
Exploiting Just-Noticeable Difference of Delay for Improving Quality of Experience in Video-Conferencing

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Quality of Experience in Video Conferencing

- Signal Quality



Video



Audio

- Interactivity



Ease in communication

Video Conferencing over IP

- Quality cannot be assured in best-effort IP

network

Receiver

– Delay Jitter

– Loss

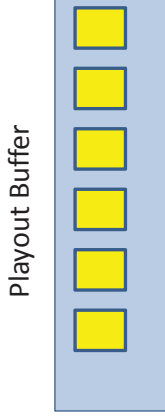


3/21

Video Conferencing over IP (cont'd)

- Channel Level Methods

Receiver



– Delay Jitter

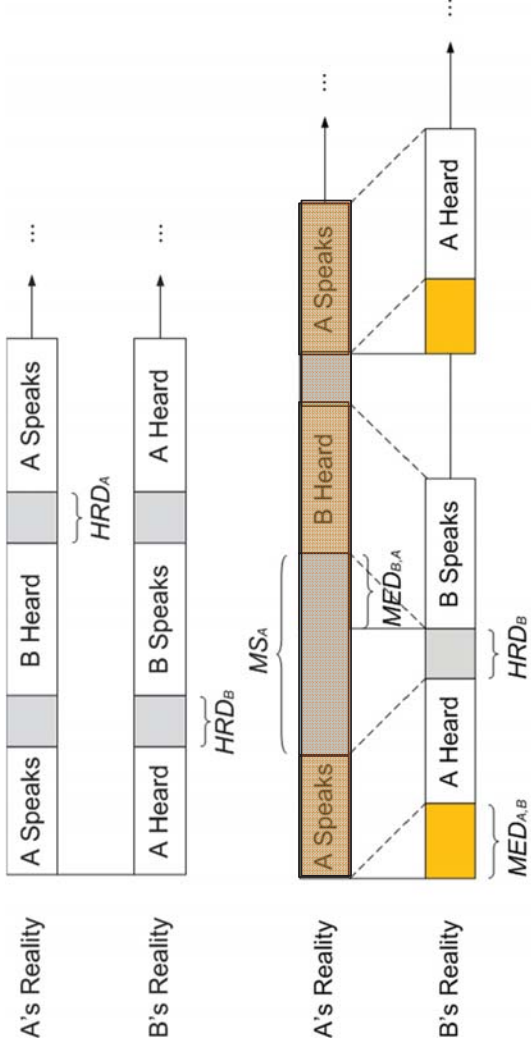
– Loss



4/21

Effects of Delay

- Conversational interactivity

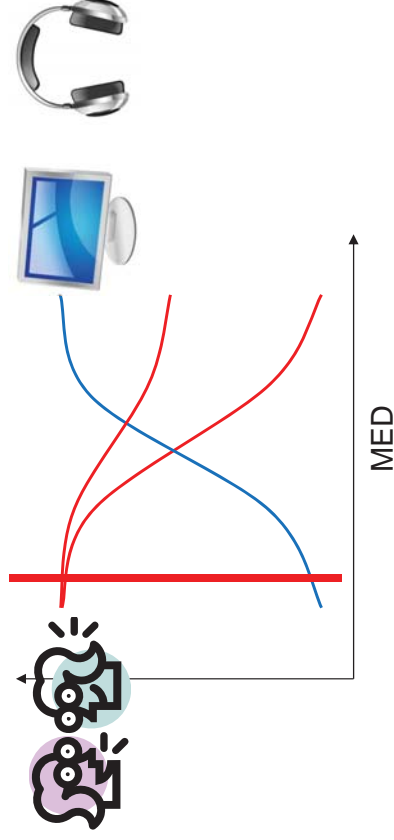


Mouth-to-Ear Delay (MED)

