Video Transport Over Ad Hoc Networks
Multistream Coding With Multipath Transport

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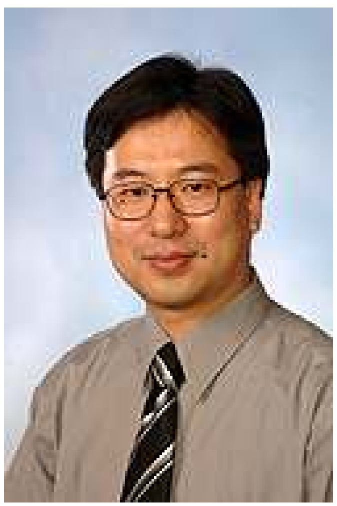

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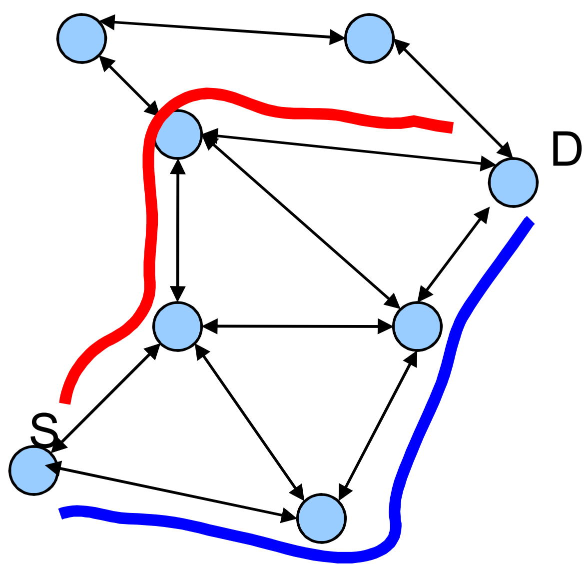
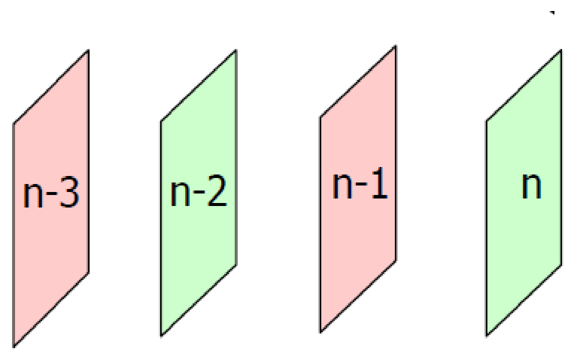
Editorial Board
• IEEE Transactions on Wireless Communications (TWireless)
• Elsevier Ad Hoc Networks Journal
• Wiley International Journal of Communication Systems.

Purpose

- What gain is possible by combining multipath routing and multistream video coding





Motivation

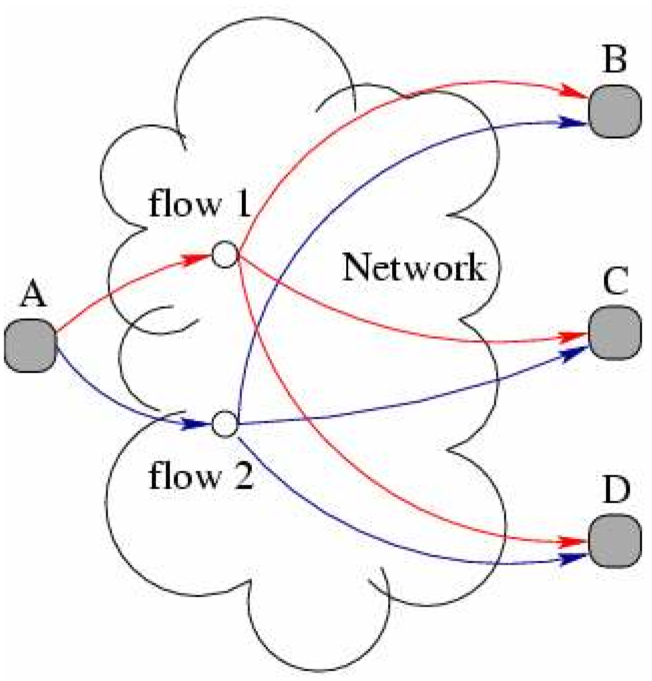
- Realtime multimedia services have stringent bandwidth, delay and loss requirements
  - Receiver will display received data continuously
- Internet is best-effort with no QoS guarantees
  - IP is best-effort
  - TCP is not suitable for realtime service
  - UDP is non-adaptive, susceptible to congestion
- Wireless mobile ad hoc networks
  - Have frequent link failures and topology changes

