Recent Developments in Multimedia Communications Technologies

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Outline

- What is Multimedia Communications?
- What are technical challenges?
- What are economic issues?
- Future

MM communications

- Multimedia:
  - Audio, video, text, graphics, 3D
- Communications:
  - Unicast: one to one; braodcast: one to many, multicast: many to many; anycast
  - Wired vs. wireless
  - Analog vs. digital
  - One way streaming, two way interactive, live
  - Broadband vs. narrowband

Why MM communications today?

- Stars are all aligned:
  - Fast, high bandwidth networks everywhere:
  - Fast electronics cheap and available
  - Fast PCs, PDAs everywhere
  - Display technology

Applications:

- Enterprise:
  - On line training
  - Video conferencing or broadcasing meetings
- Consumers:
  - Home entertainment:
    - Cable and DSL everywhere
    - Set top boxes
- Wireless

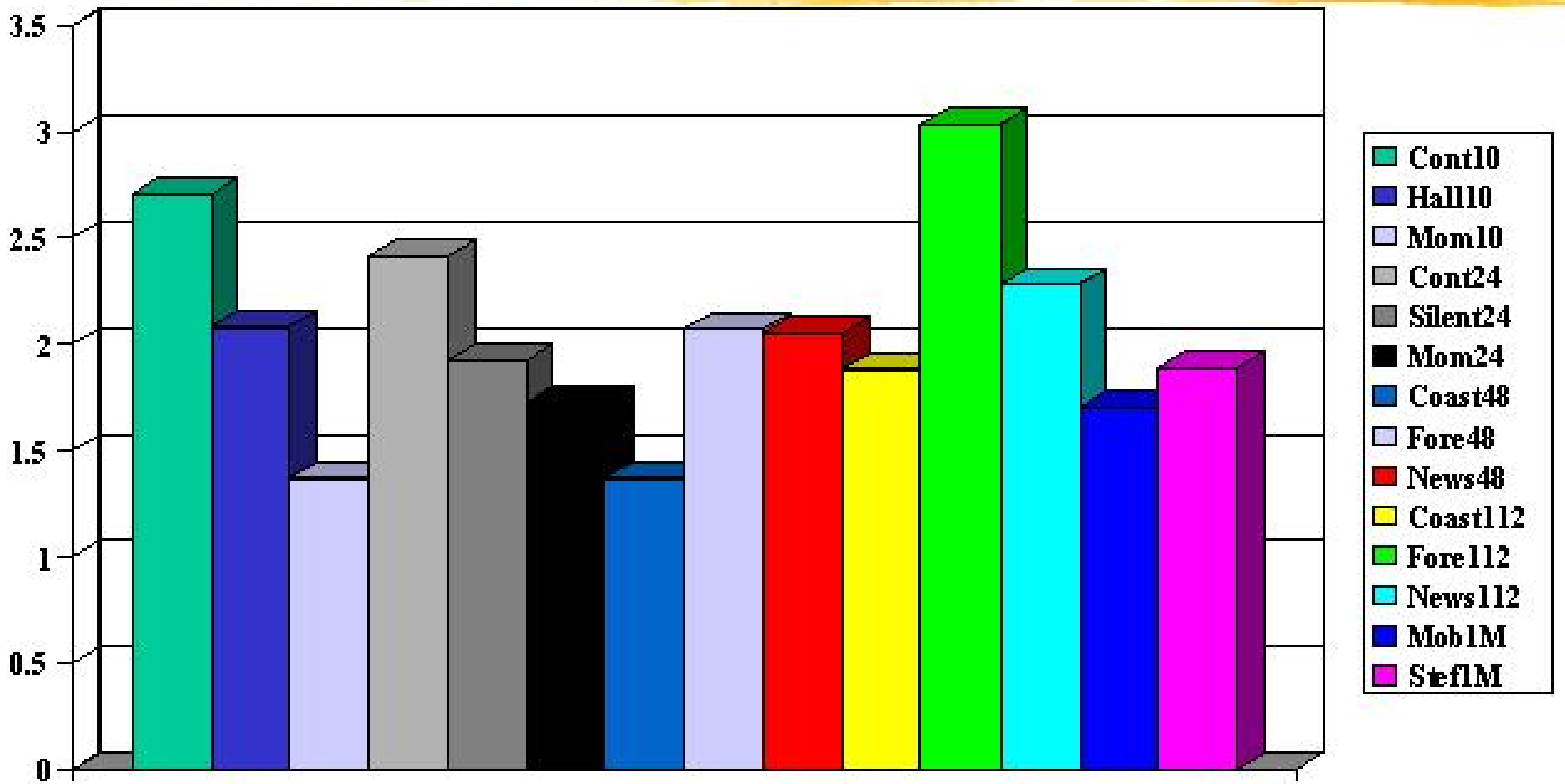
Close to 1 in 10 U.S. households now has high speed internet services

	US users	Speed Mb/s	Monthly Price
Cable modem	7 mill.	1.5	$46
DSL	3.3 mill	1 - 1.5	$50
Wireless	.3 mill	0.5 –1.5	$50
Satellite	.06 mill	0.15-0.5	$75
Fiber	N/A	4.5-9	$85

Can TV like Quality be offered over today's available networks?

- Recent advances in compression technology make near D1 quality at 1Mb/s a reality
- Broadcasters, ISP, movie studios all in need of such technology:
- Example:
  - Truvideo proprietary codec based on matching pursuits technology: demo
  - Many dBs better than MPEG-4 or H.26L

TruVideo's 4.0 Gain Over MPEG4 – Luma (dB)



Why isn't streaming flying yet?

- Technical: TV quality delivery over today's best effort internet needs better solutions: compression and networking;
- Economies of scale don't apply: more users to view, means higher infrastructure cost for streaming;
  - goes linear with # of users for popular content: mutlicast?
  - niche paying markets for content that is otherwise unavailable;

Multimedia communications

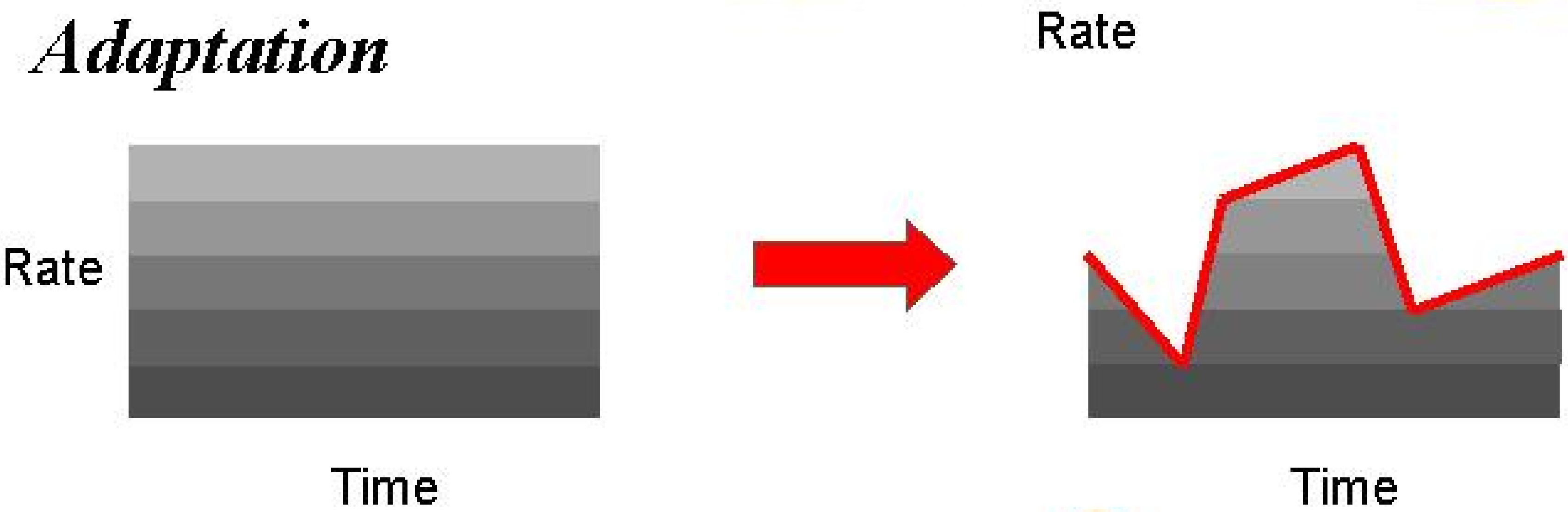
- MM requirements different from data:
  - delay sensitive: late packet as good as lost.
  - massively compressed
  - not sensitive to loss
  - graceful degradation to loss and delay
  - unlike data BER is not an indicative of performance; audio/visual quality is.
  - bits of unequal importance
- Solution lies somewhere in between Signal Processing (SP) and Networking.

Bag of tricks from SP and Networking and intersection

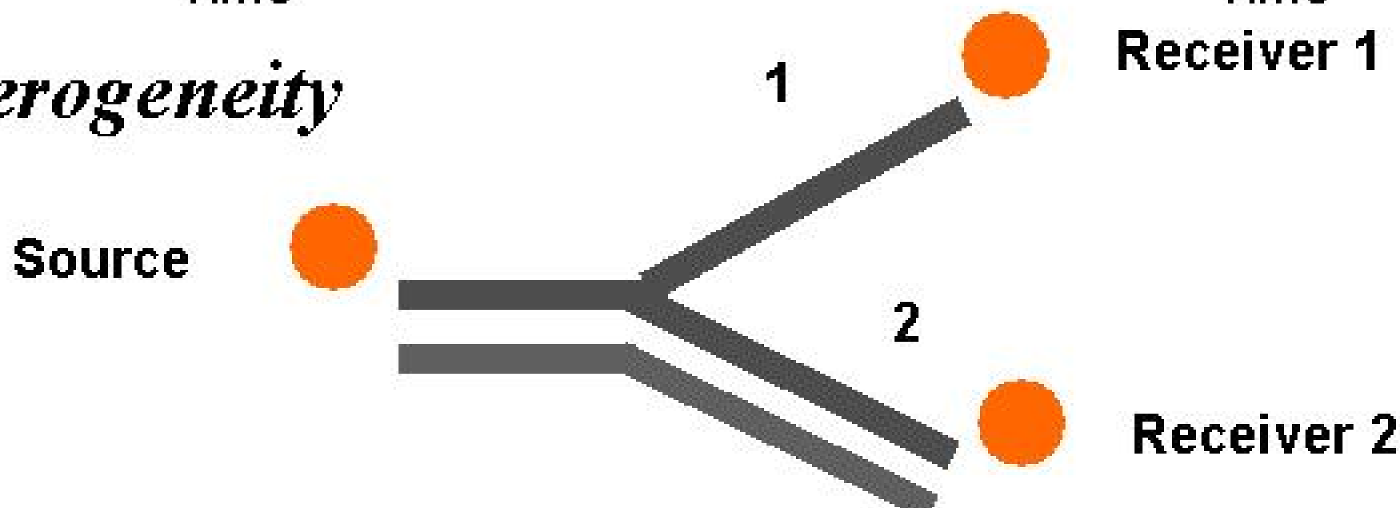
- Signal Processing and communications:
  - Source coding, channel coding, joint source channel coding, unequal error protection
  - Layered compression; multiple description coding;
  - Error resilient compression: reversible VLC, sync,
- Networking:
  - Protocol design
  - QoS enabled networks: diffserv, MPLS
  - Architecture: edge architecture, overlay, distributed
- Intersection: packetization issues