5/21

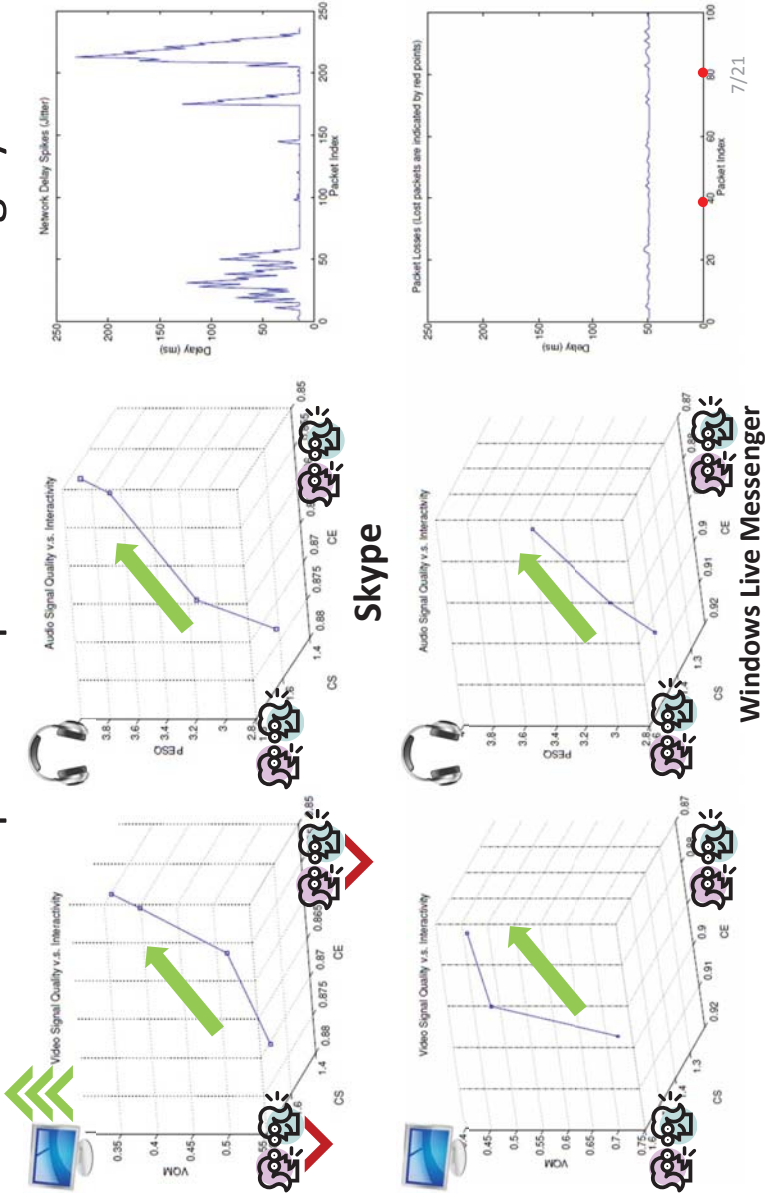
Trade-offs: Delay and Interactivity

- MED need not be constant
 - Adjusted to attain best perceptual quality under lossy network



6/21

Problem: Suboptimal Operations of Existing Systems



Key Idea

- Increase buffering time (and MED) for packets
 - To improve signal quality: validated in many Internet connections
 - Without degrading interactivity **How?**
- Just-noticeable difference
 - A concept from psychophysics
 - Human cannot perceive small difference
- Increase MED by JND

Network Behavior

- A detailed study on the current Internet
 - From more than 10,000 traces from PlanetLab

Description	Fraction	Loss Rate	Delay Mean (ms)	Jitter (ms)	Congested
Good	45%	0.02%	23	6	N
	22%	0.10%	94	7	
	9%	0.05%	153	2	
Lossy	7%	2.18%	45	13	N
Jittered	4%	0.09%	57	83	Y
	5%	0.21%	1691	545	
	1%	0.43%	2490	714	
Lossy and Jittered	4%	11.34%	701	257	Y
	2%	9.39%	63	47	
	1%	3.22%	85	61	

9/21

Network Behavior

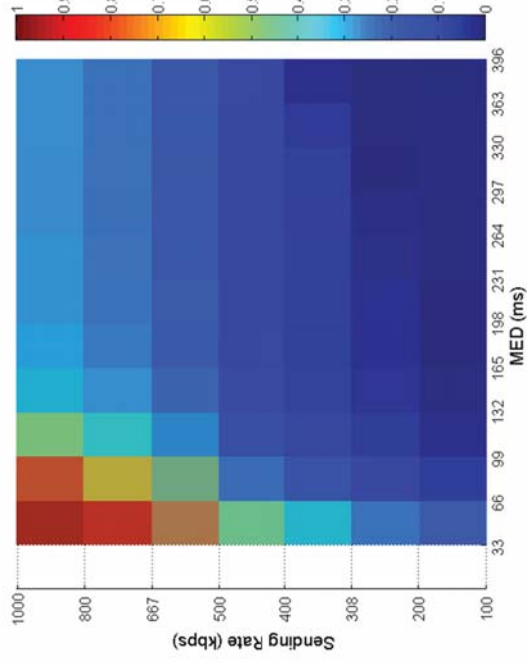
- Loss rate, delay and jitter
 - Monotonically non-decreasing with sending bit rate (supported by hypothesis test):
 - Traditional rate control
 - However not changed in some links even though sending rate is reduced:
 - Rate control does not work

