

Assessment of VoIP Quality over Internet Backbones

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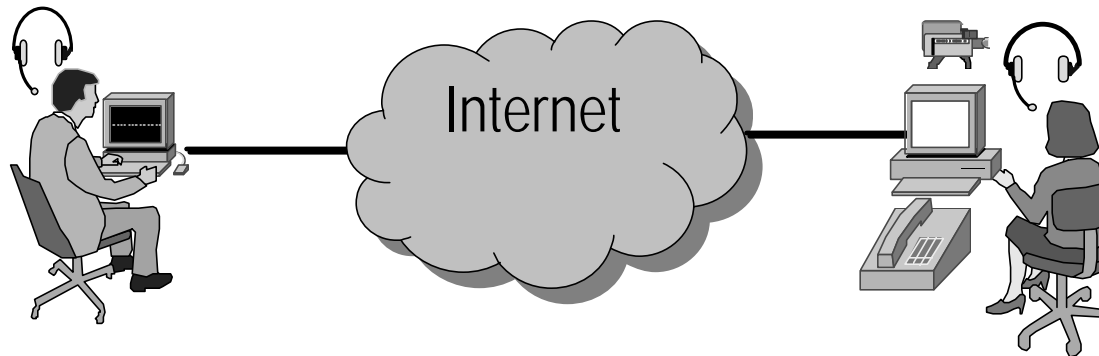
RouteScience Technologies, Inc.



INFOCOM 2002, 06/25/02

Motivation

- The Internet has been successfully used to support data applications.
- Desirable to support more applications.
 - Voice over (IP)
 - Strict quality and interactivity requirements.
 - Users have high quality expectations.

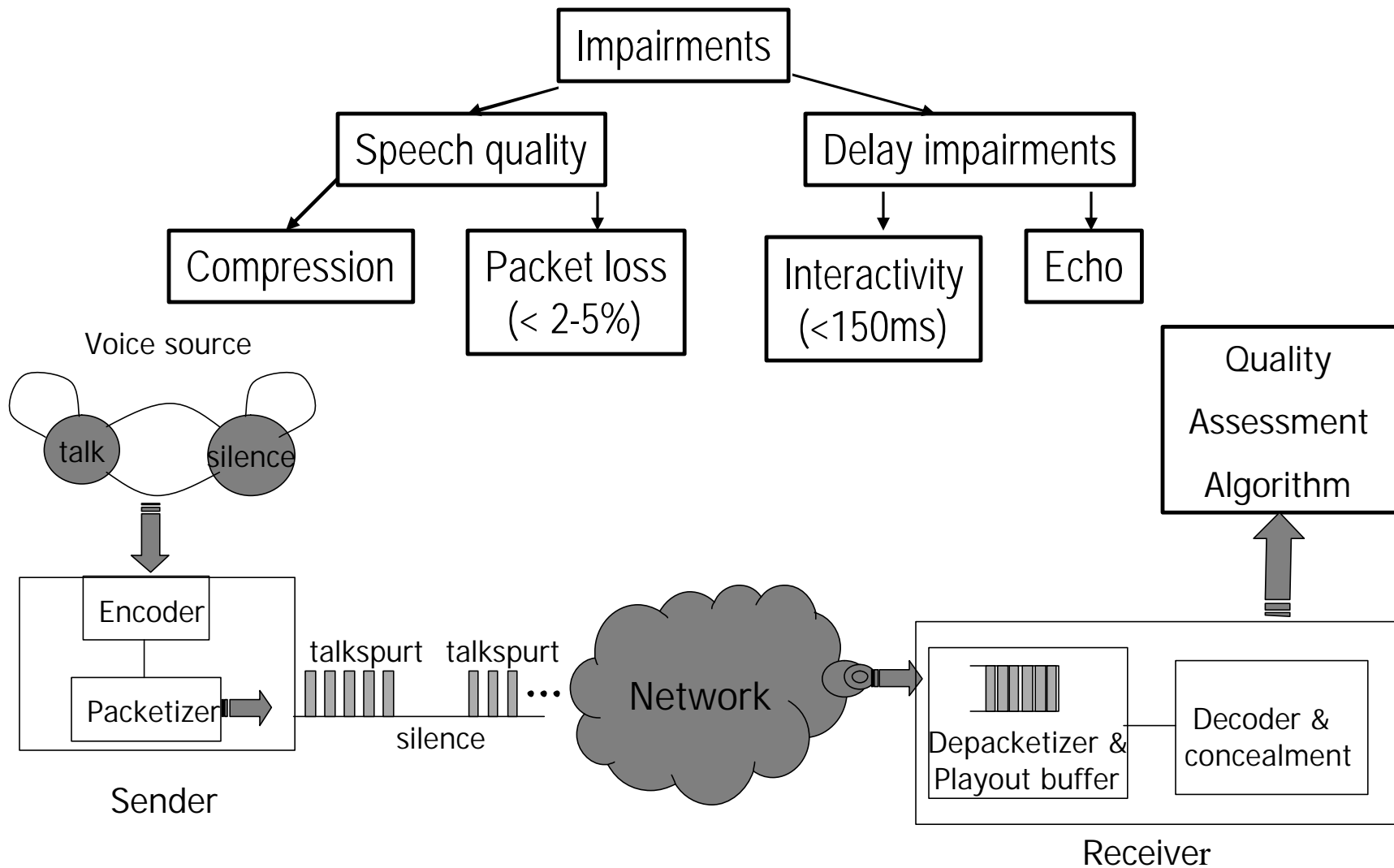


- Question:
 - How well does the Internet support voice communications today?

Outline

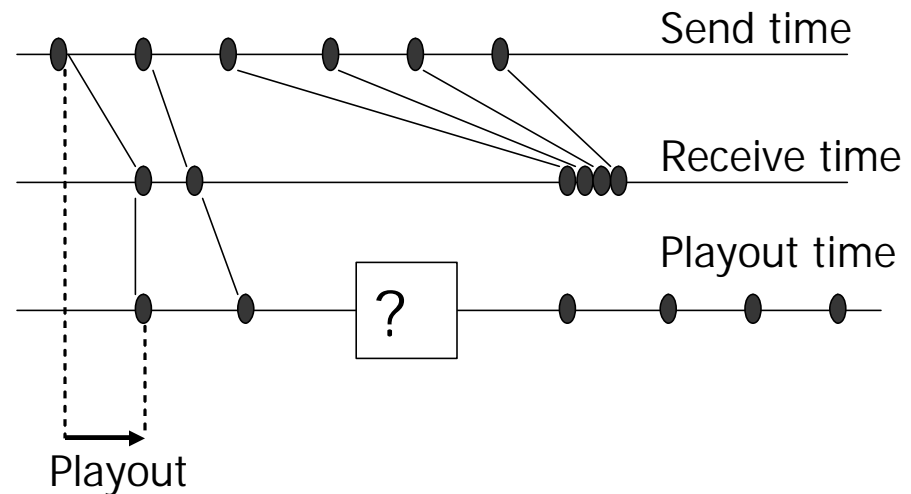
- VoIP System and Impairments
- Measurements of ISP backbones
- Voice Quality Assessment
- Numerical Results
- Summary

