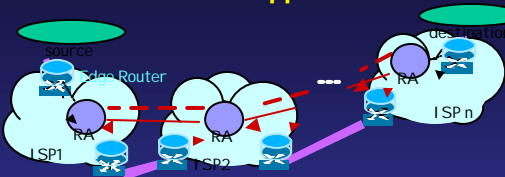
9

## Open Issues

- Resource Provisioning
  - How are peering SLAs established between two domains? multiple domains?
- Adaptive Reservations
  - How to adapt aggregate reservations based on traffic fluctuation?
  - What are the trade-offs between granularity, QoS and signaling complexity?
- Admission Control
  - End-to-end?
  - In stages: Per ISP cloud? Per domain?

10

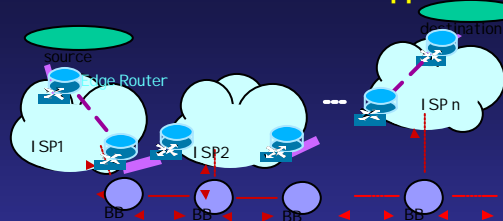
## Int-Serv Approach



- End-to-end per-flow reservation
- End-to-end admission control
- Per-flow state information: potential bottleneck

11

## Diff-Serv Bandwidth Broker Approach



- Coarse-grained performance assurance
- Admission control at the Edge Router
- Trade-off end-to-end QoS for scalability

12

### Our Approach: Clearing House

- Coordinates resource provisioning between multiple domains to provide statistical QoS
  - Performs path discovery based on QoS constraints
  - Performs local admission control
  - Setups and re-negotiate resource reservations
  - Services wide-area call requests

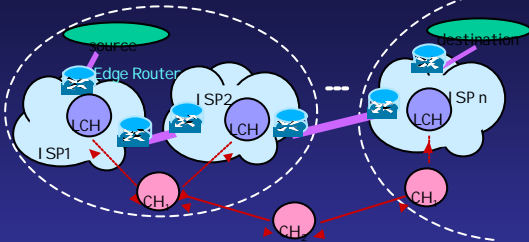
13

### Design Goals

- Deliver finer-grained statistical QoS
  - Graceful degradation under heavy load
  - Preserve existing connections
- Retain scalability of state-less approach
- Optimize network utilization
  - Statistical multiplexing, dynamic reservations
- Continuous path monitoring for dynamic routing
- Easily extended to support multicast, mobility and secure billing

14

### Proposed Clearing House Architecture



- Introduce logical hierarchy
- Distributed database
  - reservation status, % link utilization, optimum path

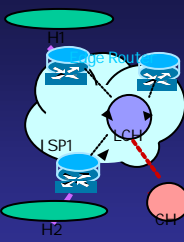
15

### Assumptions

- Networks are capable of supporting differentiated service levels
- Traffic statistics and network performance can be easily measured
  - Monitoring system or ISPs
- Control and data paths are separate

16

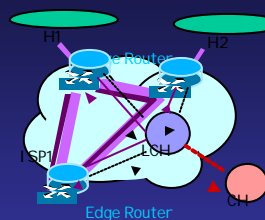
### Clearing House Infrastructure



- Local Clearing House**
- Maintains intra-ISP reservation status
    - BW reserved, % link utilization, network performance, optimum path
  - Service intra-ISP reservation requests
    - Local admission control based on reservation status
  - Acts as a monitoring agent for external traffic
  - Sends regular update to parent CH-node

17

### Static & Dynamic Reservations



**Static Reservation**

- Based on mean and variance of aggregate traffic for different time of the day

**Dynamic Reservation**

- Adapt reservations on a smaller time-scale based on existing reservation and bandwidth predictor

18

### Clearing House Nodes

- Store inter-ISP network state within its domain
- Setup static reservations using aggregate traffic statistics
- Service reservation requests from LCHs
  - Local admission control and adapt reservations
  - Forward requests to parent-CH

19

### Resource Reservation Strategies

- Separate resource reservation and call-setup
- Aggregation of reservation requests
- Hierarchical approach
- De-couple notifications & reservation requests