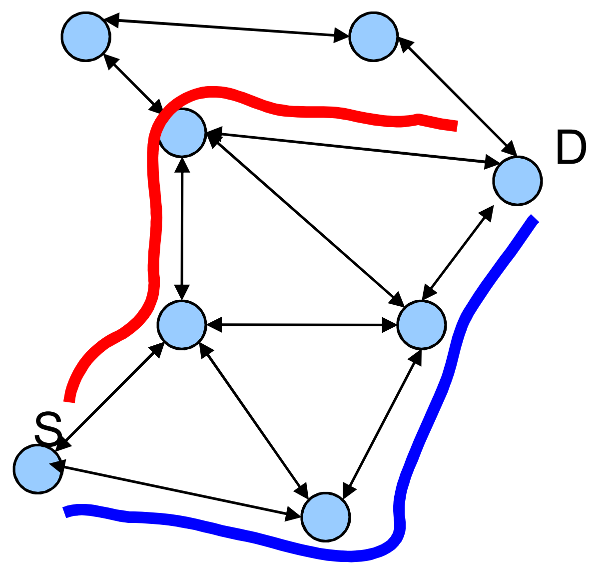
Motivation

- Multipath transport (MPT) provides a means to deal with some of these problems
  - Load balancing inside network
  - Load balancing among servers
  - Larger aggregate capacity for video session
  - Path diversity for better resilience
  - Traffic partitioning results in better queuing performance
- The benefits are gained at the cost of
  - Increased computational complexity
  - Higher network traffic load

Multistream video coding

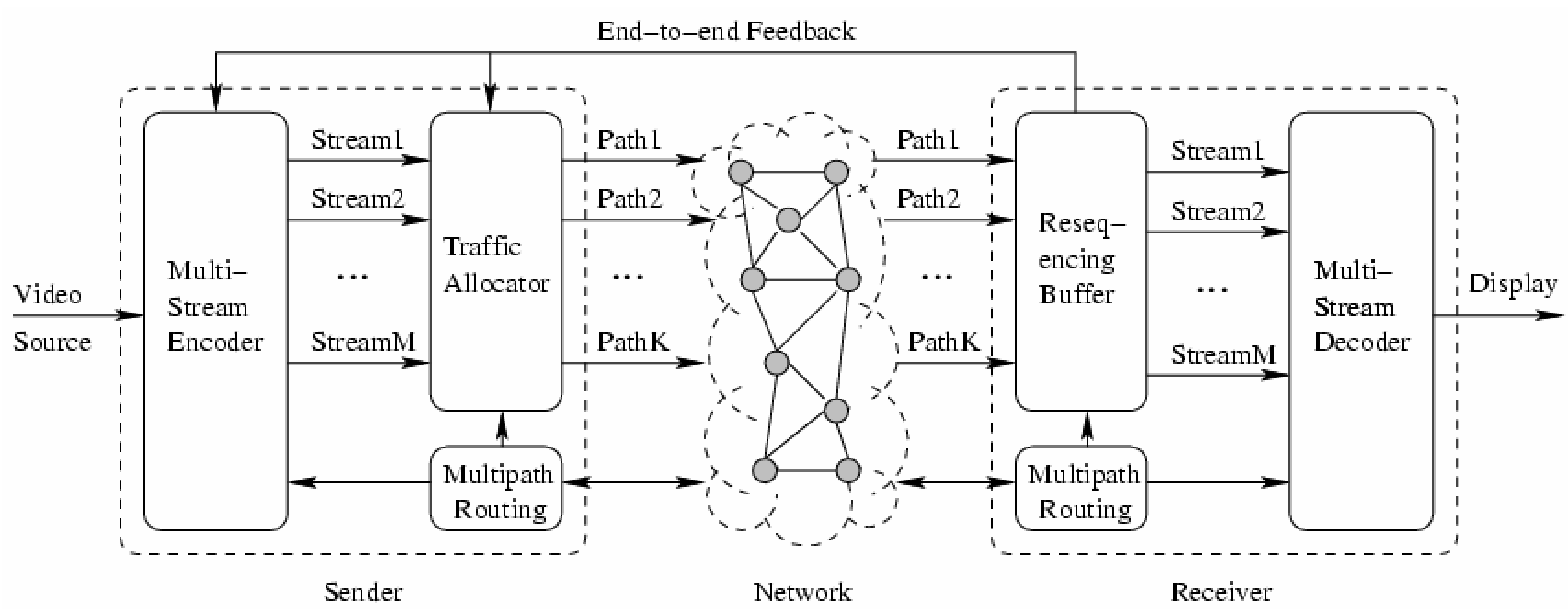
- Seen this concept before with multicast but in this paper feedback is allowed and application is point to point