VoIP system and impairments



Playout Scheduling

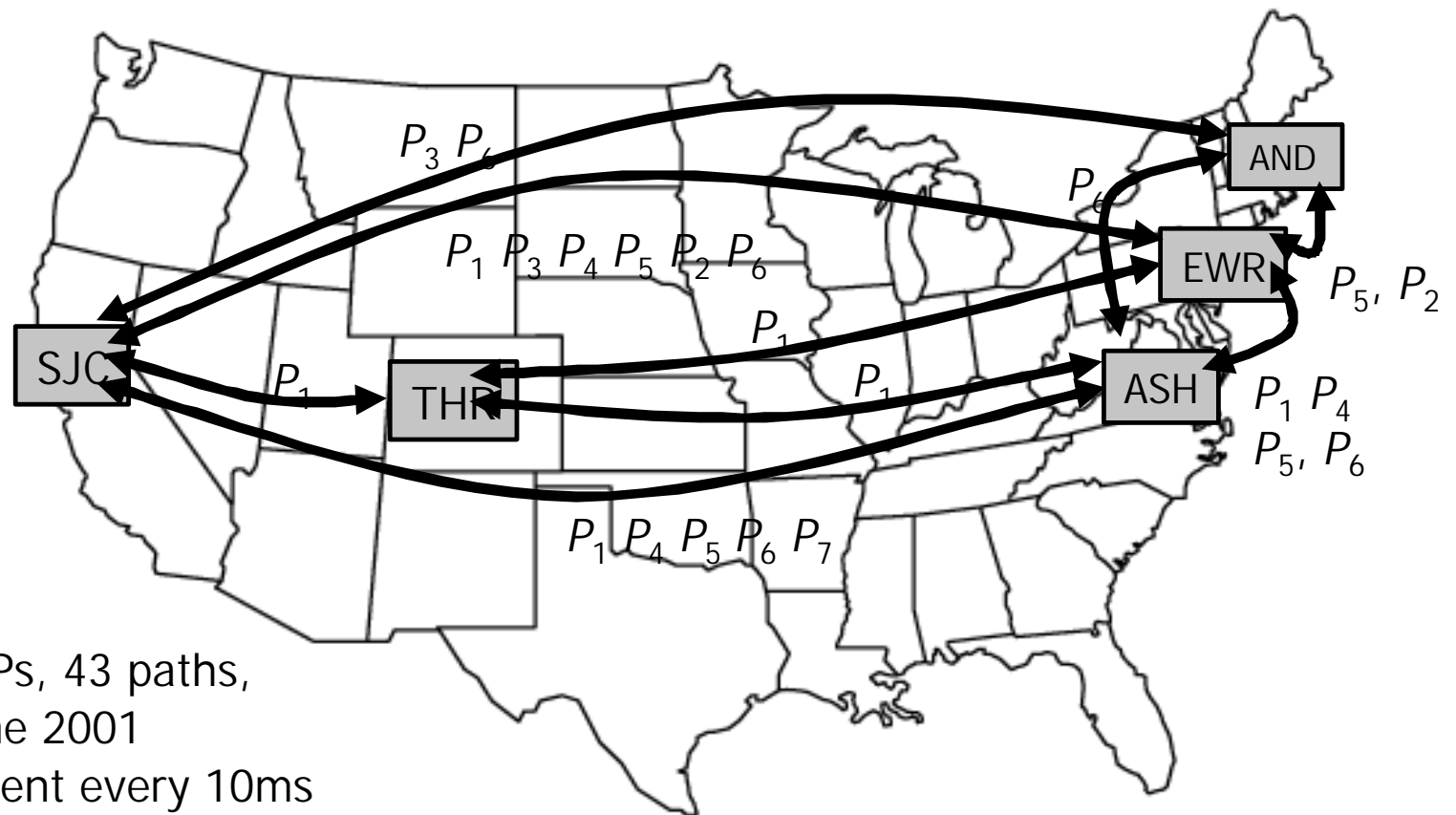
- Playout scheduling
 - Fixed playout
 - Adaptive playout



- Example algorithms
 - [RKTS94]: Ramjee, Kurose, Towsley, Schulzrinne
 - Estimate delay and variance using moving averages and spike detection
 - Adapt playout time at the beginning of each talkspurt
 - [MKT98]: Moon, Kurose, Towsley
 - Improvements in estimation and spike detection

Measurements collection

- Measurements collected and provided by RouteScience Tech. Inc.
- Probes sent over the backbone networks of major ISPs



- 5 cities, 7 ISPs, 43 paths,
- 3 days in June 2001
- 50B probes sent every 10ms
- Synchronized using GPS

Delay and loss characteristics

- Delay

- **Fixed part:**

- East coast: 3.25-11.8 ms
 - Coast-Colorado: 28.3-77.8 ms
 - Coast-to-coast: 31.3-47.2 ms

- Delay variability:

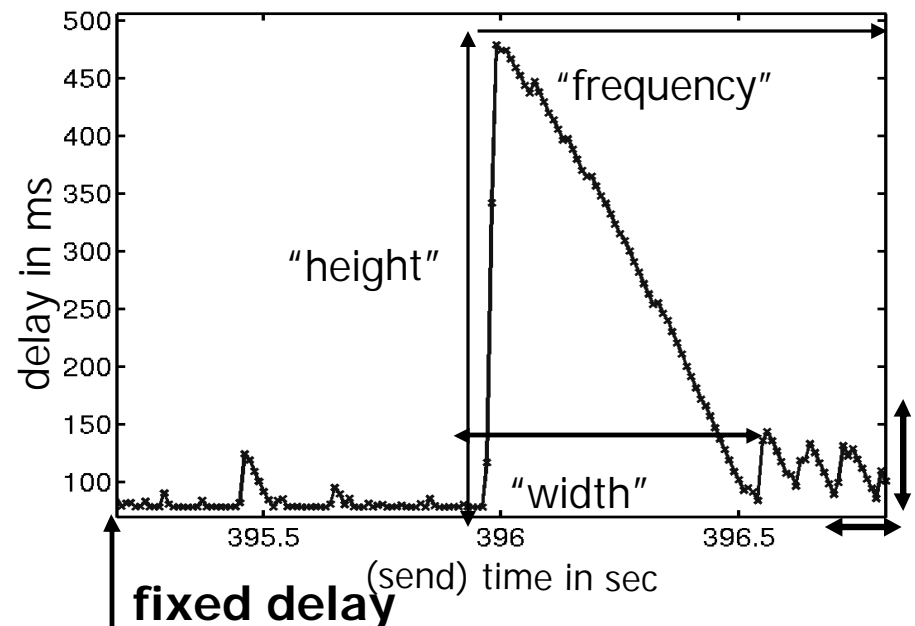
- Pattern: mainly **spikes**
 - During the day