10/21

Network Behavior with Buffering

- A longer MED helps

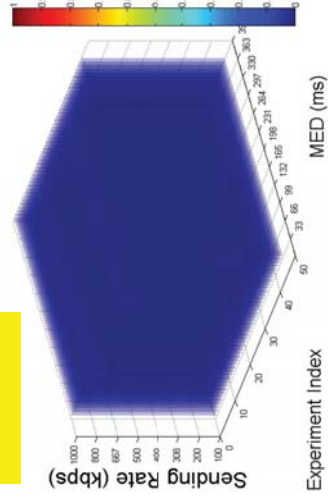
- Buffering ξ
- Recoveri
- Thus red *within th_n*



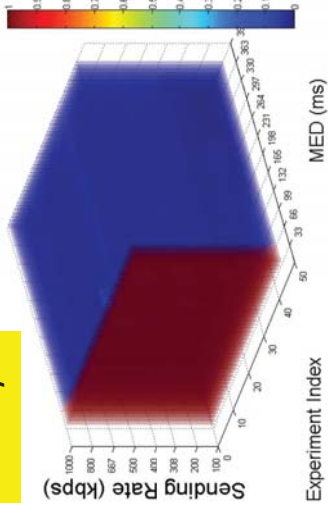
Ohio \Rightarrow North Carolina

Network Behavior with Buffering

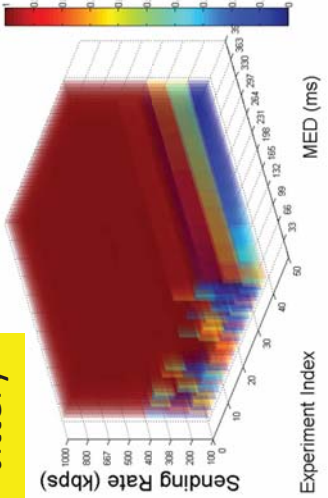
Good Oklahoma \Rightarrow South Florida



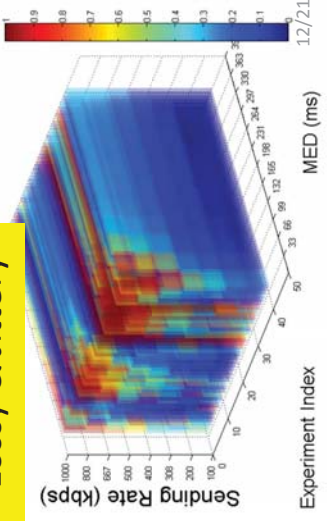
Lossy Massachusetts \Rightarrow France



Jittery California \Rightarrow Minnesota



Lossy & Jittery Ohio \Rightarrow North Carolina



Just-Noticeable Difference of Delay

- Definition
 - Let p_0 = fraction of subjects who correctly find the difference of the two given sessions
 - 75% JND of delay MED_A
 - maximum $|MED_B - MED_A|$ with which $p_0 \leq 0.75$
 - Why 75% rather than 50%?
 - User can guess to get 50%, but should really perceive the difference to get 75%

13/21

Measuring JND

- Comparative Subjective Test



MED=50 ms

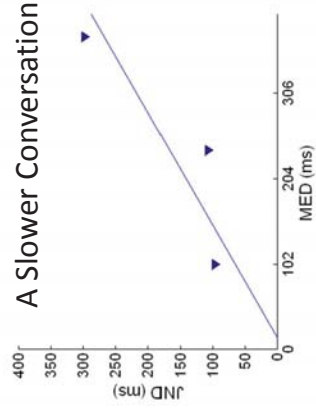
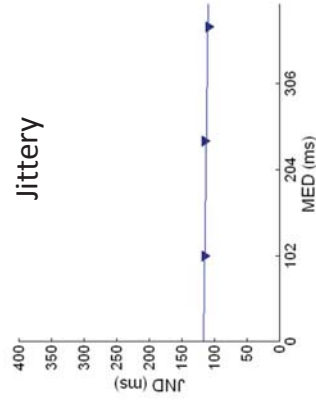
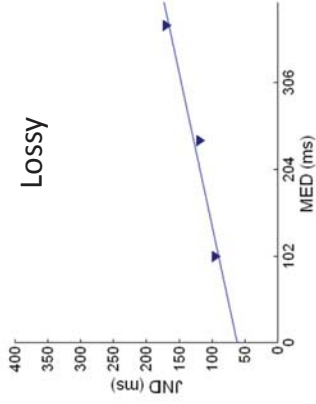
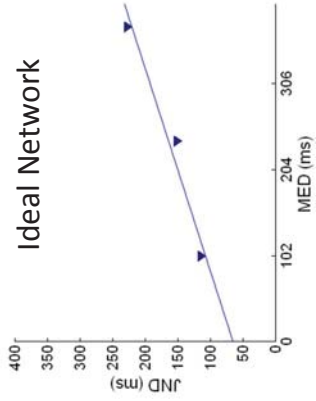