Layered video invented by SP to deal with Networking issues

Adaptation



Heterogeneity



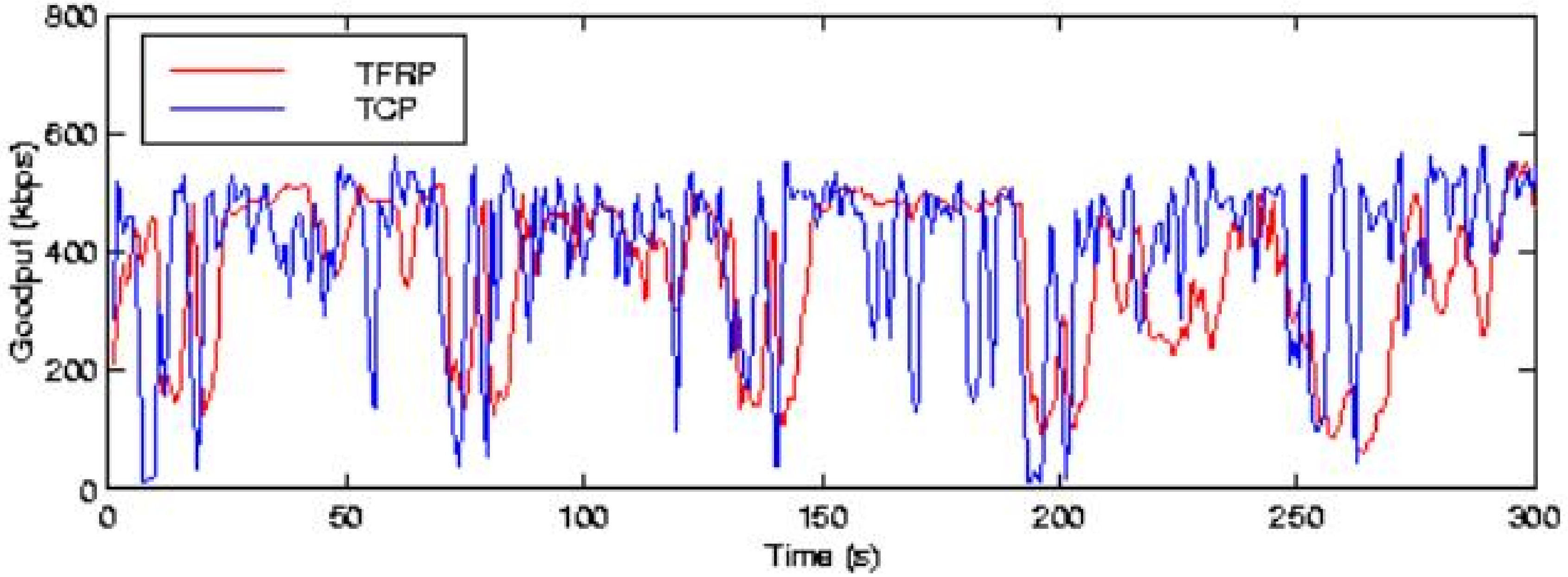
Typical application needs mix and match of solutions from bag of tricks

- Example:
  - Unicast streaming
  - Multicast streaming
  - Diffserv
  - Distributed streaming

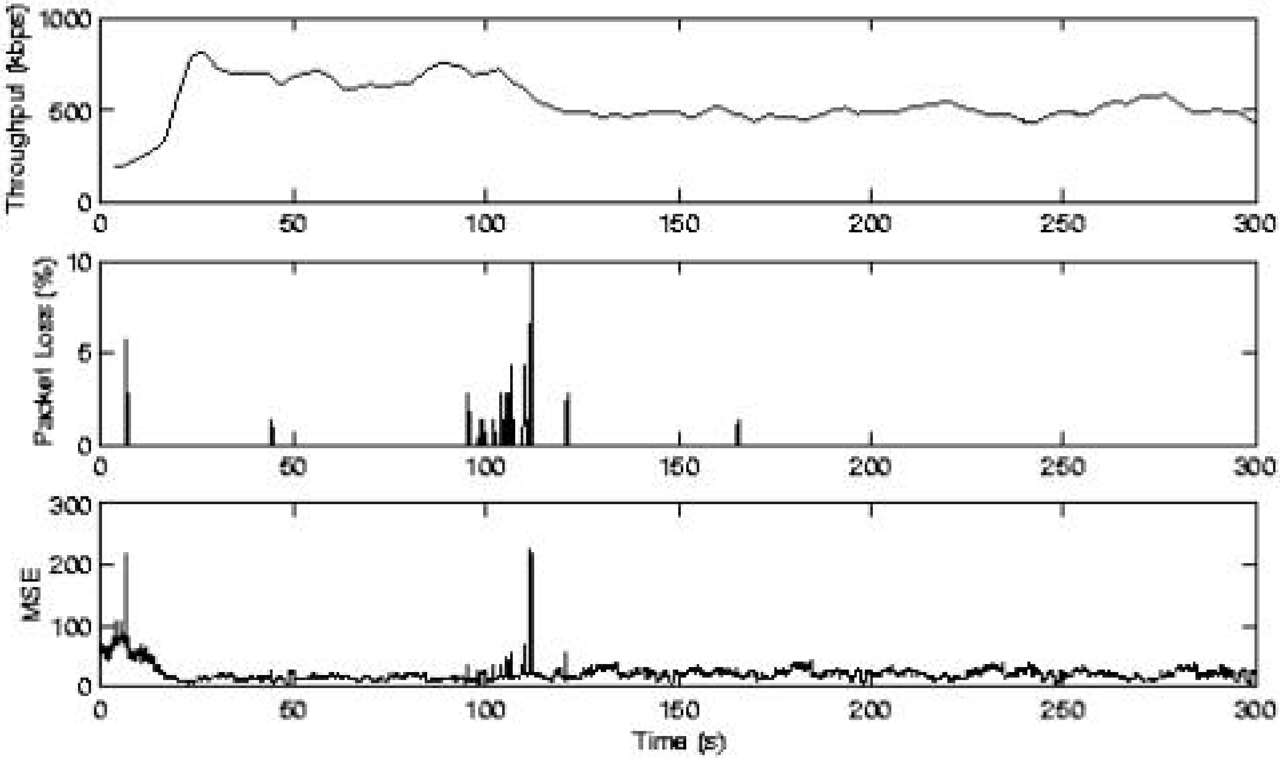
Example: unicast streaming of video over best effort packet switched networks

- Layered Video + Rate Adaptive TCP friendly UDP protocol at Transport Layer + Error Resilient Packetization
- Tan and Zakhor, IEEE Trans. On MM, 1998

Throughput for concurrent transmission from Toronto to Berkeley

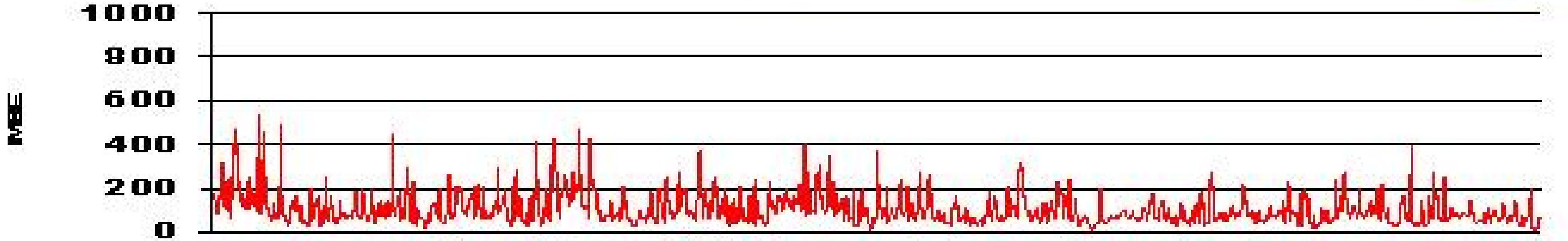


Adaptation of TCP friendly protocol to changing network conditions: (Toronto - Berkeley, 2 pm, May 8, 1998)

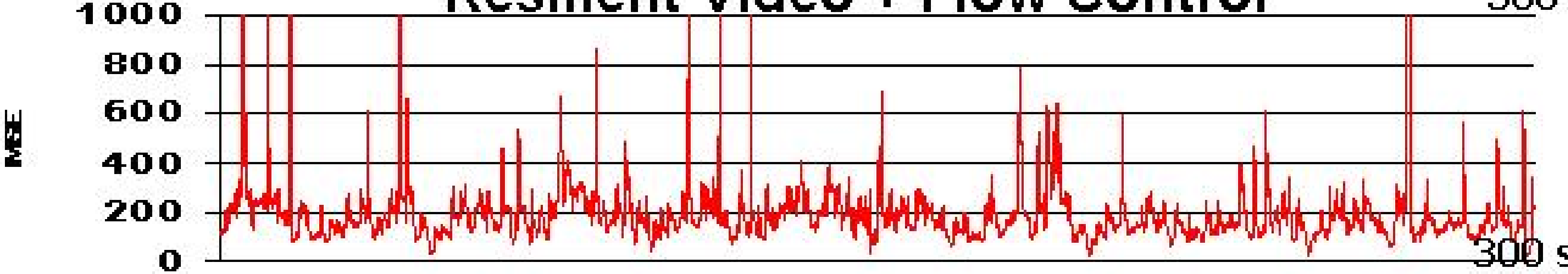


- Extra traffic started at time = 80 seconds
- Losses remain low after protocol reduces transmission rate

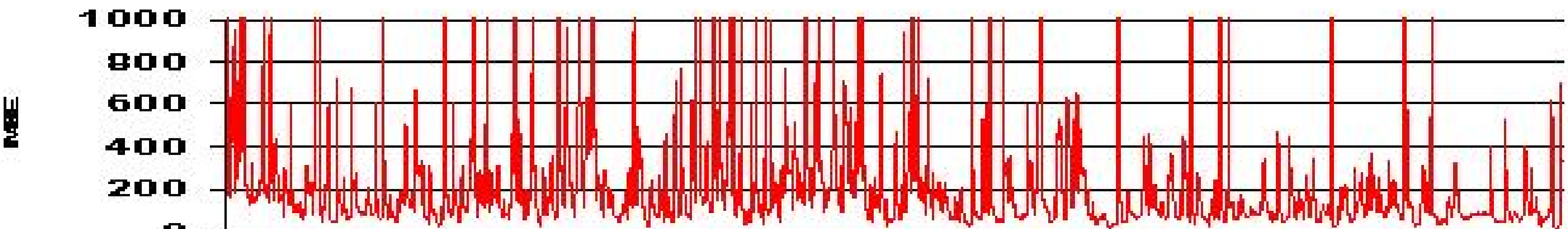
FEC without error resiliency packetization won't work



Resilient Video + Flow Control



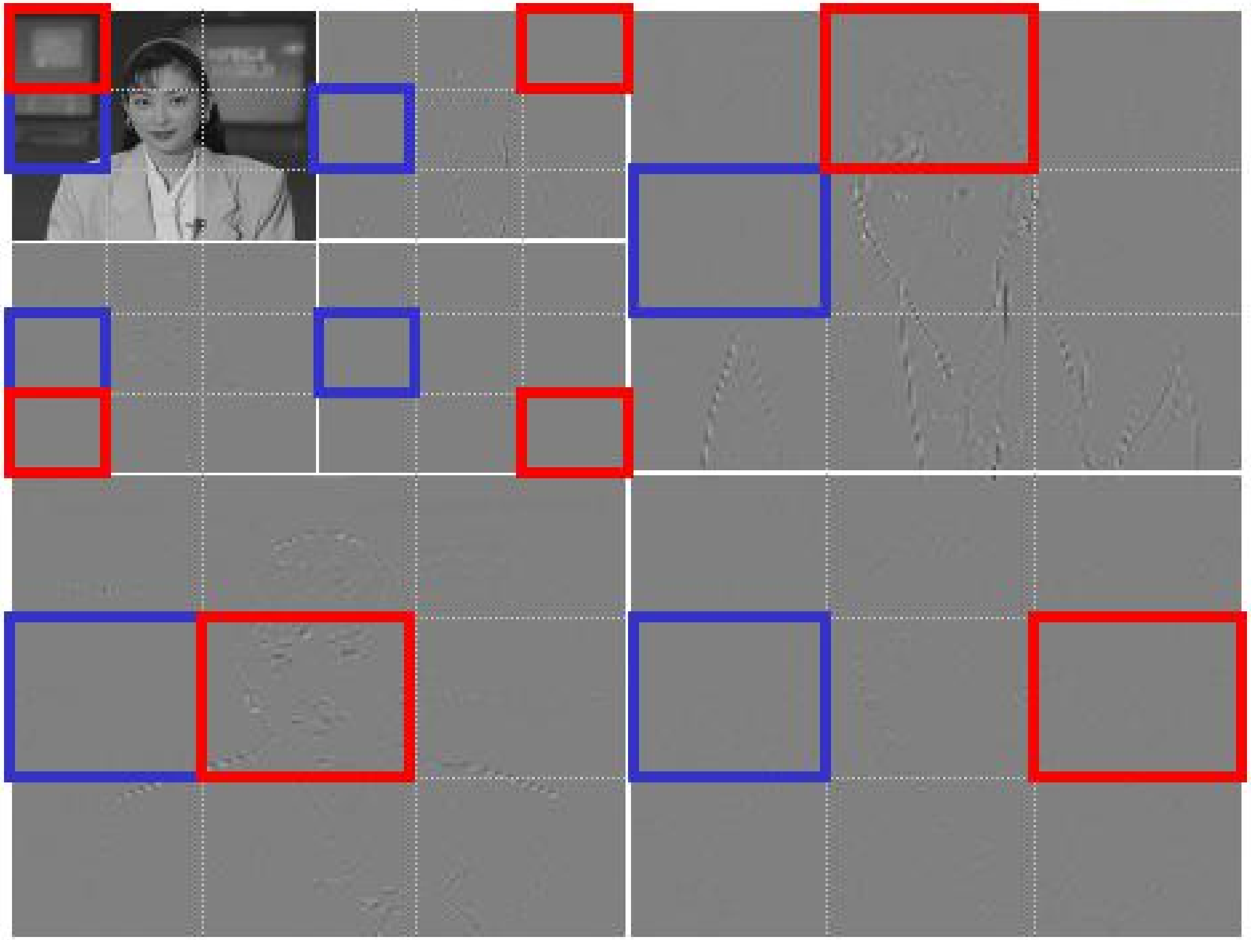
Non-resilient Video + FEC + Flow Control