- Loss

- Mainly outages – reliability problems

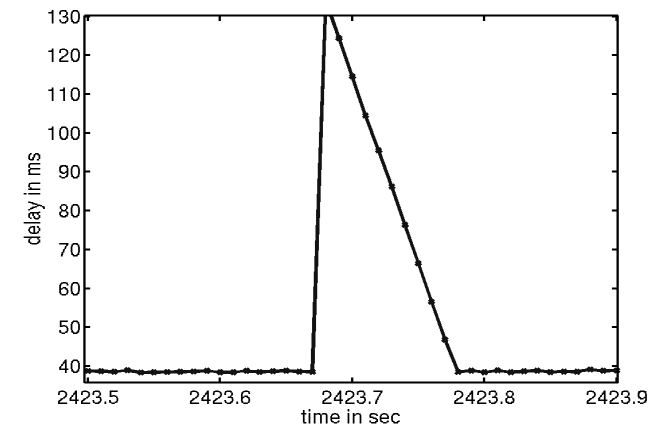
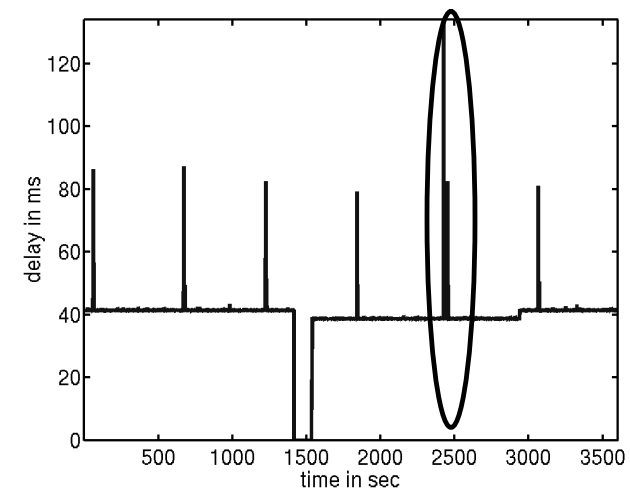
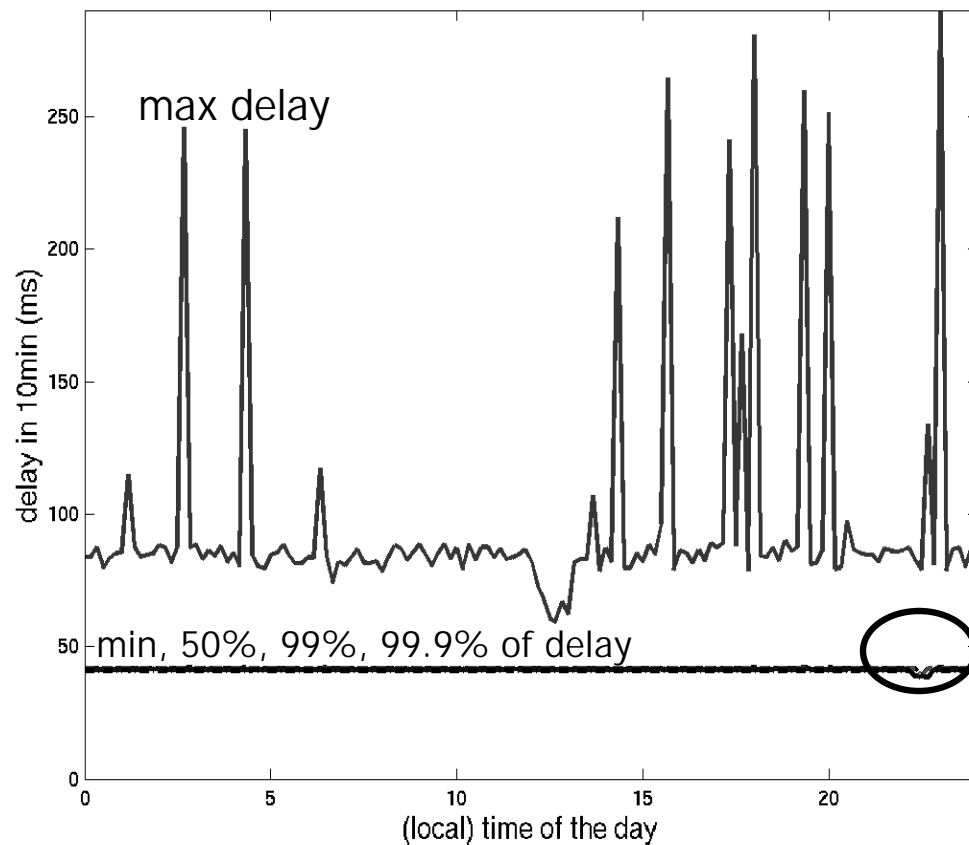
- Last 0.5-2 minutes. Happen at least once per day for 6/7 providers
 - Usually preceding changes in the fixed part. Often happen simultaneously in more than one paths of the same provider

- Consistent patterns per provider (and per path, time of the day)



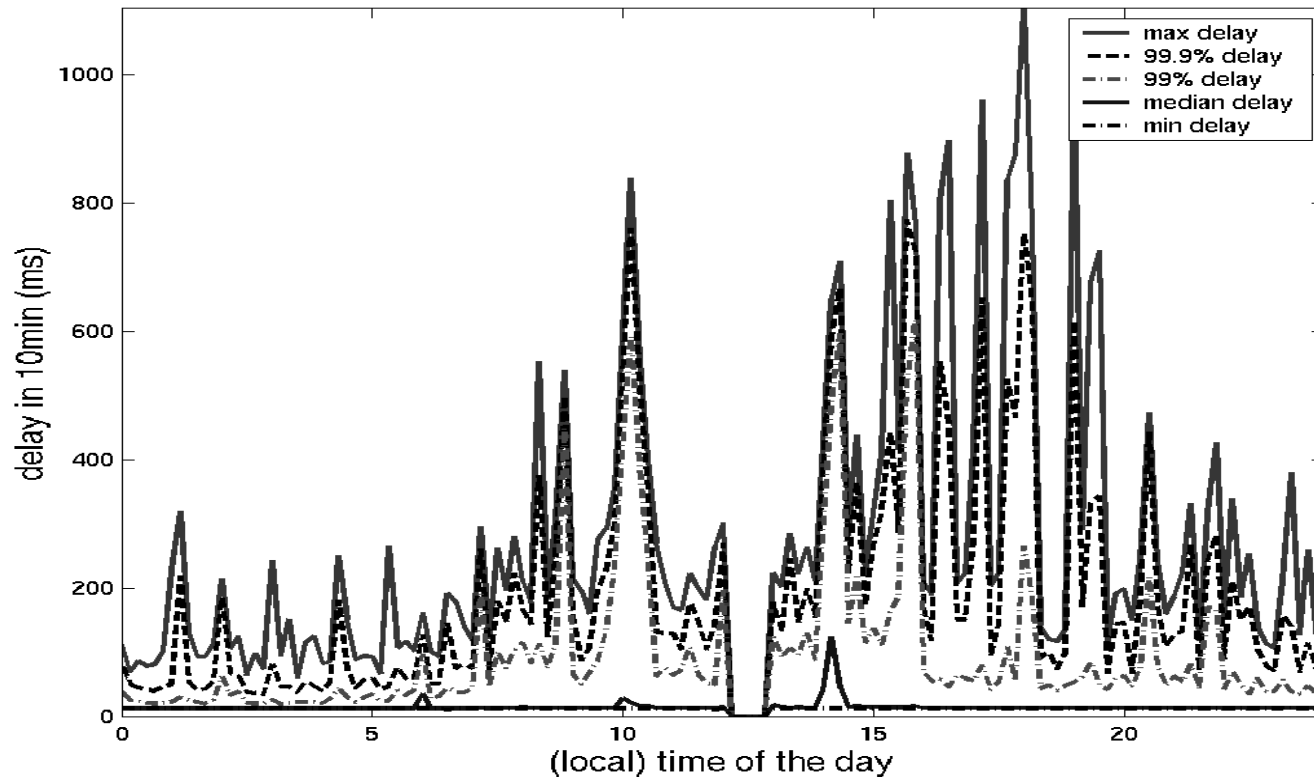
Example 1: a low variability path

- Long distance path SJC-P7-ASH (fixed delay = 40.5 ms)
- No loss except for a 2 minutes outage