Reference architecture

- Five core components: (I) Multistream video coding, (ii) Traffic allocation (iii) resequencing (iv) Multistream decoding (v) Multipath routing

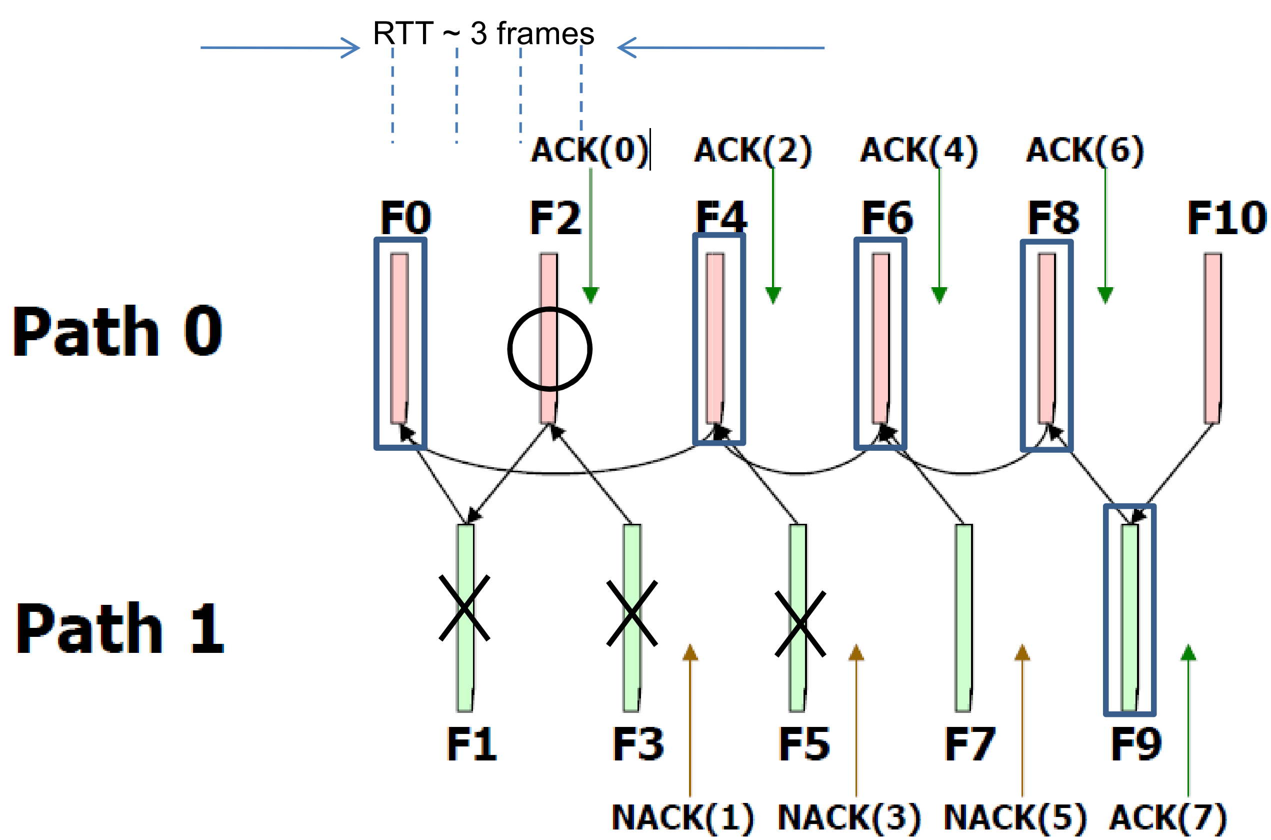


Coding schemes for Video over ad hoc networks

- Exploit path diversity using three coding schemes which are build on block based Motion Compensation Prediction (MPC)
  - Reference Picture Selection (RPS)
  - Layered coding with selective ARQ (LC with ARQ)
  - Multiple description Motion Compensation (MDMC)