Non-resilient Video + Flow Control

Achieving Error-Resilience

- Independently decodable
- Equally important
- Disperse effects of packet loss

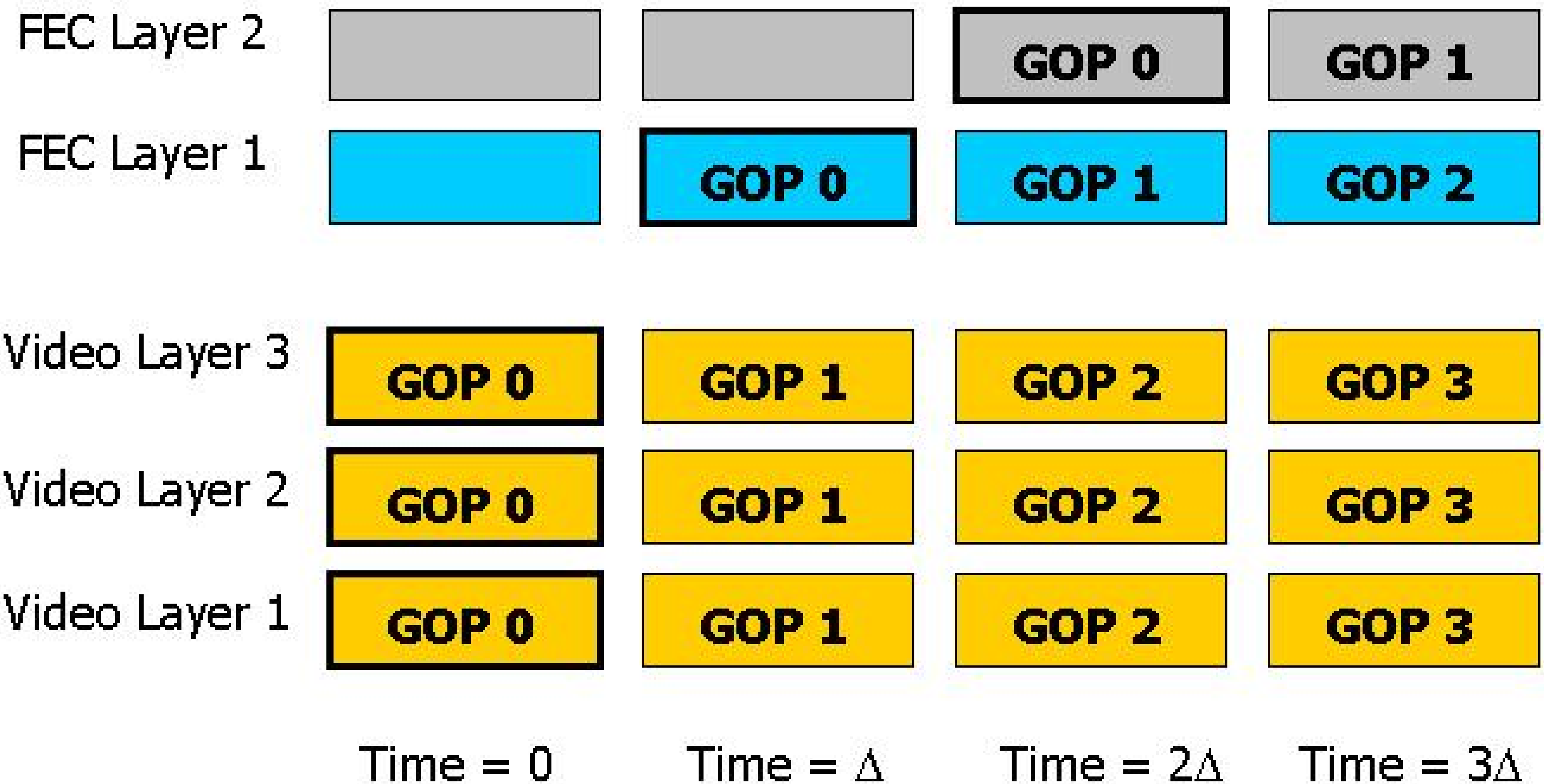


Song and dance between economics and technology

- Exmaples:
  - Multicast technology:
    - Can tremendously reduce distribution cost
    - Application level multicast: Fast Forward Networks/Inktomi
  - Diffserv: Pay more to get better quality
  - Content Distribution Networks:
    - Enabled video streaming on Overlay networks, with edge servers.
    - Example: Akamai, Digital Island, etc
  - Distributed video streaming: Napsterization of video

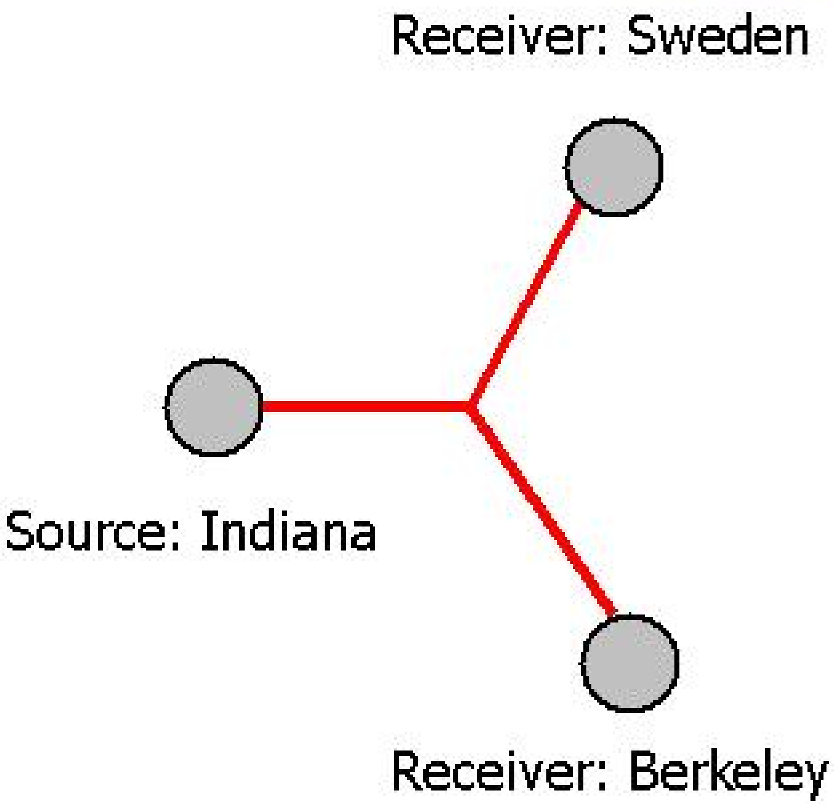
Example: Layered video + FEC in Multicast:
Tan and Zakhor, IEEE Trans. CSVT 2000

Let receivers subscribe to optimal number of FEC layers and video data layers based on its loss/bandwidth.

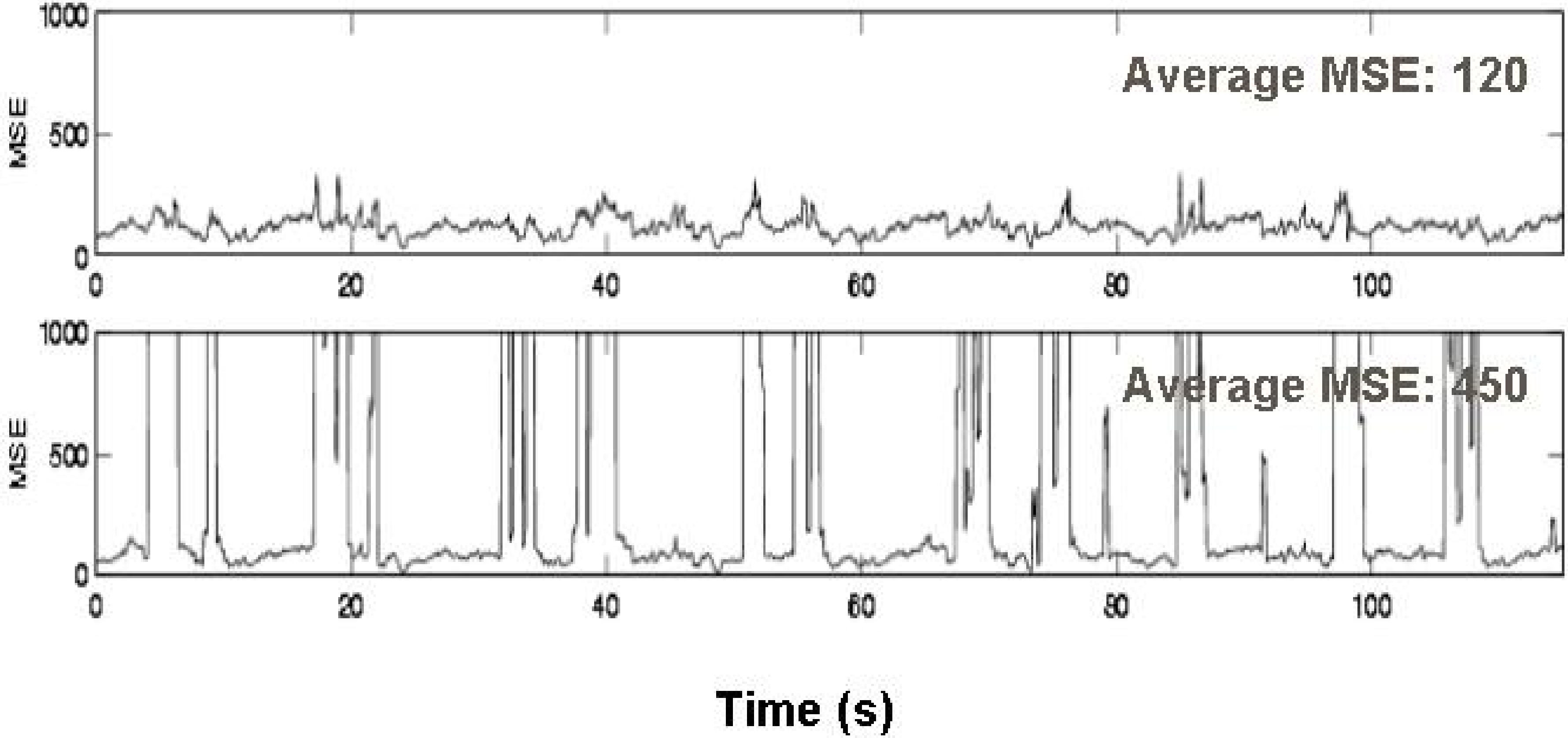


Mbone Experiment

- 6 data layers of 100kbps
- 6 FEC layers of 50kbps
  - 4 protects data layer 1
  - 2 protects data layer 2
- Two receivers each at Sweden and Berkeley
  - One uses LFEC, the other not