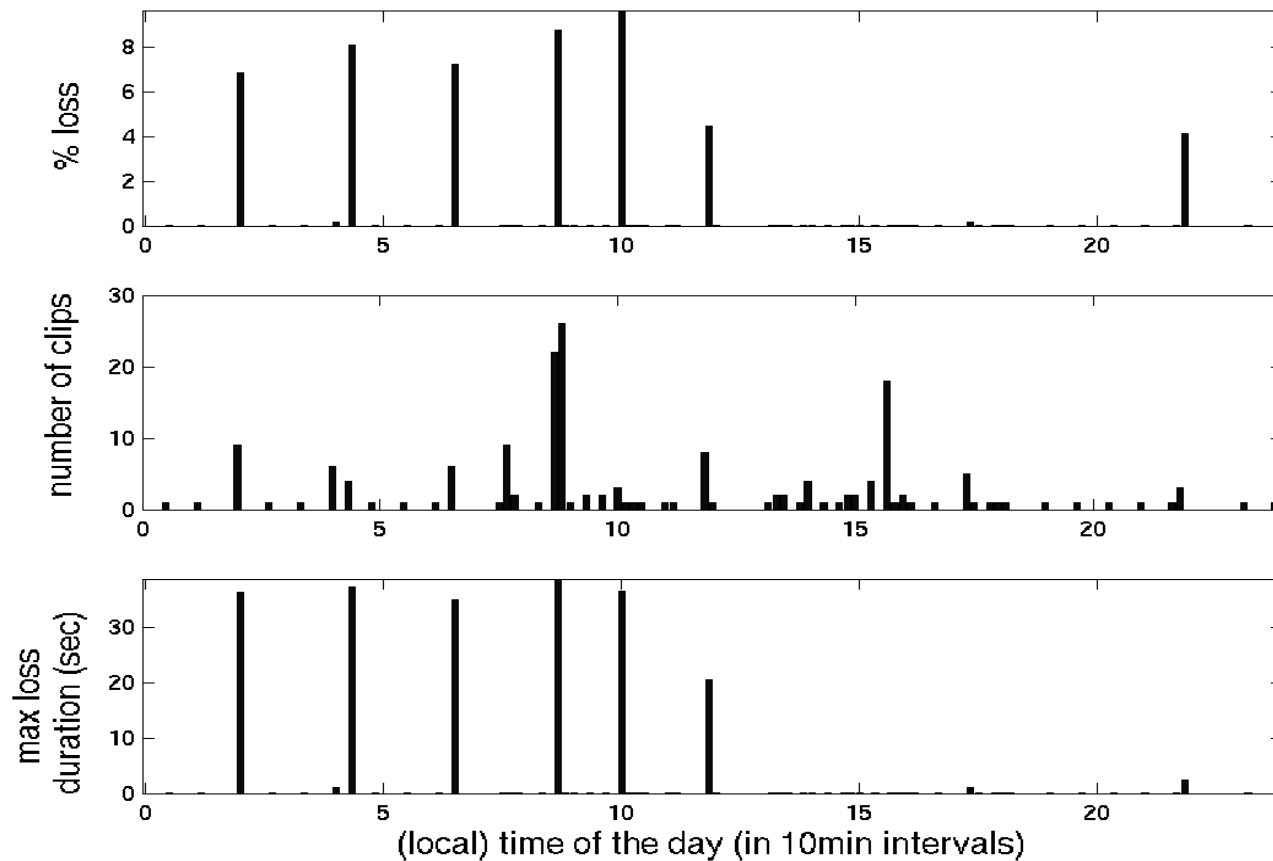
Example 2: a high variability path

- Short distance path EWR-P1-ASH (fixed delay= 11.8ms)
- Large delay and large delay variability
- Sustained periods of congestion



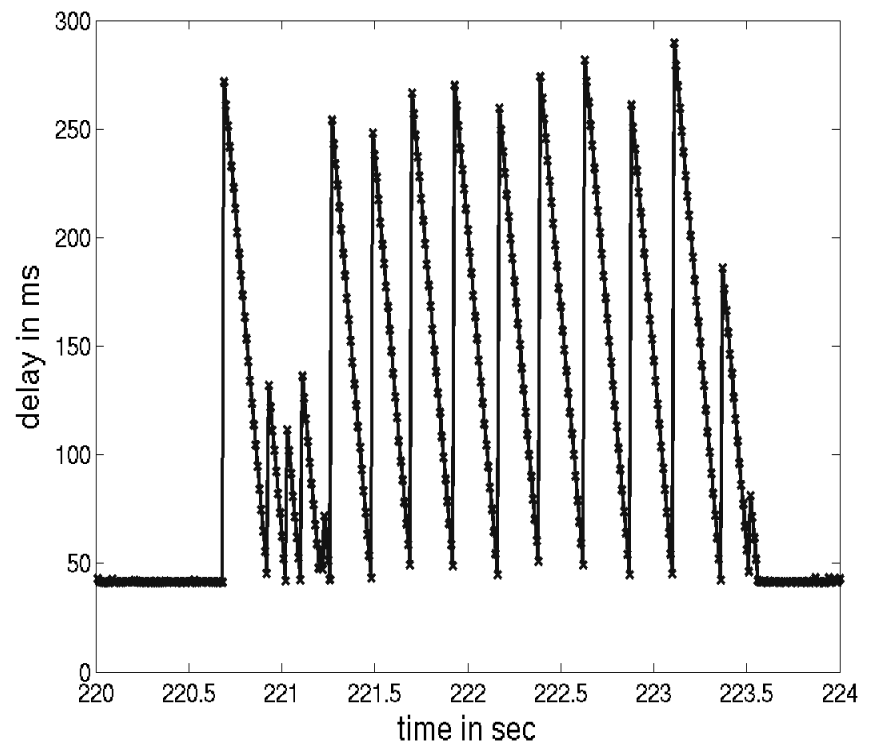
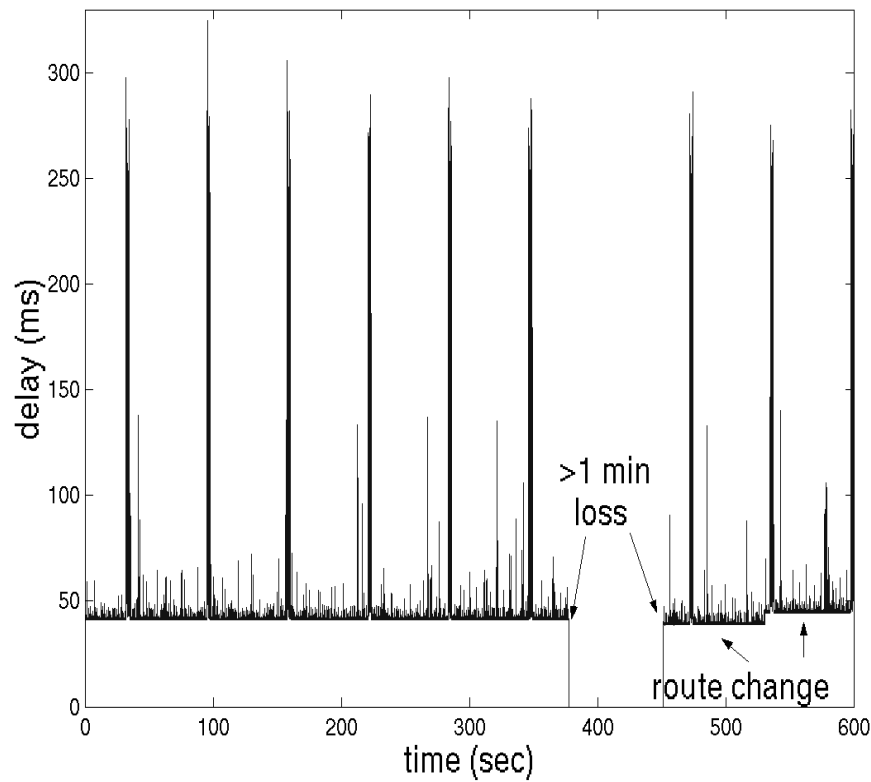
Example 2 cont'd: Outages

- Loss on the previous path (EWR-P1-ASH, on Wed 06/27/01)
 - 7 outages per day, 20-40 seconds each



Example 3: Periodic Pattern

- Clusters of spikes appearing every ~70sec.
- They last 3sec and they are as high as 300-500ms.
- All 6 paths of provider P4 exhibit this pattern all the time