**Notifications (every  $T_n$ , s)**

- Reservation status
- Link utilization
- Bandwidth predictor

**Adapt Reservations**

- Advance reservations
- Process reservation requests

20

### Using Traffic Predictor

- Traffic monitoring
  - Online measurement of aggregate rate of incoming & outgoing traffic
- Local Gaussian predictor for static reservations
  - Larger time scale (e.g. an hour, minutes)
  - $\mu = m \cdot \sigma \cdot \ln \frac{1 + \sqrt{1 + 4 \cdot \sigma^2}}{2}$
  - Compensate for the coarse granularity of the notifications & allow local admission control
- Measurement and re-negotiation interval:  $T_{mea}$

21

### Performance Evaluation via Simulation

- Traffic predictor
  - How well does the predictor track the traffic fluctuation?
  - Choice of estimation window, % over-provisioning
- Overall performance metrics
  - Throughput
  - Percentage Call-dropping
  - Mean response time to reservation requests

22

### Simulation Model

- Simulate a CH-architecture for one logical domain

23

\* Collaboration with Lakshminarayanan Subramanian: RxW Scheduling

### Simulation Study: Network Topology

- vBNS Backbone Network Map (1999)

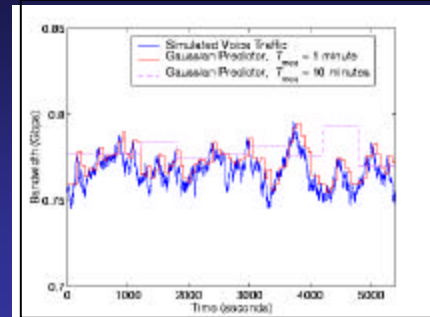
24

### Simulation: Workload Model

- Two QoS classes
  - High priority voice calls and video conferencing
  - Best-effort data traffic (e.g. web, telnet, ftp)
- Traffic model
  - Voice calls
    - Poisson arrivals, mean duration of 120 s
    - Traffic load ??? Erlangs
  - TCP connections get equal share of the non-reserved bandwidth

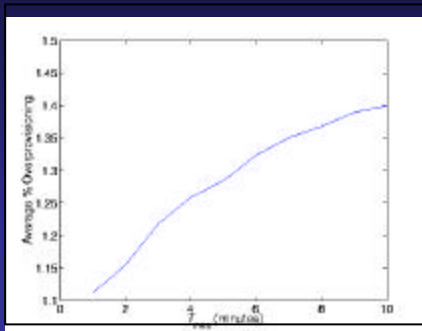
25

### Predictor Characteristics



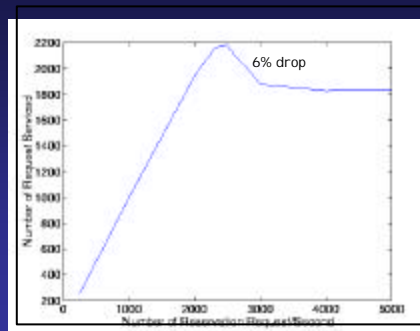
26

### % Over-provisioning Vs. $T_{mea}$



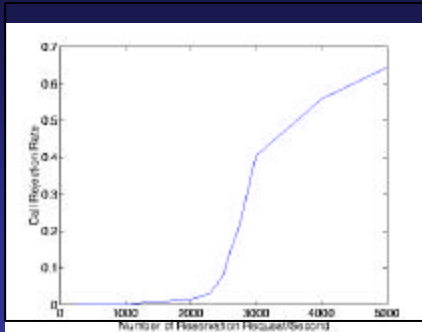
27

### Average Throughput



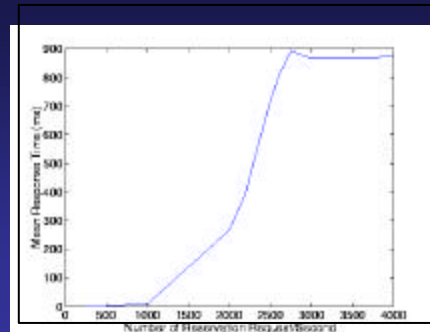
28

### Call Rejection Rate Vs. Load



29

### Mean Reservation Request Service Time



30

## Advantages

- Maintain scalability through aggregation of reservation requests
- Core routers only maintain coarse-grained network state information
- Reduce reservation setup time
  - Static reservations allow fast admission control decisions
- Speed up optimal path selection
  - Hierarchical storage of network status vs.. trial-and-error approach
- QoS assurance
  - Static and dynamic reservations
  - End-to-end coarse-grained admission control by traversing the hierarchical CH-tree