Mbone Experiment

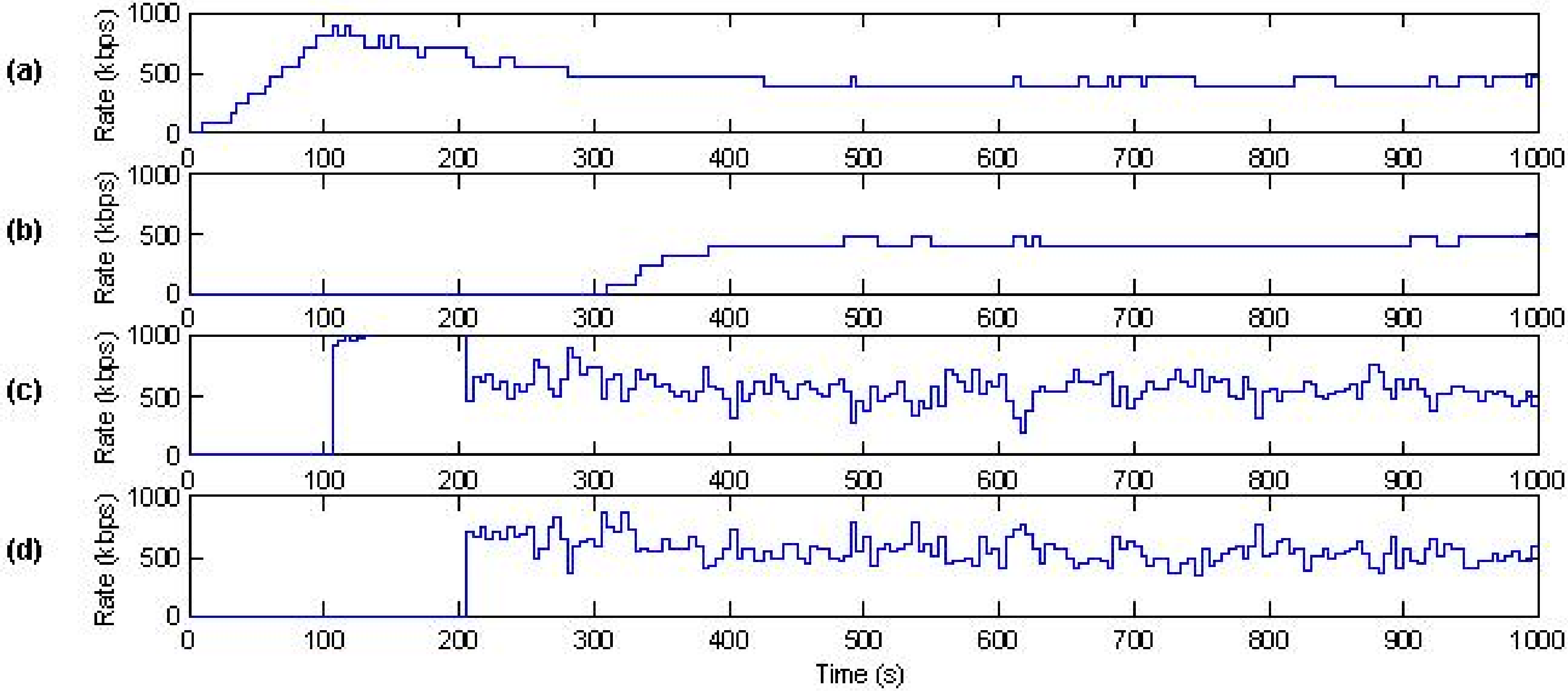


Visually...

Without LFEC | With LFEC

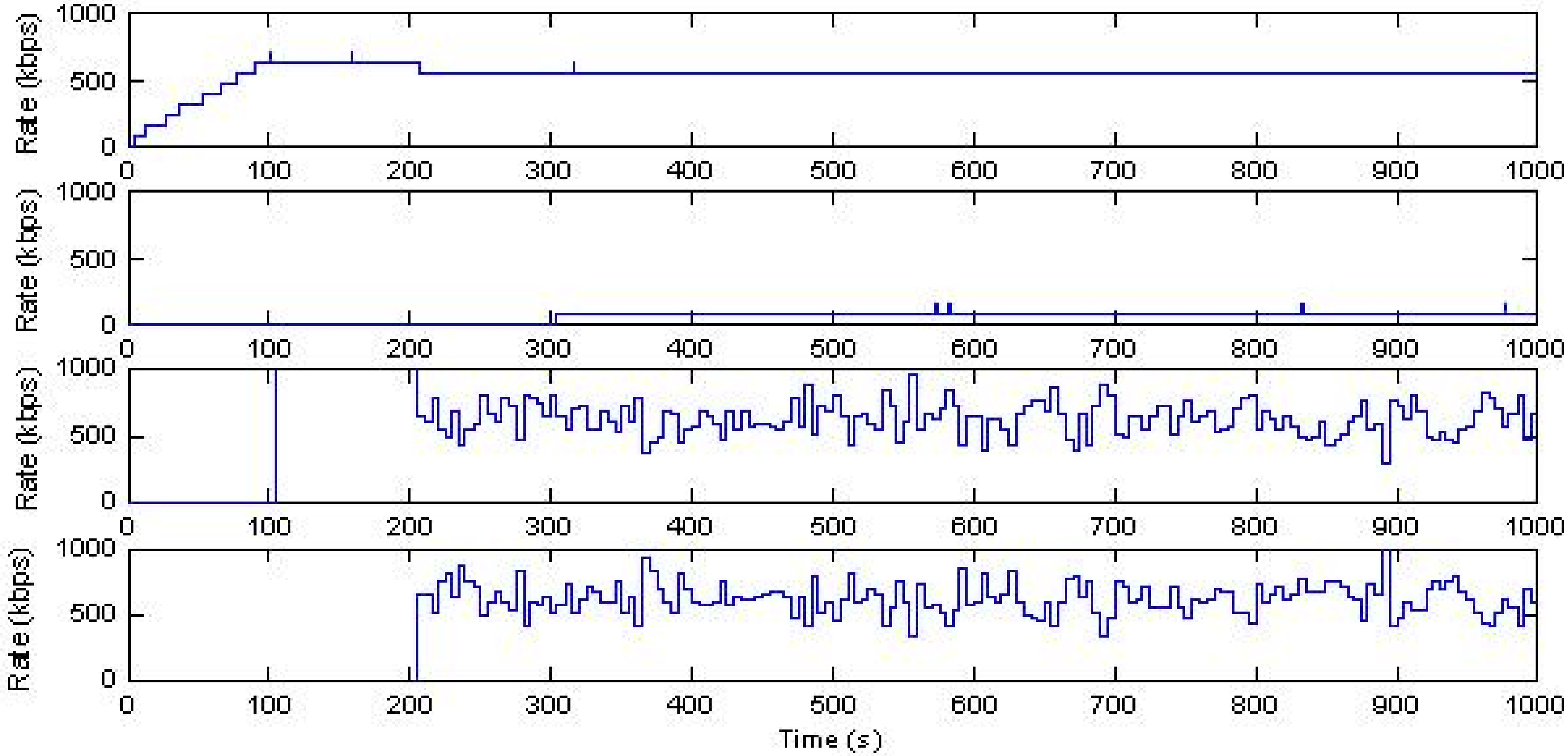
Layer add or drop decision by the receivers

TCP Friendly Equation based rate control (ERC) results in fair sharing of bandwidth among multicast receivers as well as TCP cross traffic.



(bottom) flows on "dumbbell"

Naïve add/drop strategy by receivers results in unfair usage of bandwidth

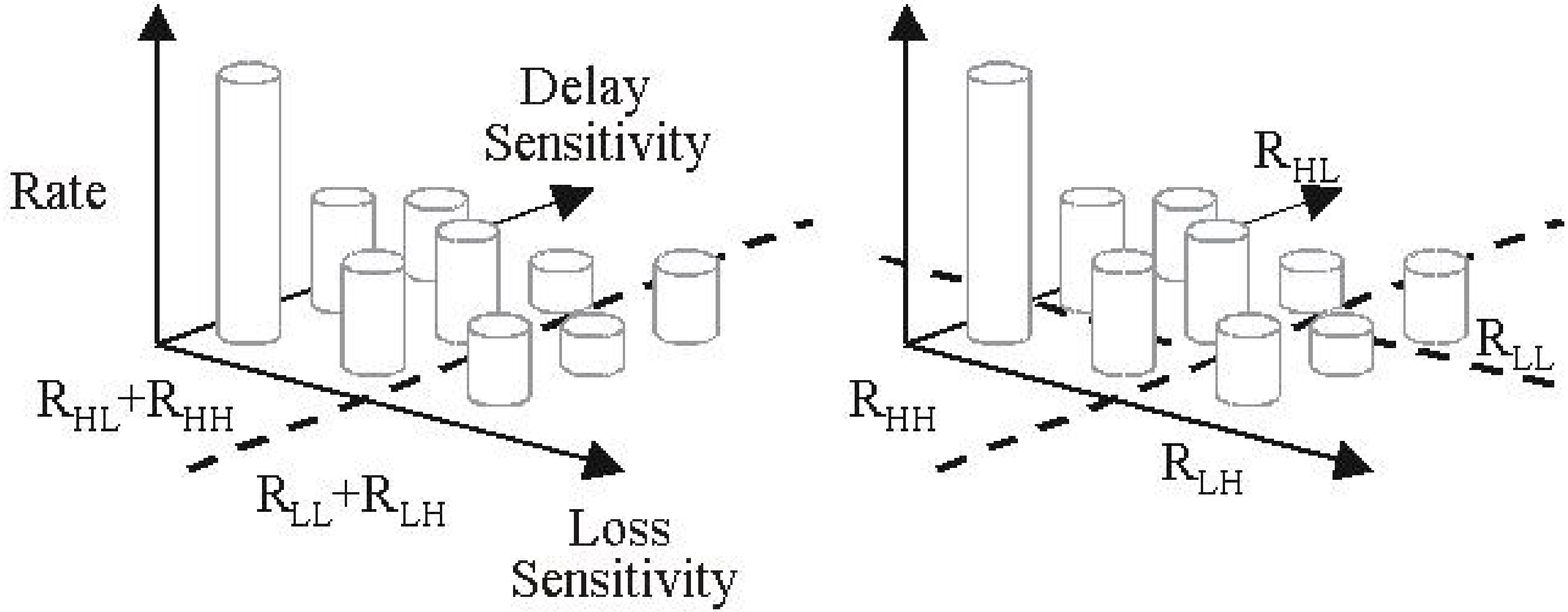


Diffserv based video streaming

- Qos enabled packet switched networks: diffserv, MPLS, traffic engineering, source based routing
- Diffserv: Routers process few classes of traffic differntially, resulting in different loss/delay
- How to send video over diffserv enabled networks:
  - Decompose video into streams of different delay/loss:
  - Send each substream to a different diffserv class.
- Advantages:
  - Better utilize network resources
  - Provide some level of quality of service.