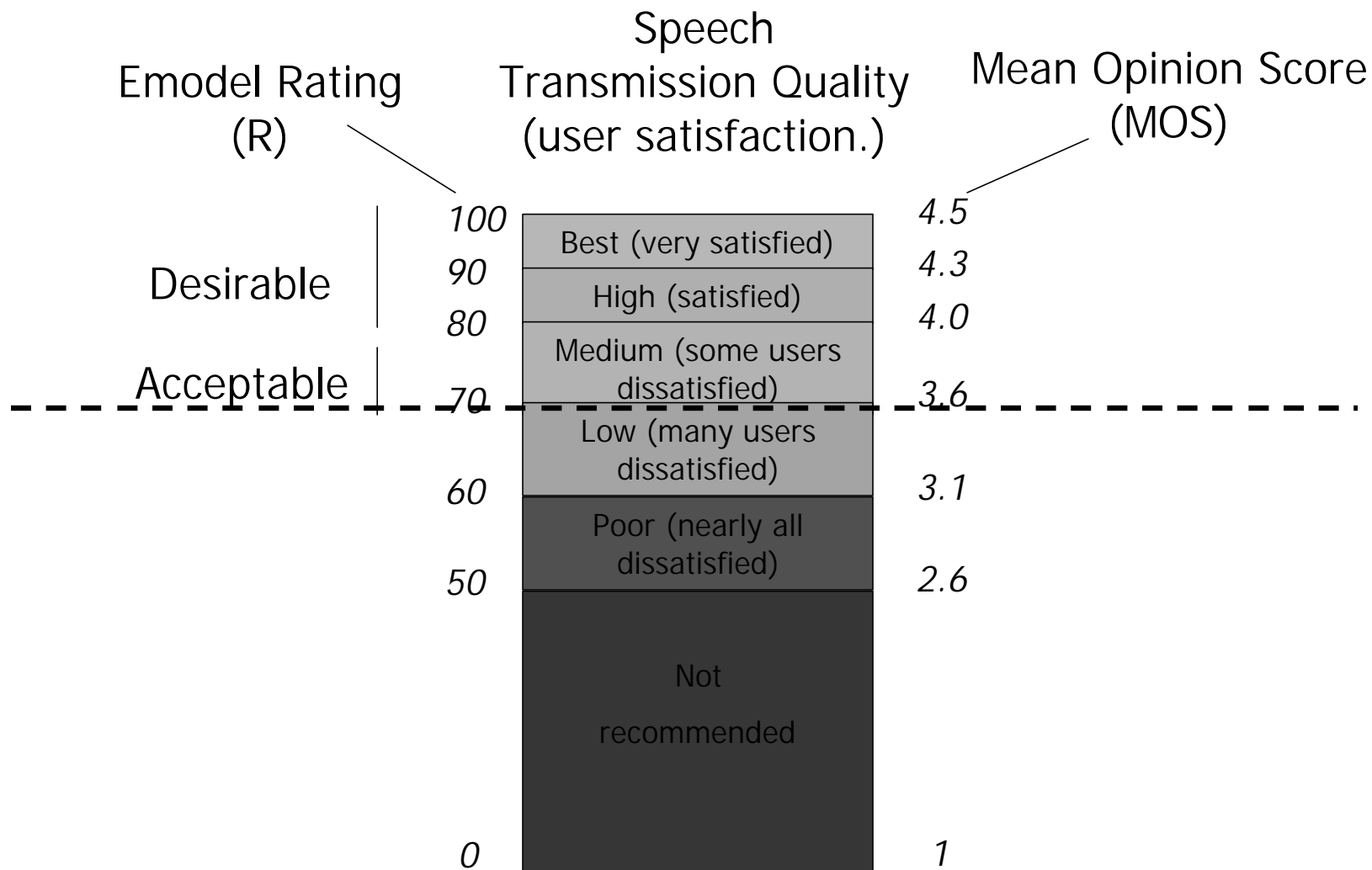
Summary of paths

	Number of paths per delay pattern				outages	
	Very low variability	Loaded paths	Occasionally higher delay	Periodic Pattern	Duration (sec)	Per day
Provider 1	2	6	4		1-40	1-10
Provider 2	1		1 (hours)		1-15	2-3
Provider 3	2		4		6-20	1-2
Provider 4				6	15-30	3-5
Provider 5	2		4 (minutes)		1-3	1
Provider 6	5		4 (seconds)		1-12	1-2
Provider 7	2				116,160	1

↑
1/3 of paths already have excellent VoIP performance

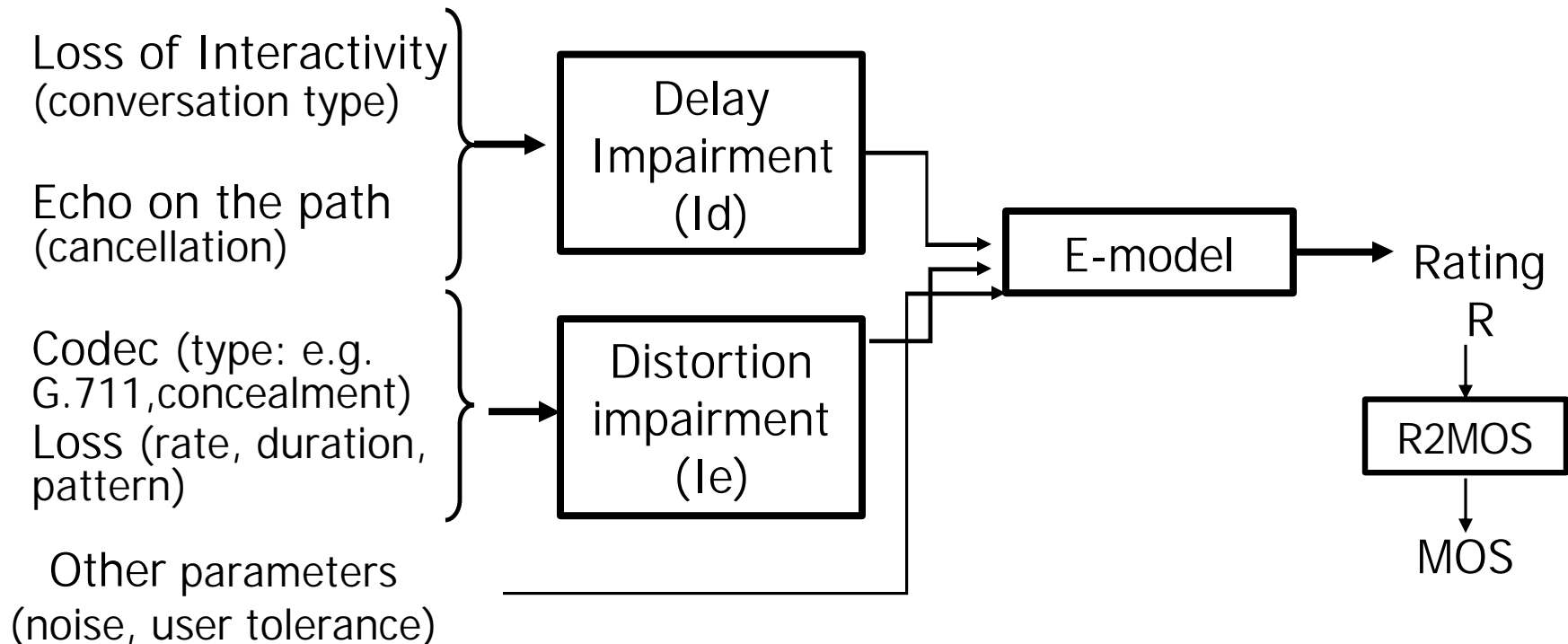
↑
poor VoIP performance can perform well (playout)