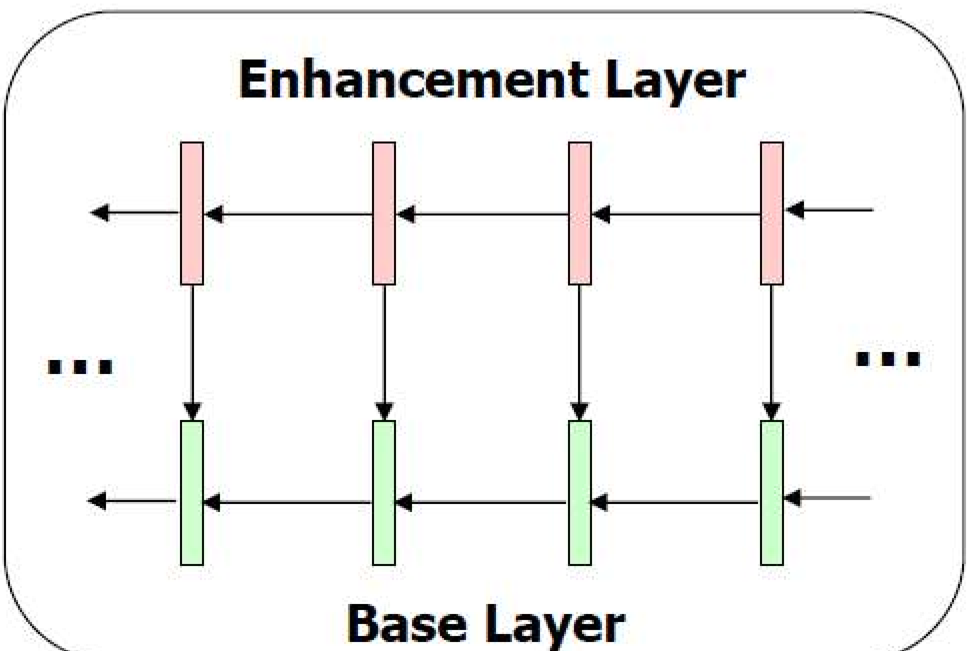
Scheme 1: RPS

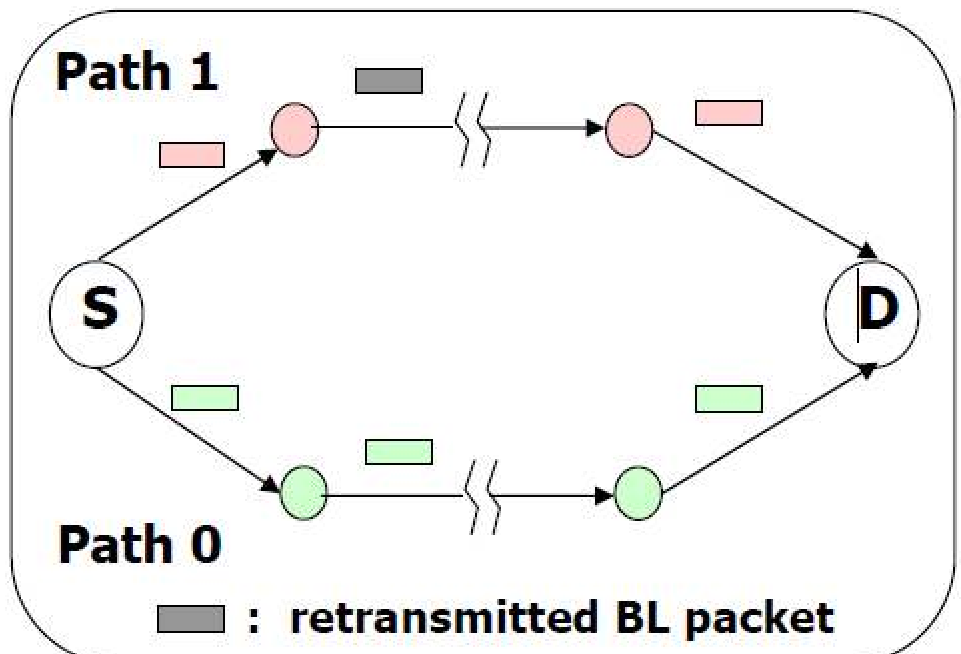
- Even/odd frames sent on separate paths
- Encoder keeps K recently encoded frames
- Predict damaged frames based on NACK
- Use undamaged frames (got ACK) as reference