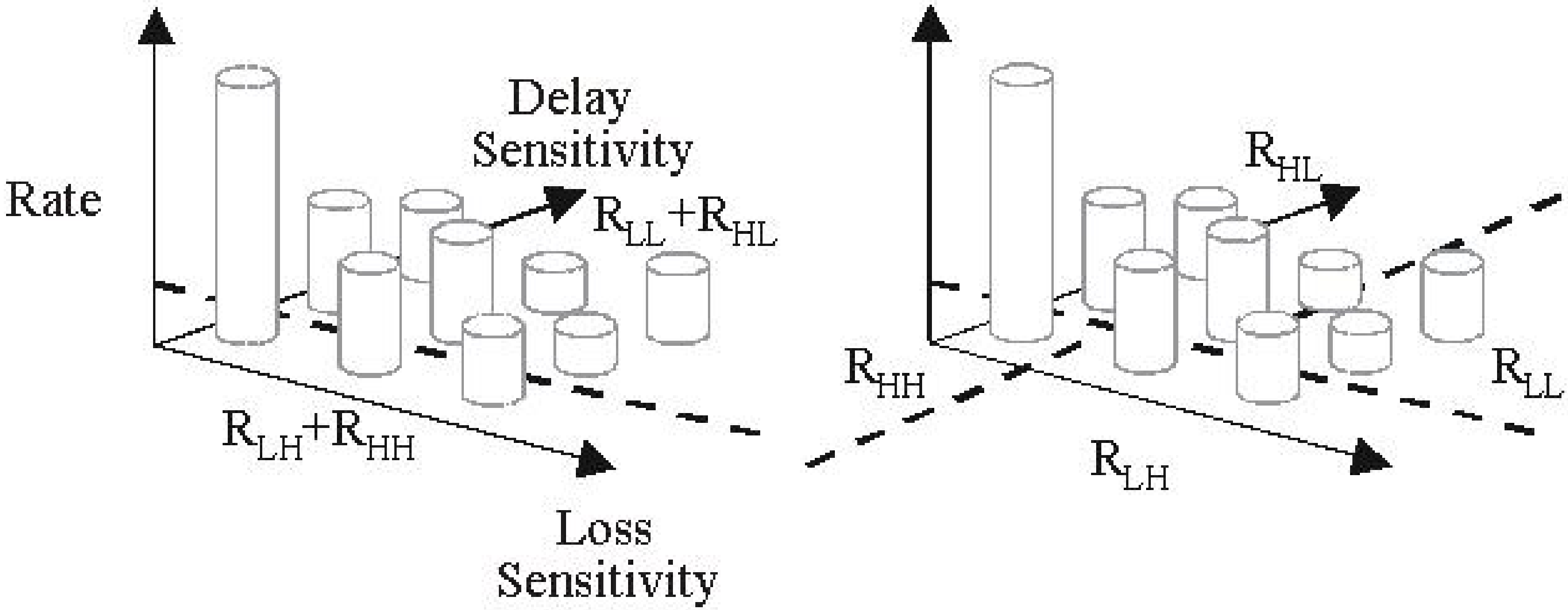
Loss Optimized Classifiers

Tan and Zakhor, Packet Video Workshop 2001



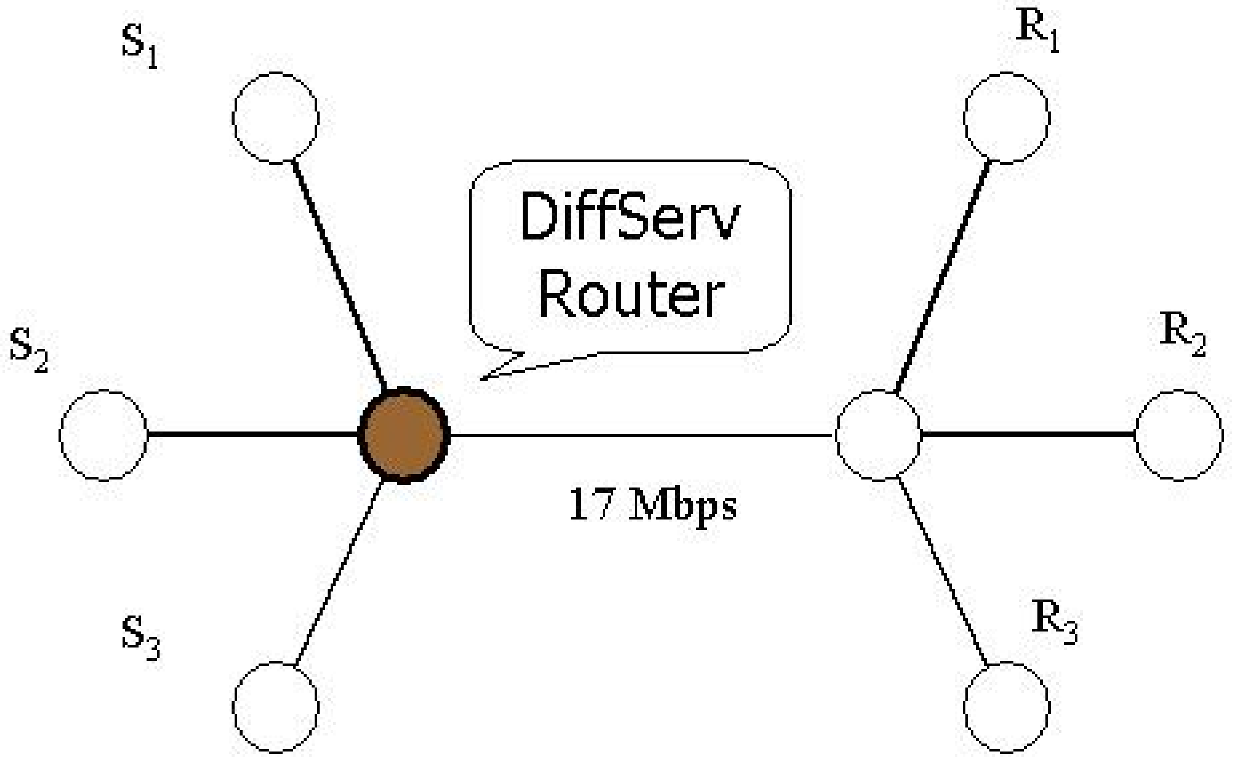
Loss-optimized classifier

Delay Optimized Classifiers



Delay-optimized classifier

Simulation Setup

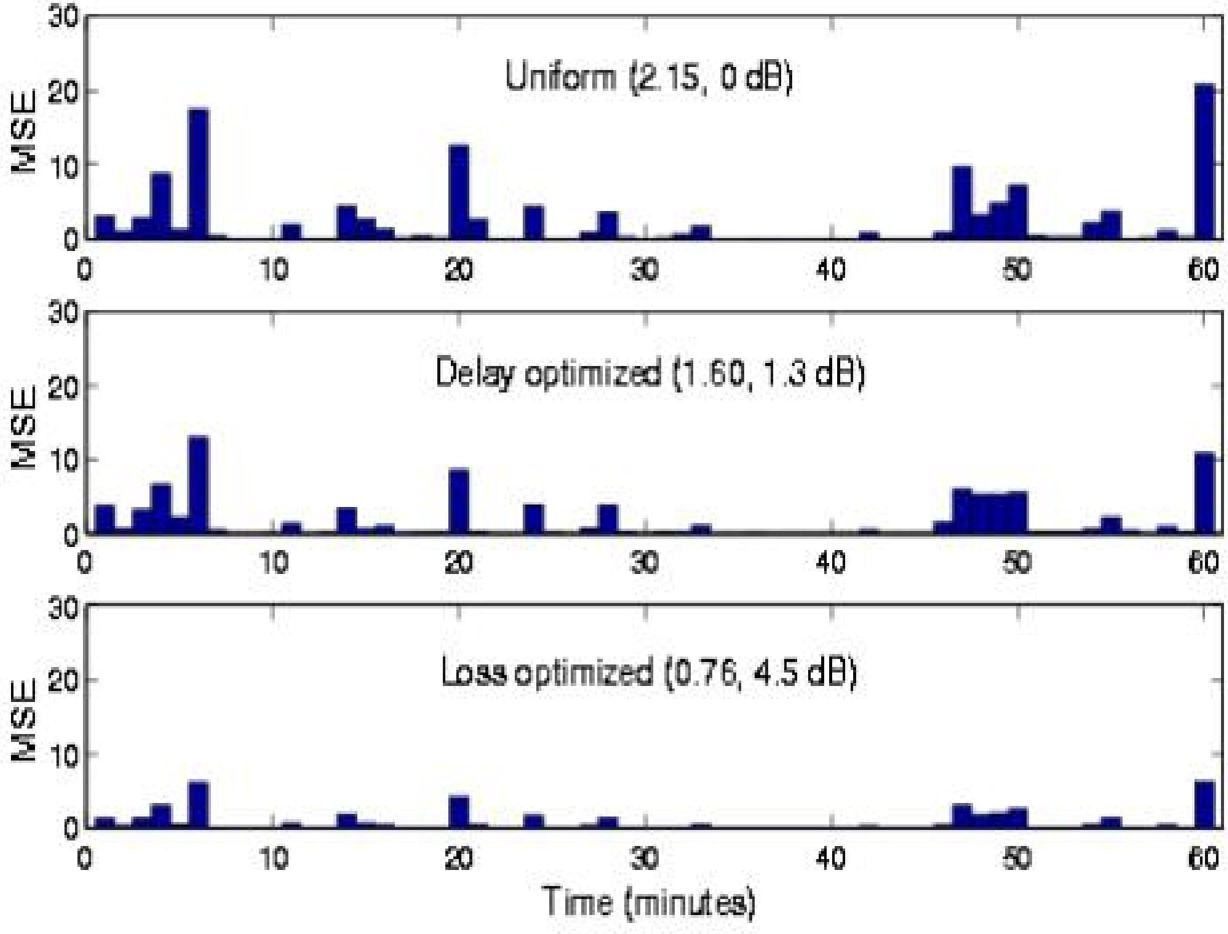


Simulation Results - Distortion

Uniform

Delay-optimized (1.3 dB)

Loss-optimized (4.5 dB)