VoIP Quality



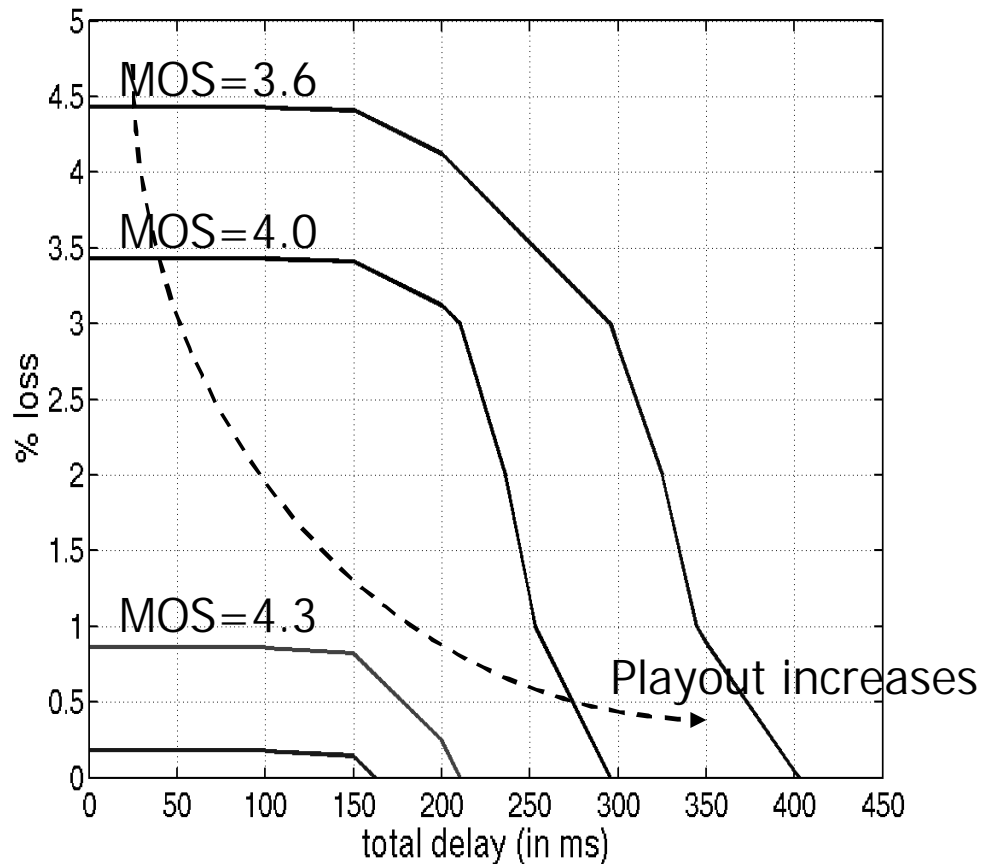
Emodel

- Many studies have assessed individual impairments
- “Emodel” combines all impairments into a single rating
 - “Impairments are additive in the appropriate psychoacoustic scale” : $R = (R_0 - I_s) - I_d \text{ (echo, delay)} - I_e \text{ (codec, loss rate)} + A$