31

## Outline

- Introduction
- Resource Provisioning via a Clearing House Architecture
- **Workload Modeling: Packet Voice**
  - **Traffic Characterization**
  - **QoS Mapping**
- Future Work
- Summary

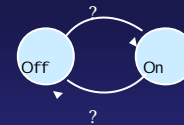
32

## Why Packet Voice?

- *Packet voice: real-time transmission of digitized audio information in packets*
- Wider Range of Applications
  - VoIP (Voice over IP)
    - Large-scale deployment expected
  - Desktop multimedia conferencing
    - Audio, video and mediaboard: audio quality is more important
  - Distance learning (remote lecturing)
  - Electronic classroom/seminar
  - Broadcasting
    - delivery of news & entertainment programming

33

## Traditional Voice Model



- Single speaker: On-off model
- Talkspurt & silence periods are exponentially distributed
  - $1/\lambda = 0.650$  s
  - $1/\mu = 0.352$  s
  - Activity cycle = 0.35

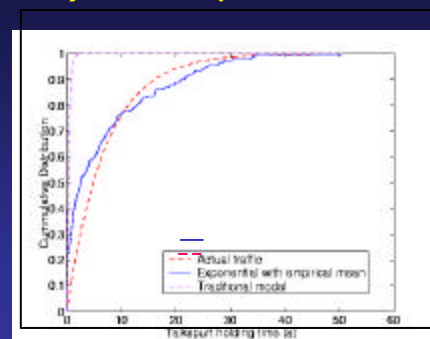
34

## Traffic Characteristics

Type	Mean Talkspurt	Mean Silence	Activity Cycle
Lecture w/o interruption	14.62 s	0.22 s	0.98
Lecture w/ interruption	14.75 s	3.52 s	0.73
Audience	5.04 s	98.66 s	0.17
Group conferencing	101.26 s	1.89 s	0.97
<b>Traditional model</b>	<b>1.004 s</b>	<b>1.587 s</b>	<b>0.39</b>

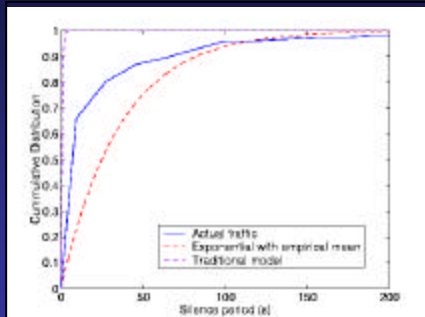
35

## Rejection of Exponential Model



36

## Rejection of Exponential Model



37

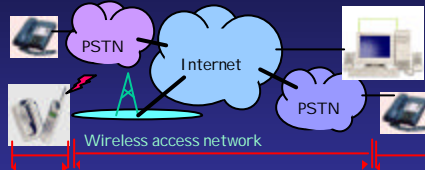
## Statistical QoS

- Map application-level performance requirements to network centric parameters
  - packet delay and/or jitter
  - packet loss rate
- Statistical QoS
  - Upper bound for the actual packet delay and loss rate
  - More predictable performance
    - delay and loss profile

38

## Packet Voice: Delay Requirements

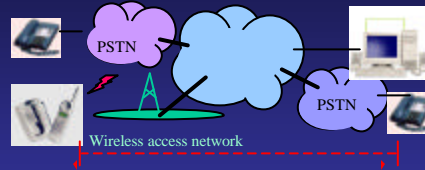
- Acceptable one-way delay: 0-150 ms (ITU-T G.114)
- transmission + propagation + queuing delay