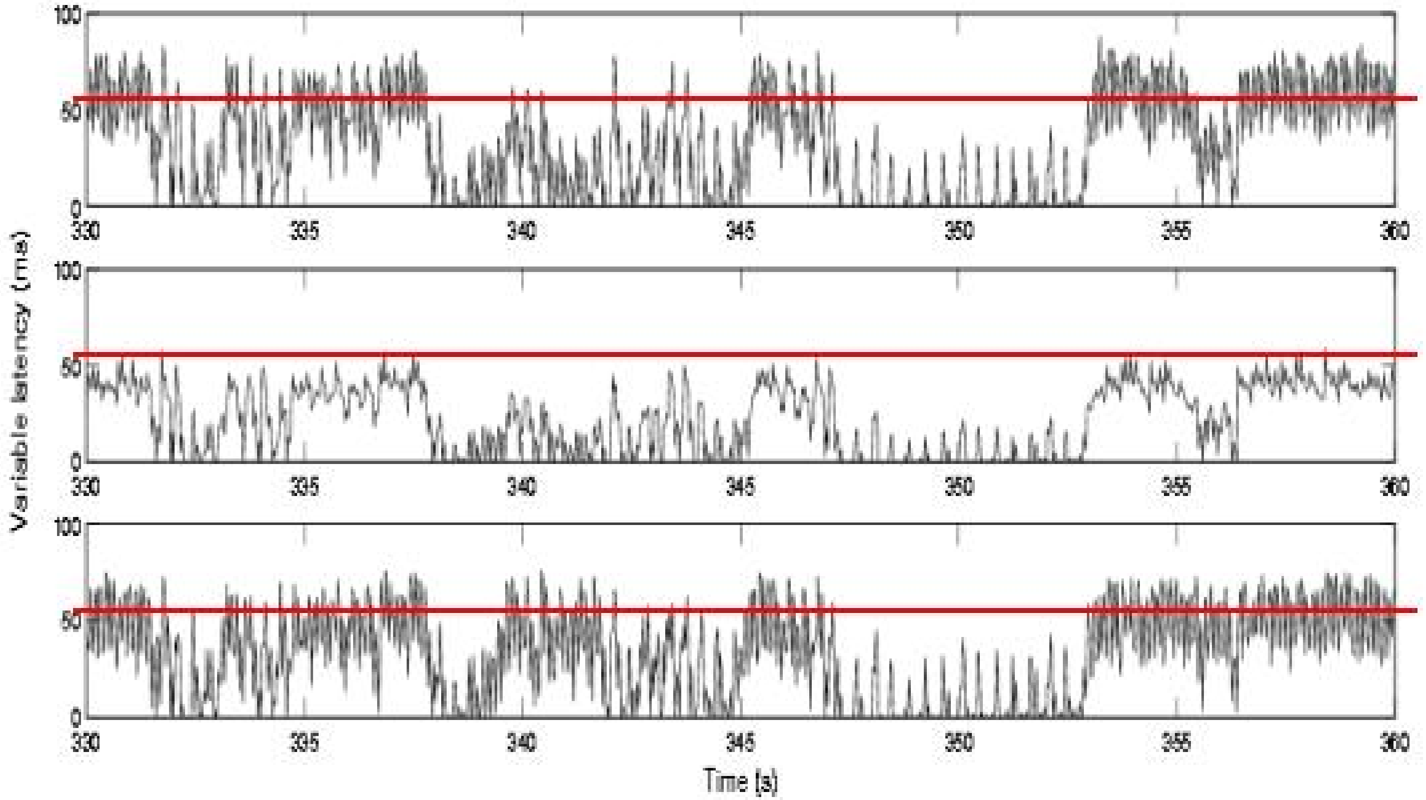


Delay Results – heavy load

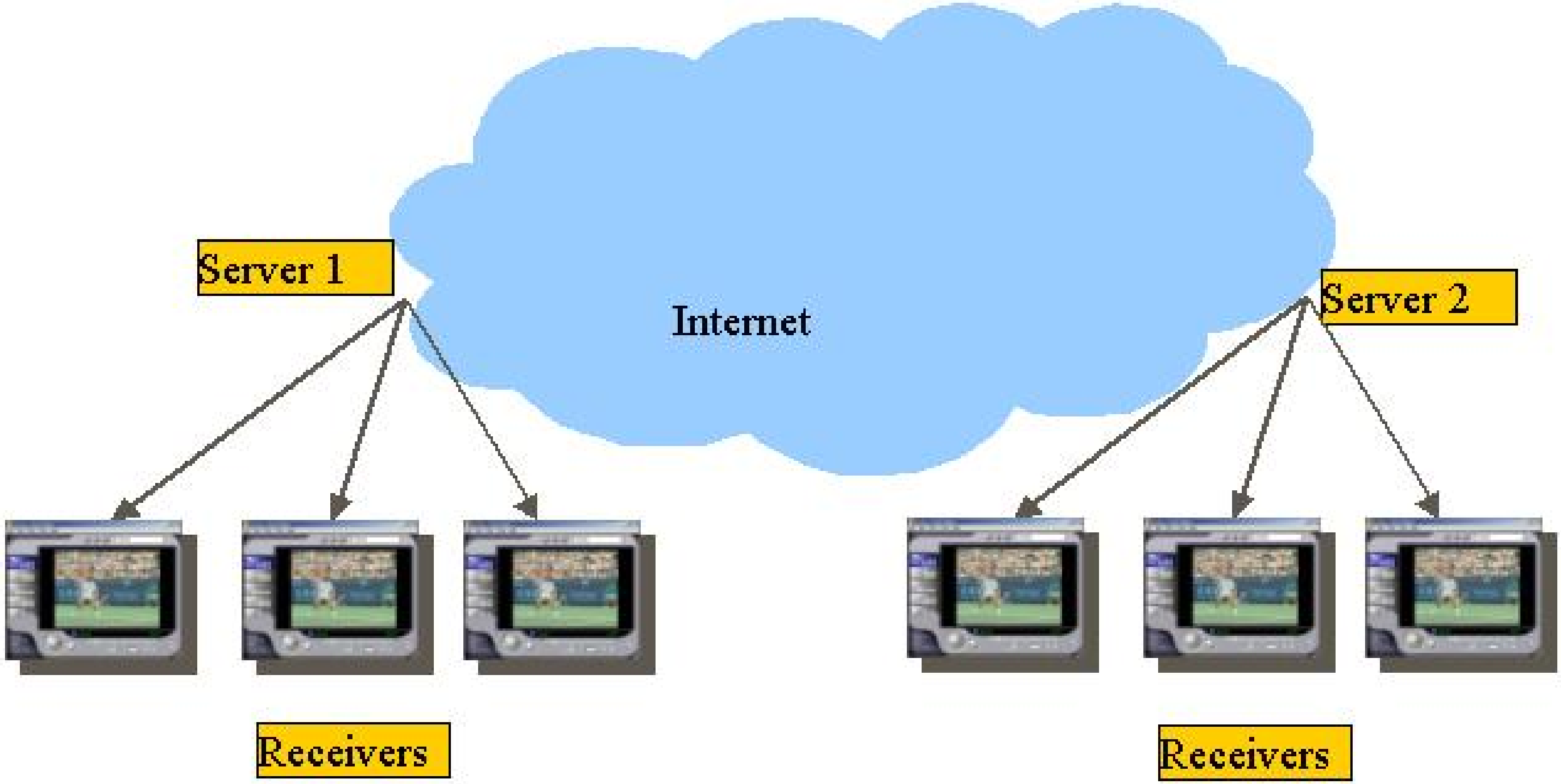
Uniform

Delay-optimized

Loss-optimized

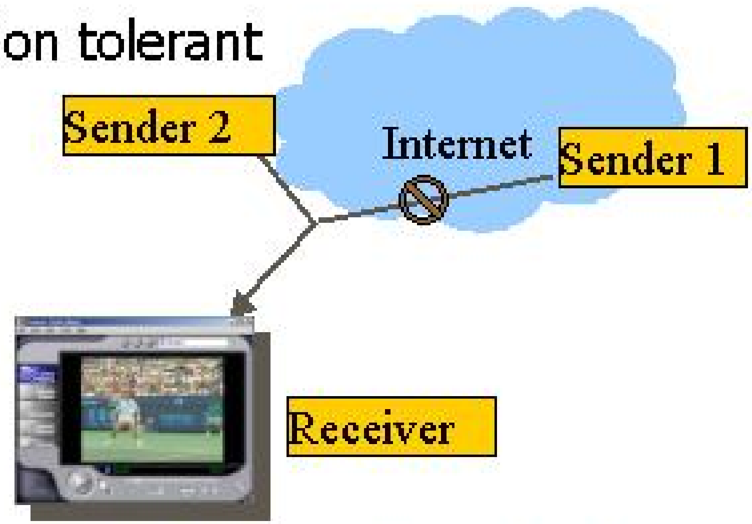


Edge Architecture



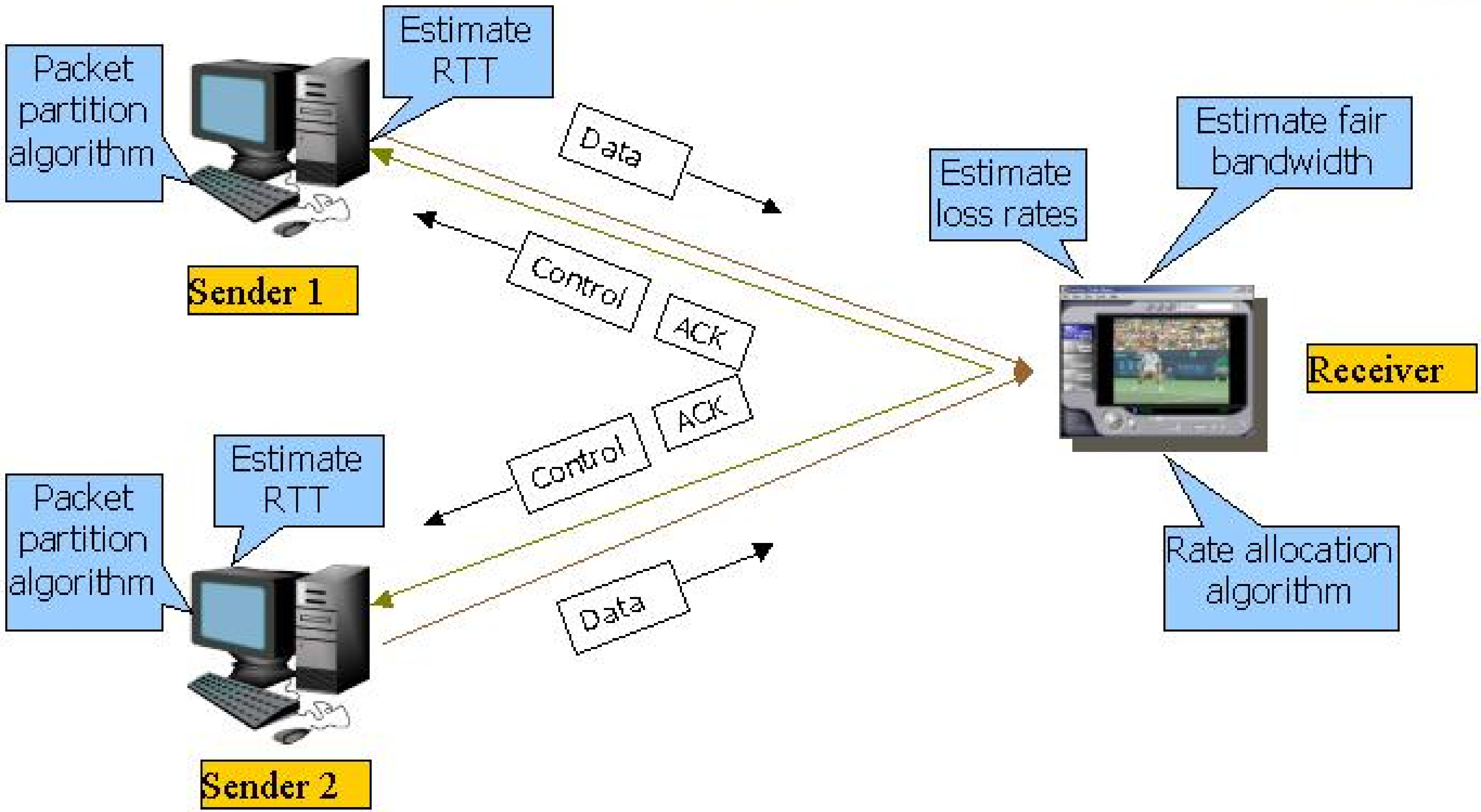
Distributed Video Streaming: napsterizing video:

- Ngyuen and Zakhor, SPIE 2002, 1/24
- Simultaneous distributed streaming of video from multiple senders
  - Higher aggregate bandwidth
  - Fault and network congestion tolerant

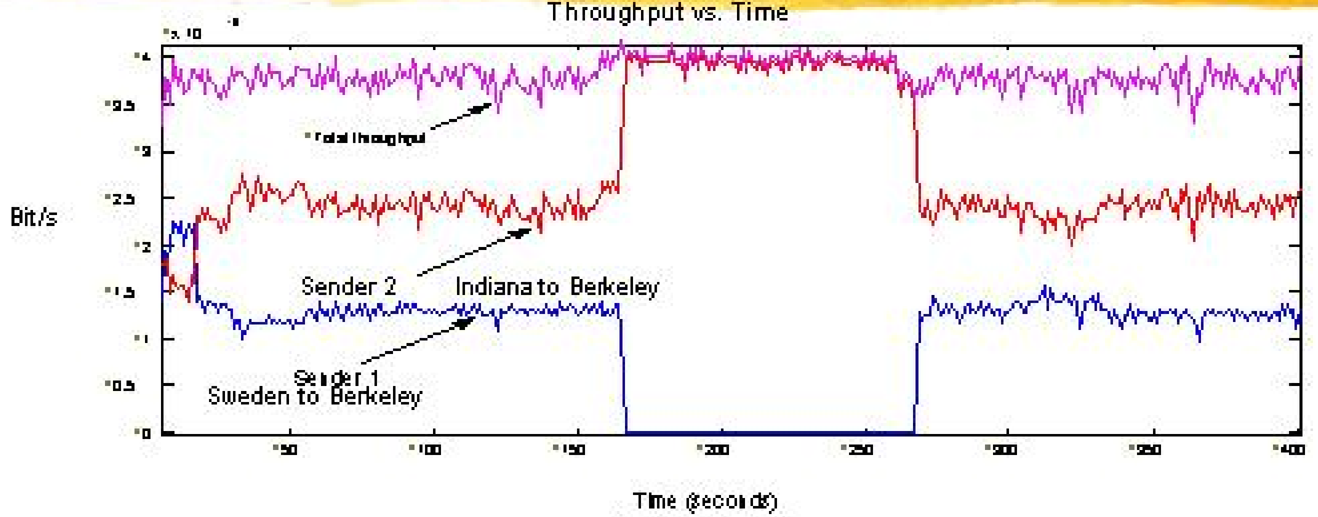


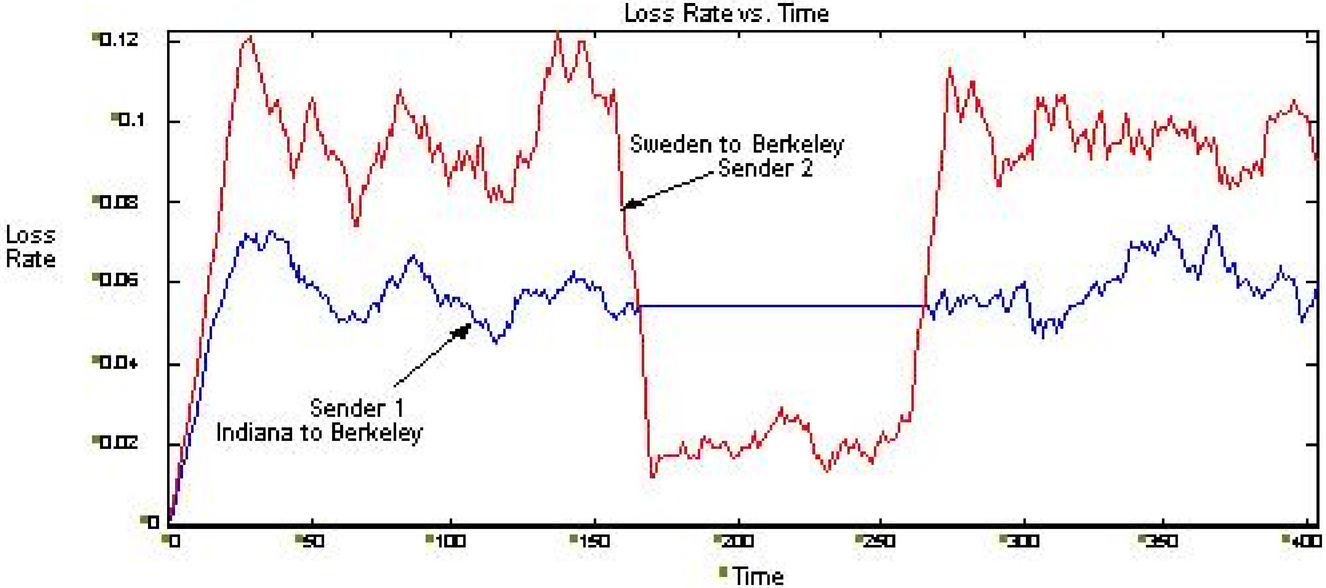
- Challenge: Design required protocol to facilitate distributed streaming

Protocol Design (cont' d)



Internet Experiment





Wireless Video Networking

	Seen, heard of or read about	Already have	Expect to drive in the next 12 months	Interested in but no plans to buy
PDA/hand held with wireless web access	62%	2%	2%	23%
Web enabled cell phone	60%	7%	1%	20%
MP3 player with hard drive	42%	2%	1%	16%
MP3 player without hard drive	42%	2%	1%	17%

Consumer Interest and buying for mobile internet music platforms

Obstacles to wireless streaming

- Channel, Channel, Channel:
  - Time varying
  - Long bursts and periods of low throughput
  - Small available bandwidth, low bit rates
- Existing wireless networks:
  - HDR from Qualcom. 1 Mb/s; not deployed yet
  - Mobitex: Ericsson
  - CDPD: omnisky and goamerica leased from ATT and Verizon: 5 to 19.2 kbps:
- Future: 3G, 4G, etc.