MED=1000 ms

Compare

14/21

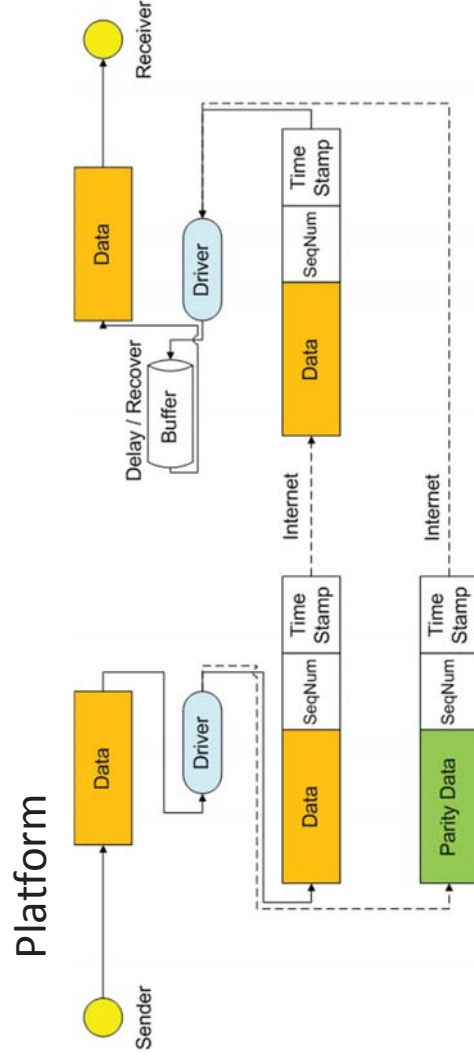
Results



15/21

Experimental Results with Real Systems

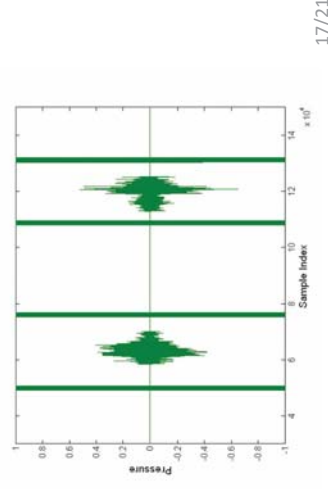
- Deploy interceptor in Windows to make buffer
 - A kernel driver developed with Windows Filtering Platform



16/21

Experimental Results with Real Systems

- Measure the QoE with our *RealTalk* testbed



17/21

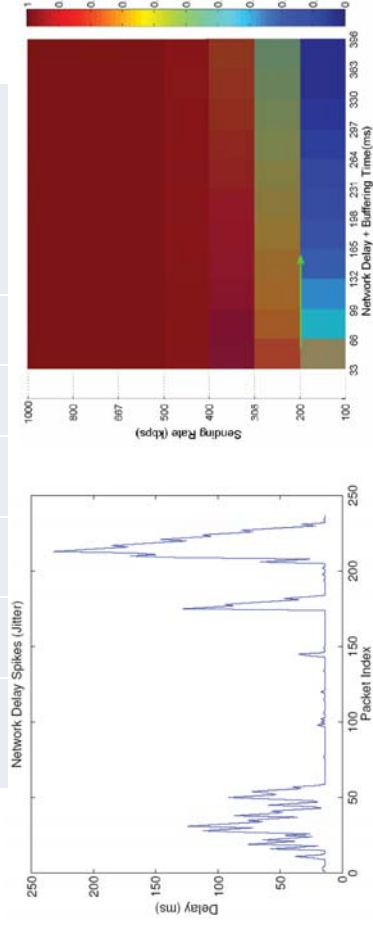
- Skype

Demonstration

- Trace based emulation (TCN): Jittery Connection: California ⇒ Minnesota

	VQM	PESQ	MED (ms)	CS	CE	% of Subjects preferring Scheme
Original	0.54	3.77	239	1.54	0.88	0%
Proposed	0.36	3.36	251	1.57	0.88	100%

Subject's Choice!