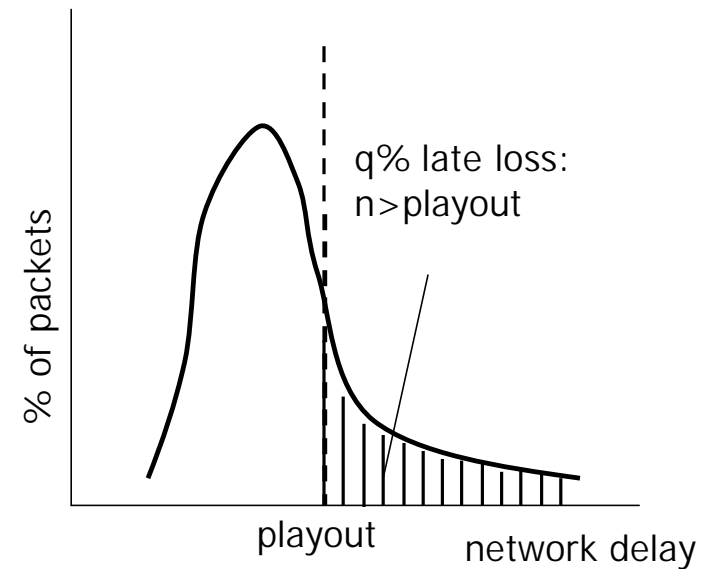


Loss-Delay trade-off

- Overall quality depends on both delay and loss

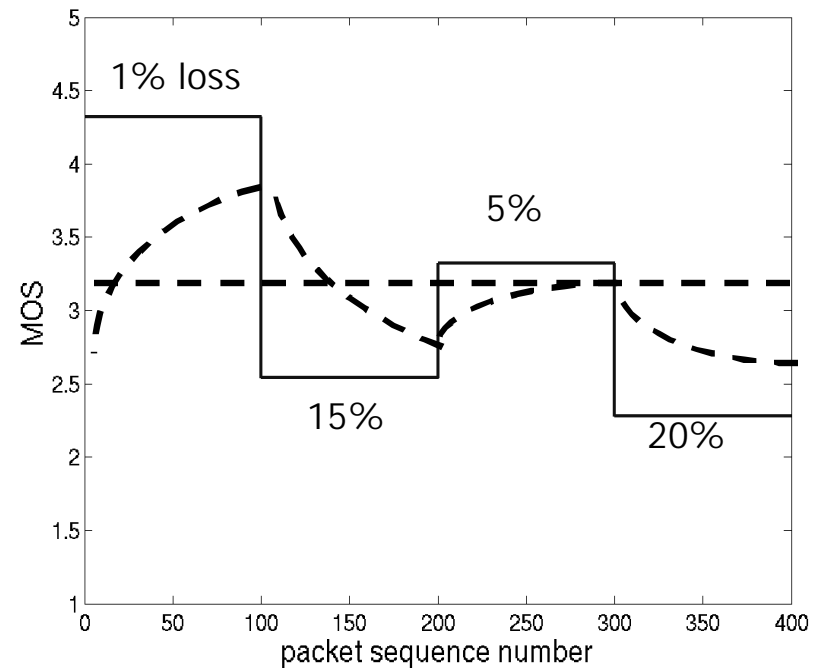


- Playout scheduling controls both



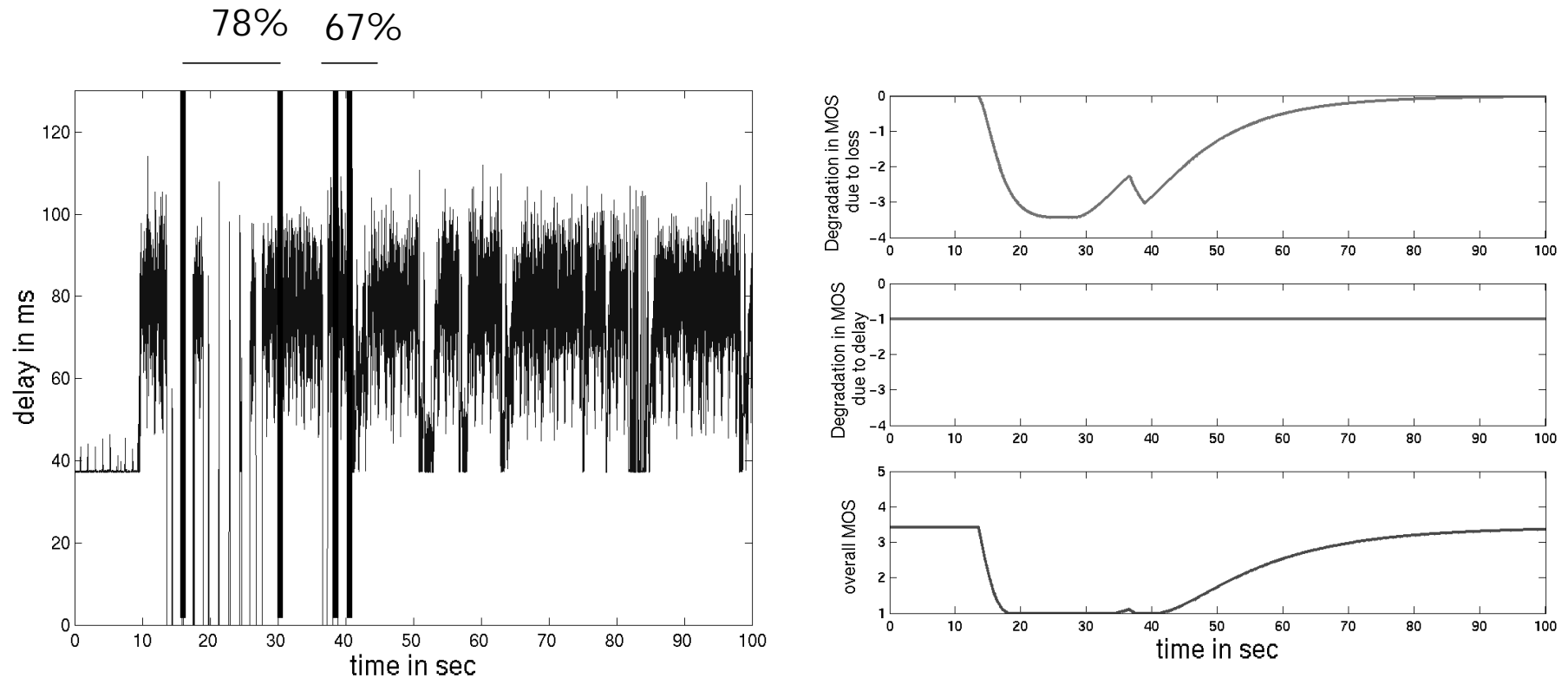
Call Assessment Methodology

- Time varying impairments and arbitrary loss patterns
 - Partition the trace into "good" and "bad" intervals
 - [A.Clark, IP Telephony 2001]
- Transitions are perceived with delay ("recency")
 - [France Telecom R&D, ITU-T ST.12 contr., 1999]
- Rating at the end of a call
 - [France Telecom R&D, ITU-T ST12., 2000]
 - [A.Clark, IP Telephony 2001]



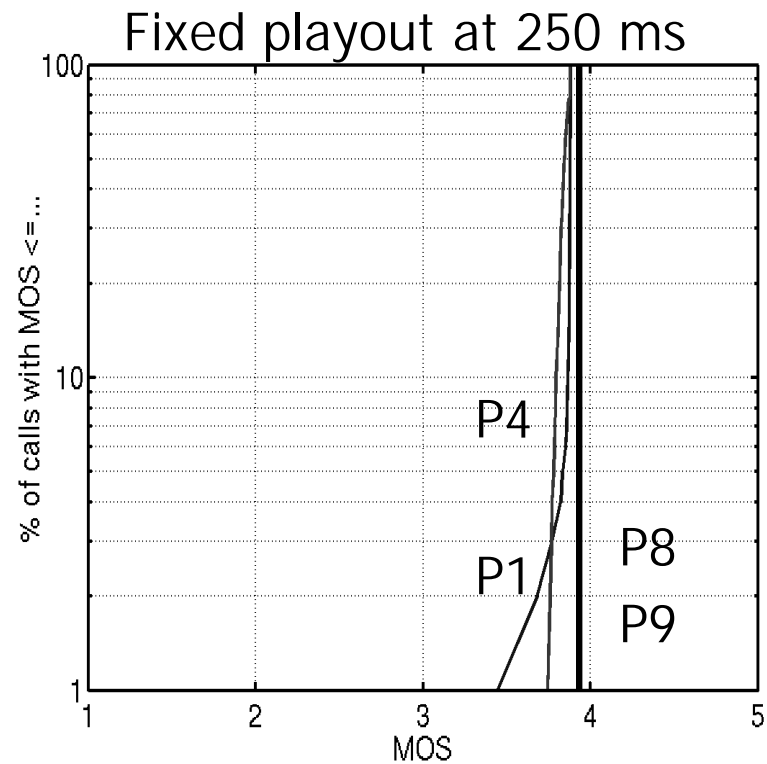
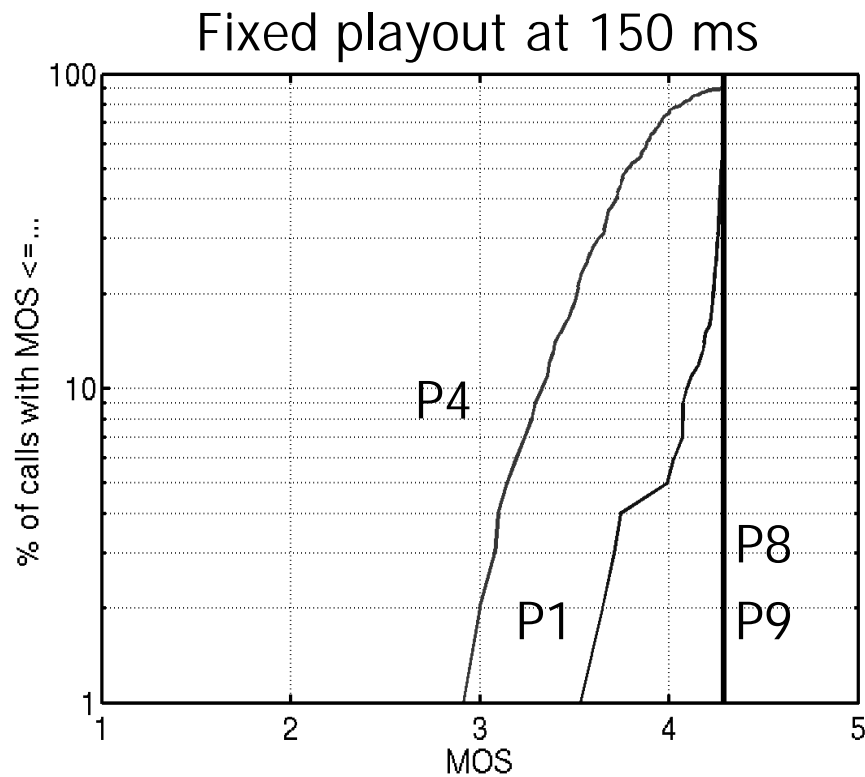
Example of call assessment

- Consider a call happening over a 100 sec network trace
- Consider fixed playout at 120 ms
- Steps for translating the network trace to call quality:



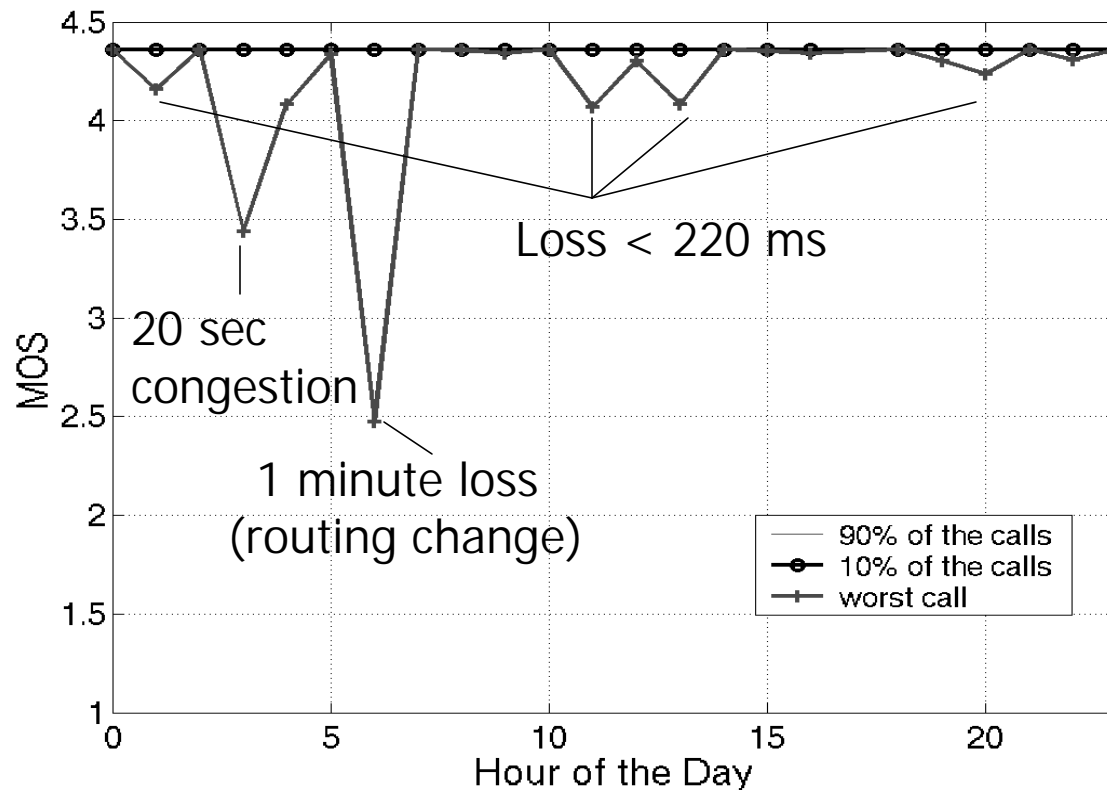
Comparing providers (one hour)

- Consider all paths from New York to Ashburn at the same time (3-4pm EST, Wed 06/27/01)
- The quality of a call depends on the provider



A low variability path

- EWR-P6-SJC, Wed 06/27/01
 - Delay in [38, 40] ms and spikes 80 - 250 ms. Some loss.
- Fixed playout at 100ms

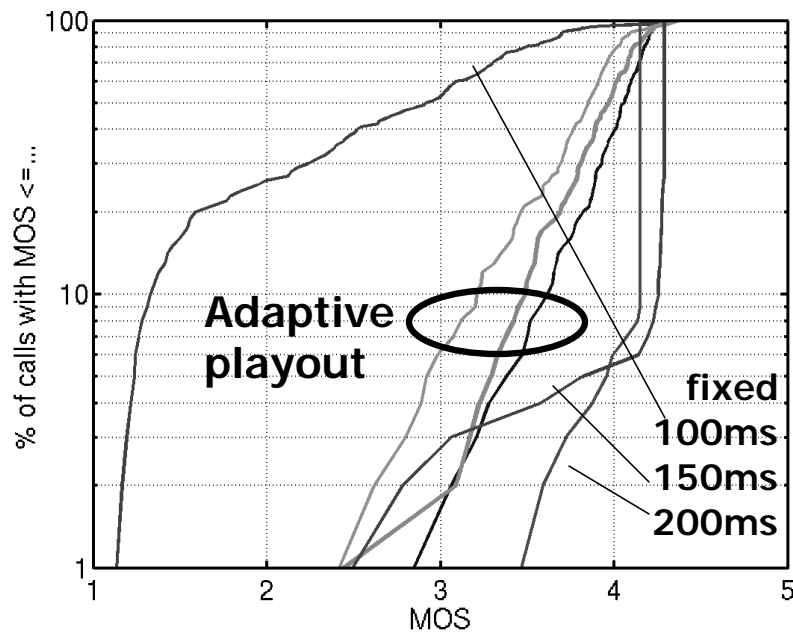


A high variability path

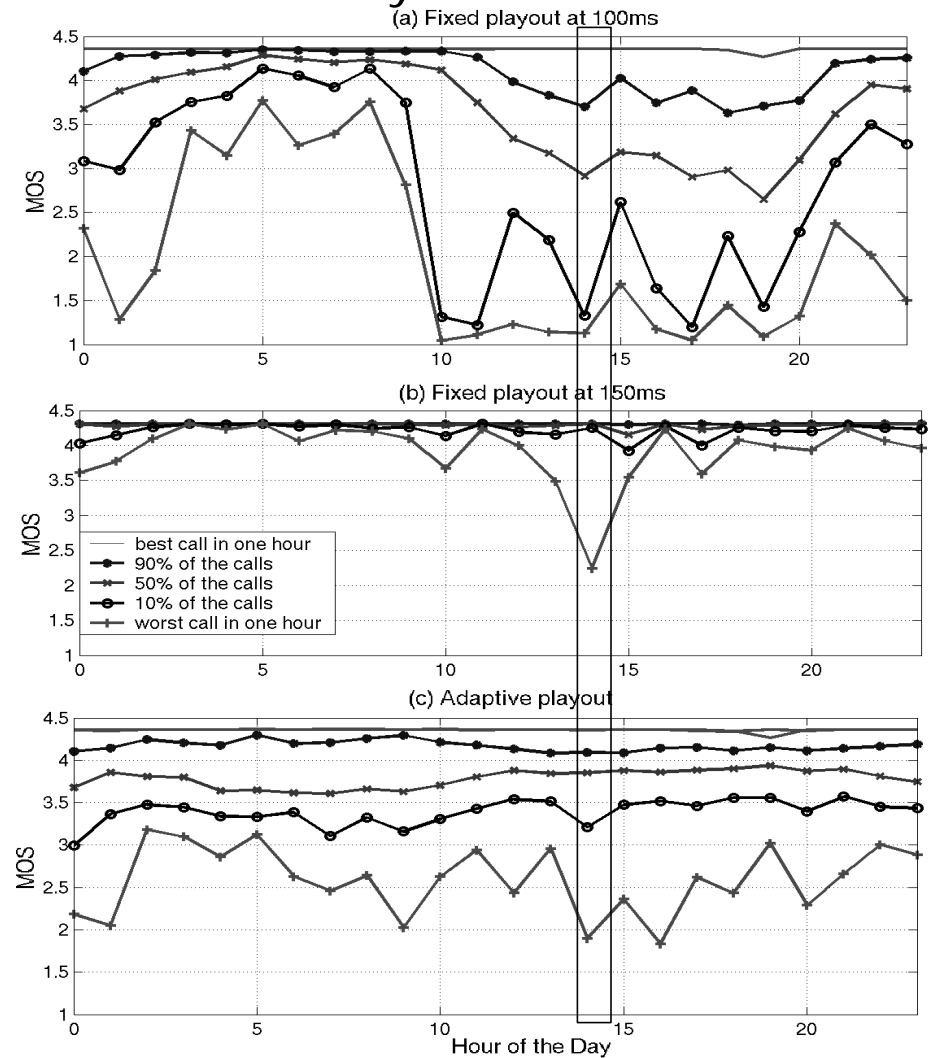
■ THR-P1-ASH

- Min delay = 77.8 ms
- Max Delay = 120 – 670 ms
- Loss negligible

Call statistics for 1 hour: 14-15



An entire day: Wed 06/27/01



Summary

- We have studied the VoIP quality over Internet backbones using:
 - delay and loss measurements
 - and perceived quality measures
- We found that:
 - The Internet is capable of carrying VoIP at high quality
 - this is already the case for many ISPs
 - However, today, there are still problems in the backbones:
 - Outages and network control traffic
 - Delay jitter: spikes

Assessment of VoIP Quality over Internet Backbones.

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