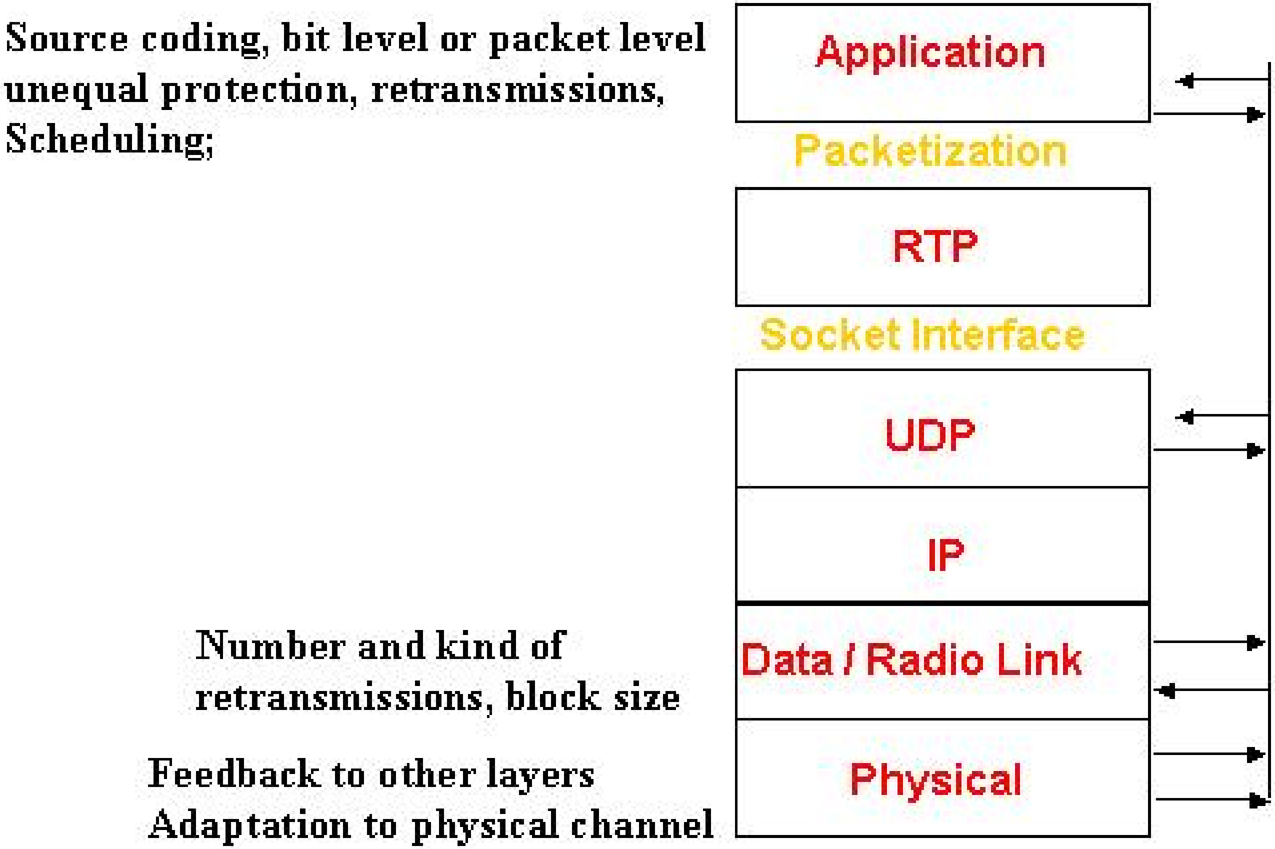
What is the killer app in wireless video?

- Nannycam, webcam for traffic conditions
- Wireless bandwidth too expensive for entertainment:
  - Good compression important.
- What compression technology?
  - MPEG-4 vs. Proprietary;
  - Demo: Truvideo codec streamed over CDPD network.(courtesy of Steve Van de Bogart)

Technical Issues on Wireless Video Networking

- Major issues:
  - Wired: congestion, transport layer
  - Wireless: loss at the physical layer, time varying, unpredictable channel
- Different approaches for interactive vs. streaming:
  - Retransmission, large buffer for streaming
  - Interactive or live require low delay;
    - FEC;
    - Physical diversification schemes: antenna, path, time, space, frequency, etc.

Layer Adaptation to Channel and Source Data



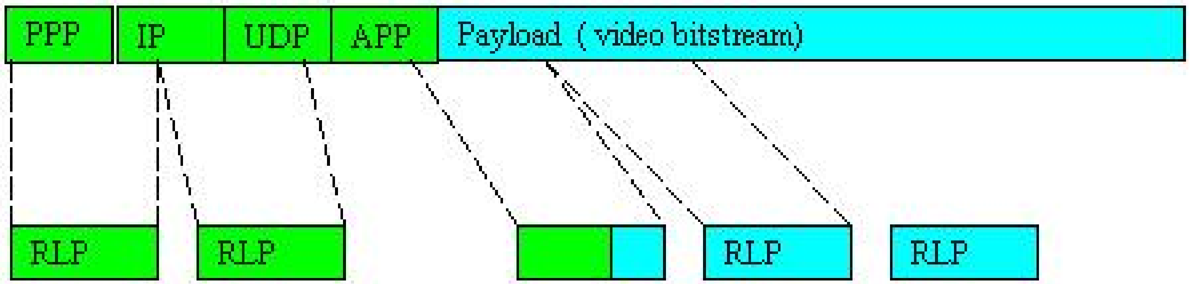
Make sure layers don't interact destructively

Layer Adaptation to Channel and Source Data (2)

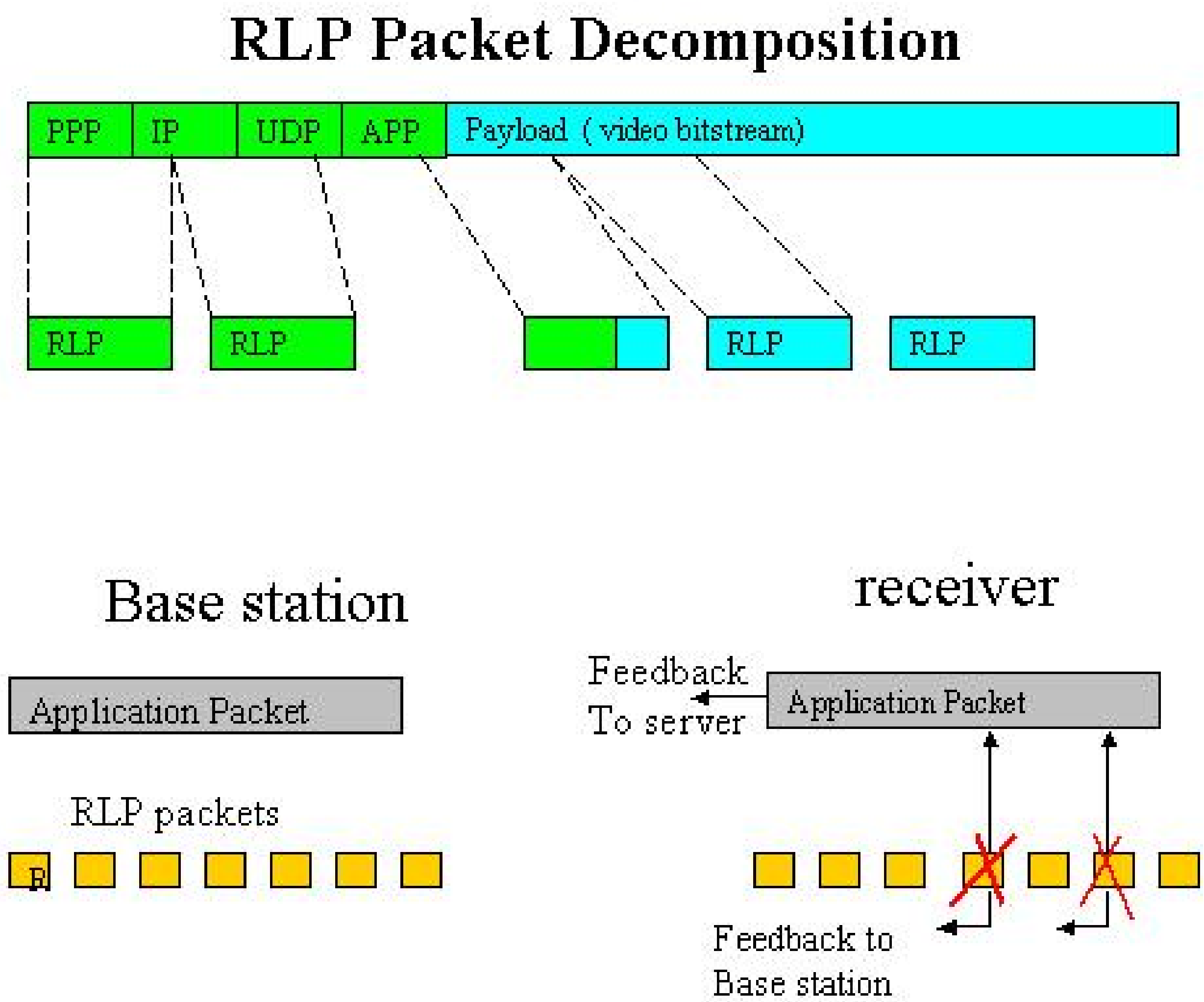
- FEC and ARQ can be applied to any layer:
  - At lower layer, implementation complexity to adapt to packet importance
  - At higher layer, larger packets, more delay, more waste of bandwidth
- Pass along corrupted packets to higher layers:
  - UDP lite passes "up" corrupted RLP packets to application layer for retransmission.
  - Small RLP packets only are sent again, not large UDP
- Scheduling at application layer sends packets out of order based on their importance

Layer Adaptation to Channel and Source Data (3): Example

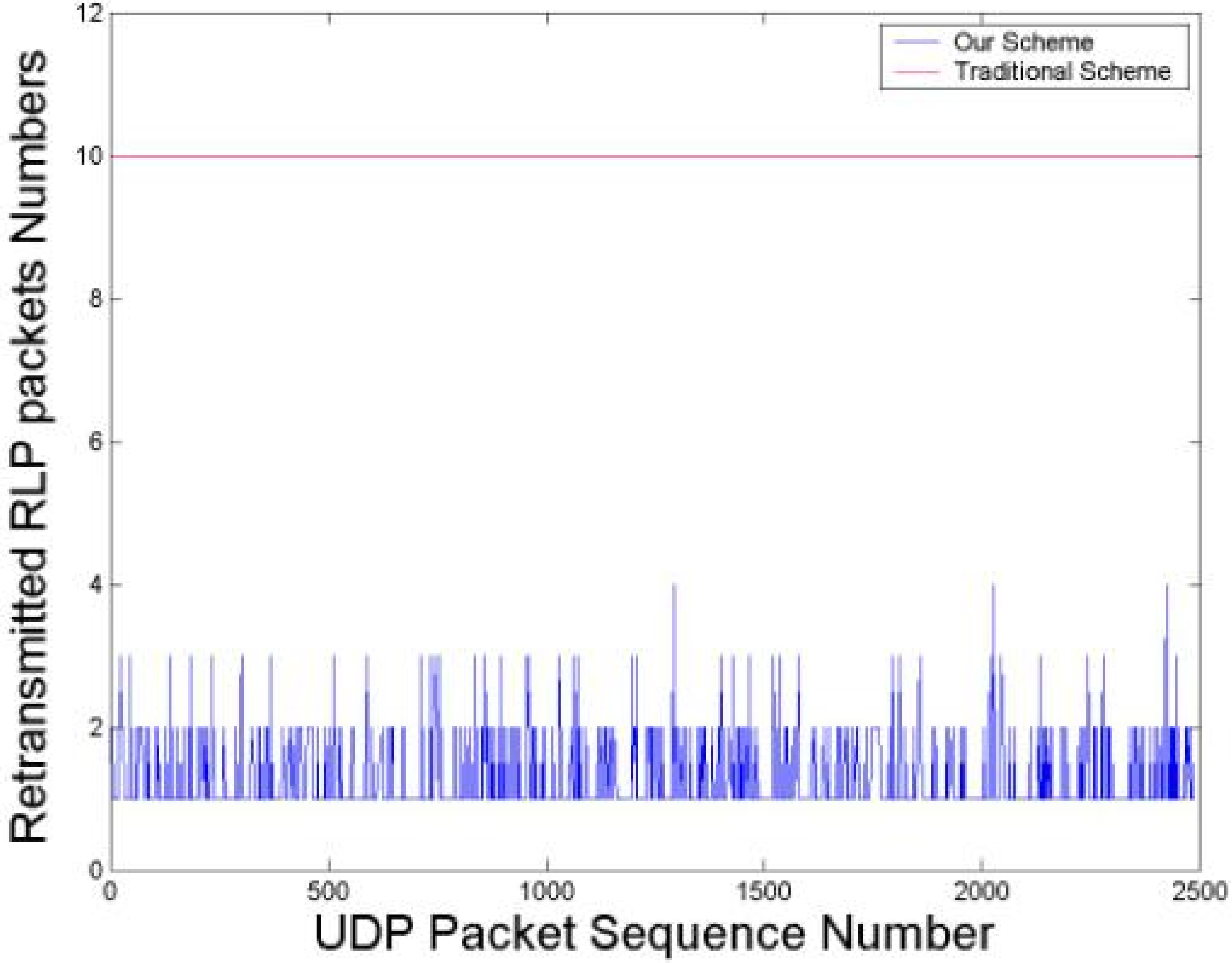
- Apply redundancy at the application layer so that UDP packet is automatically decomposed into (n,k) RS coded RLP packets with more redundancy to important RLP packets;
  - Unequal FEC computation at application layer, but FEC size at the level of RLP packets;