- Packetization & transcoding delay is negligible (e.g. 0.75 ms PCM)
- Propagation delay relatively fixed, can be estimated.
  - 80 - 100 ms (Public Land Mobile System)
  - 12 - 110 ms (satellite depending on altitude)

## Packet Voice: Delay Requirements

- Acceptable one-way delay: 0-150 ms (ITU-T G.114)
- transmission + propagation + queuing delay



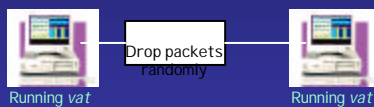
- Queuing delay: variable, need to be bounded

Worst case analysis: total queuing delay < 50 ms  
 => Assume 10\* hops, per hop queuing delay < 5 ms  
 (Vern Paxson's results: 8-12 hops typical across U.S.)

40

## Packet Audio: Loss Rate Requirement

- Subjective Testing
  - Map perceived quality to packet loss
- Experimental settings\*
  - 3 sentences in random order (6-10 seconds each)
  - 64 Kbps PCM  $\mu$ -law, 20 ms samples per packet
  - Ask 25 subjects evaluate the perceived quality

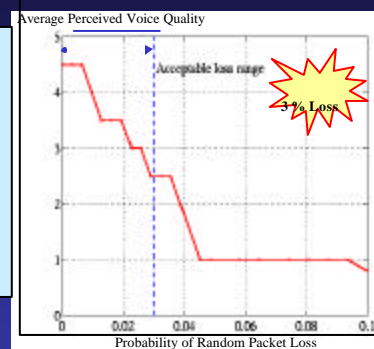


\* Collaboration with Annette Tassone, Lucent Technologies.

41

## Packet Audio: Loss Rate Requirement

- 5: Crystal clear
- 4: Can be comprehended without much effort.
- 3: A little choppy
- 2: Hard to understand
- 1: Incoherent
- 0: Gibberish

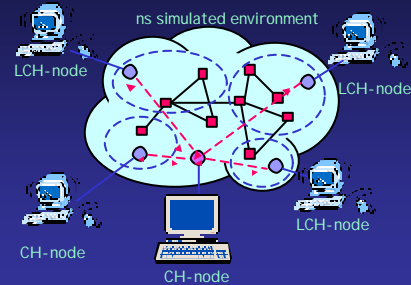


## Outline

- Introduction
- Resource Provisioning via a Clearing House Architecture
- Workload Modeling
- **Future Work**
- Summary

43

## Wide-Area Emulation Using NS



44

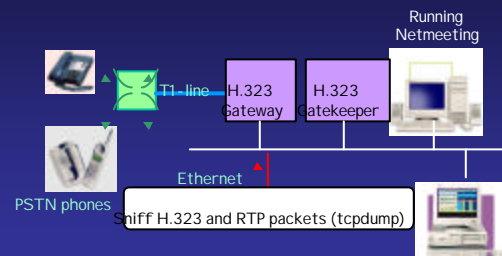
## Comparisons to Int-Serv & Diff-Serv

- Quantify trade-offs
  - Signaling overhead
  - End-to-end QoS
  - Network utilization
- Sensitivity analysis: effect of aggregation on QoS and complexity
  - Completely localized admission control vs.. end-to-end and hybrid

45

## Trace Collection

- VoIP: packet voice through H.323 gateway using the ICEBERG CTS (Jimmy Shih)



46

## Outline

- Introduction
- Resource Provisioning via a Clearing House Architecture
- Workload Modeling
- Future Work
- **Summary**

47

## Summary

- A Clearing House architecture is proposed to coordinate resource reservations and admission control across multiple domains
  - maintains scalability
  - delivers finer-grained QoS assurance than Diff-Serv
  - shortens reservation setup time
- Traditional model fails to approximate packet voice traffic in many multimedia applications
  - Actual traffic shows longer talkspurt and silence periods
  - Holding time in each state is not exponentially distributed

48

## URLs

- <http://www.cs.berkeley.edu/~chuah/research/>
- <http://iceberg.cs.berkeley.edu/>

49