- Randomly generated jittery trace (NISTNet):

Informal subjective tests also show that the proposed scheme > Skype's^{18/21}

Demonstration

- Skype



Original Operating Point

Increased MED within JND

Jittery Connection: California ⇒ Minnesota

19/21

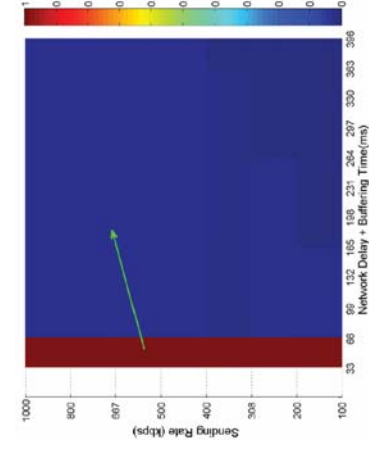
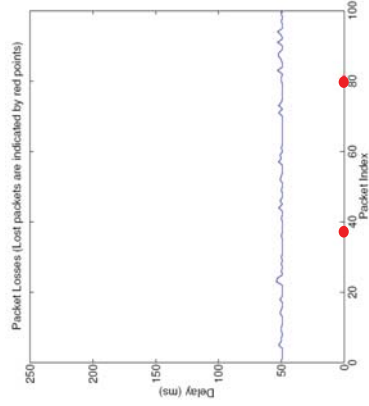
Demonstration

- Windows Live Messenger

- Trace based emulation (TCN): Lossy Connection: Massachusetts ⇒ France

	VQM	PESQ	MED (ms)	CS	CE	% of Subjects preferring Scheme
Original	0.76	3.08	276	1.63	0.87	0%
Proposed	0.41	3.72	363	1.82	0.83	100%

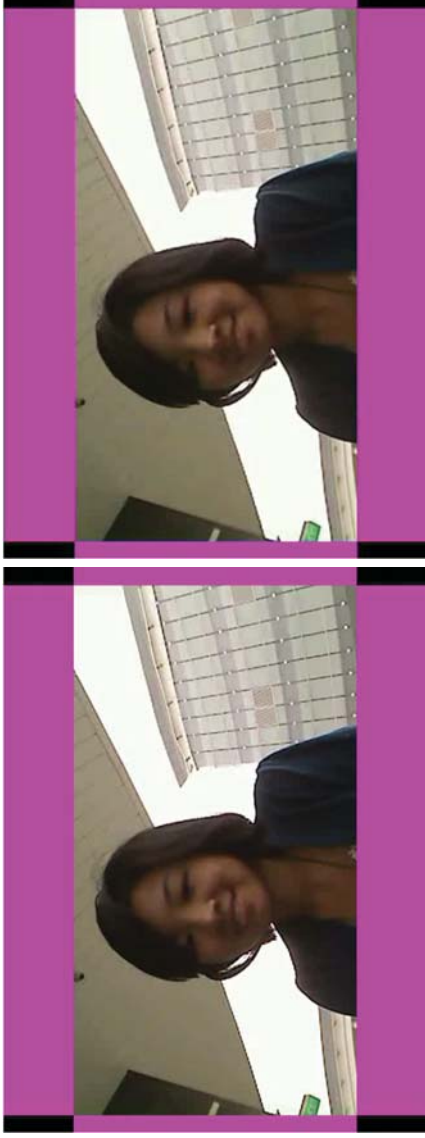
Subject's Choice!



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Demonstration

- Windows Live Messenger



Original Operating Point

Increased MED within JND

Lossy Connection: Massachusetts \Rightarrow France

21/21

Conclusion

- Problem
 - Suboptimal operations of Existing Systems in QoE
 - Skype, Windows Live Messenger
- Holistic approach
 - Network properties of the Internet
 - JND: perceptual effects to drive tradeoffs
 - Validation: traffic interceptor in Windows
 - Measurement: *RealTalk* testbed

22/21



Thank you

Question?