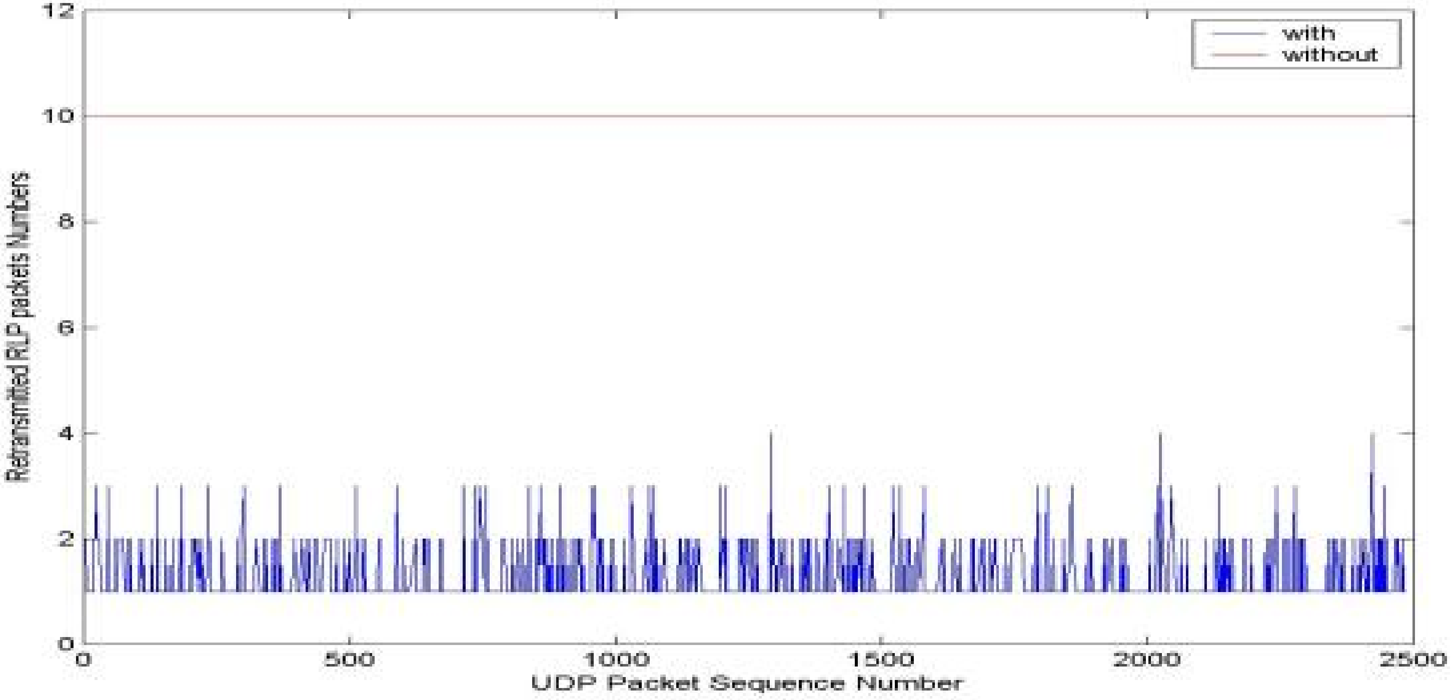
Overall System



Performance

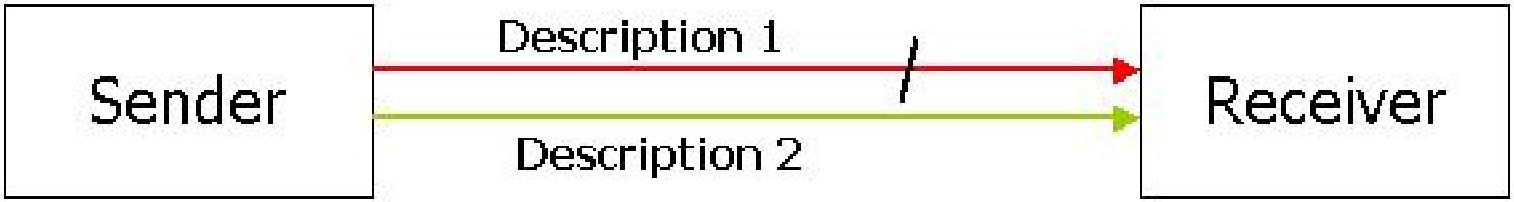


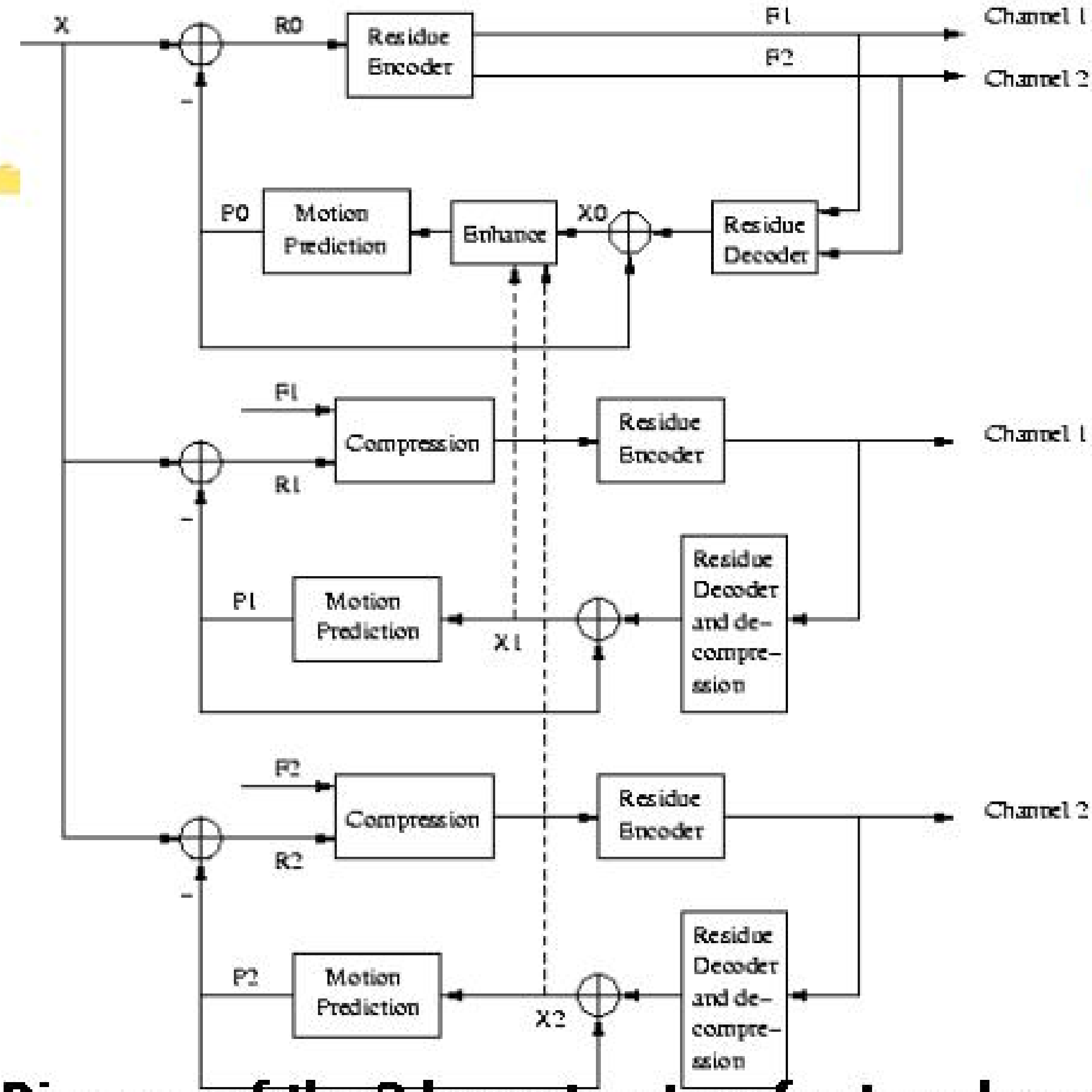
Performance



Analog of distributed streaming in wireless

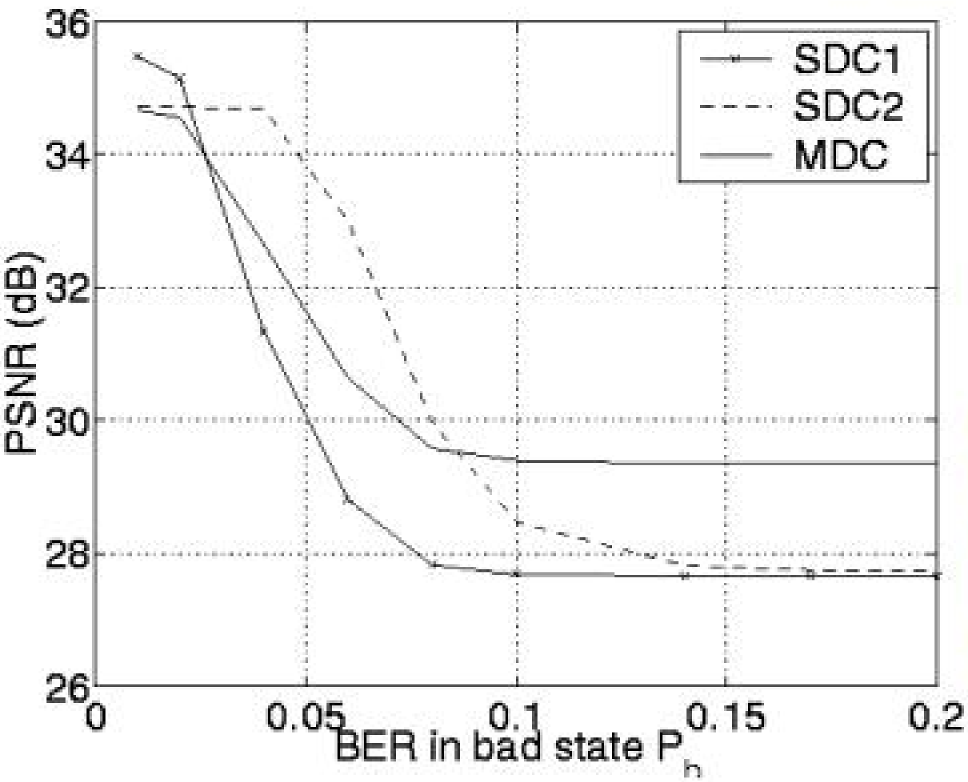
- Triband cell phones operate at 3 frequencies.
- Send three streams on each of the three channels to allow diversification;
- If conditions of channels are not known to each other, can use multiple description coding
- Any single bit stream yields acceptable quality
- More bit streams create better quality





Block Diagram of the 3 loop structure for two description coding
Tang and Zakhor, ICIP 2001

Two state slowly varying Markov Channel



- Two state Markov Channels at 900 MHz and 1.8 GHz
- SDC1, SDC2 and MDC + FEC
- Total bit rate constant in all cases
- SDC1 source rate same as MDC
- SDC2 source PSNR same as MDC

Conclusions

- MM communication revolution is here
- Host of technical and economic issues need to be resolved
  - DRM probably stickiest of all!
- Computer, entertainment, semiconductor industries are all poised to “own a piece of this pie”.