Scheme 2: LC with ARQ

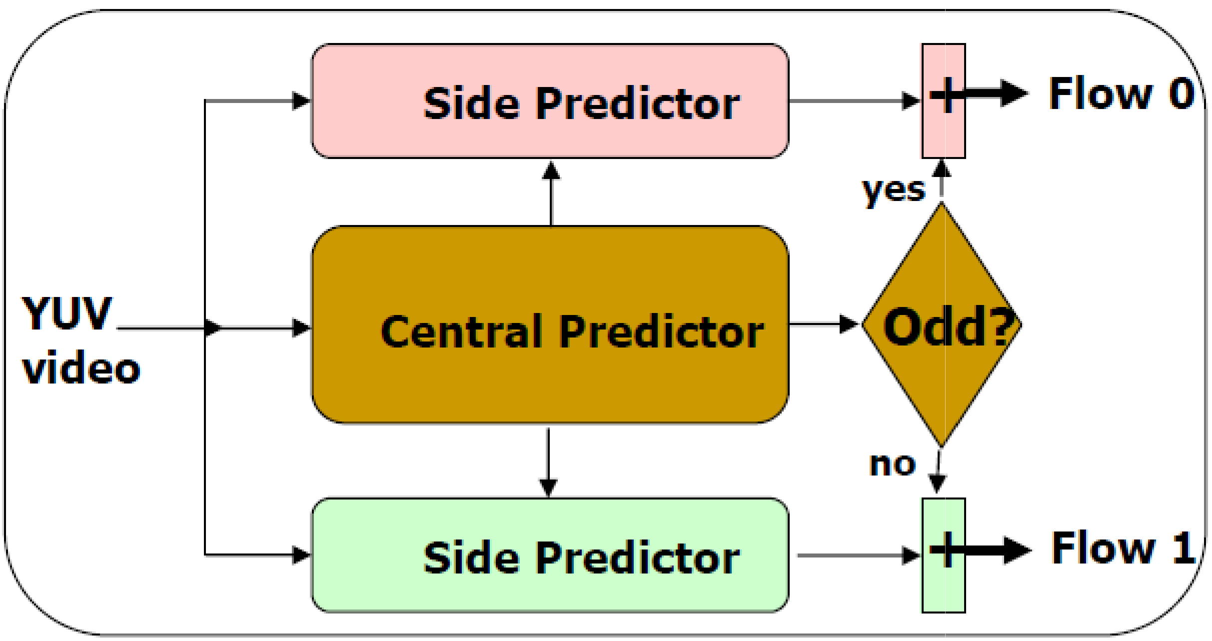
- Video encoded into 2 layers – base and enhancement
- Base layer sent on better path (has ARQ)
- Lost packets on base layer sent on enhancement Layer

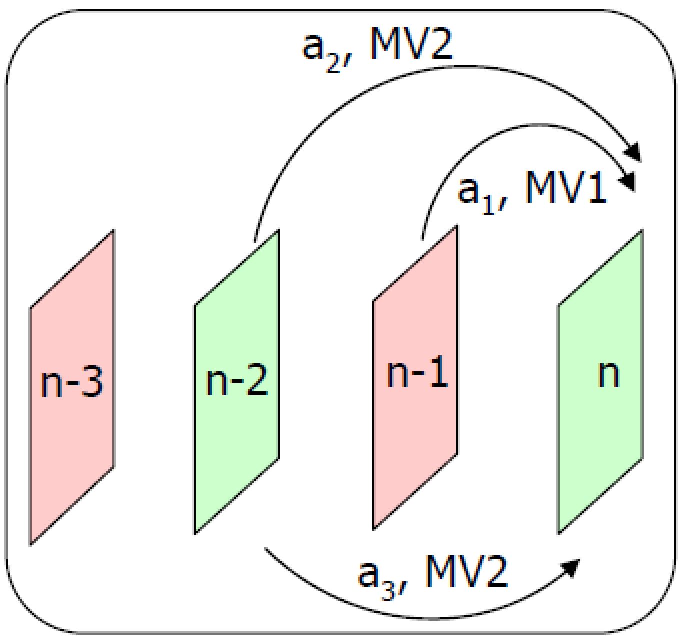




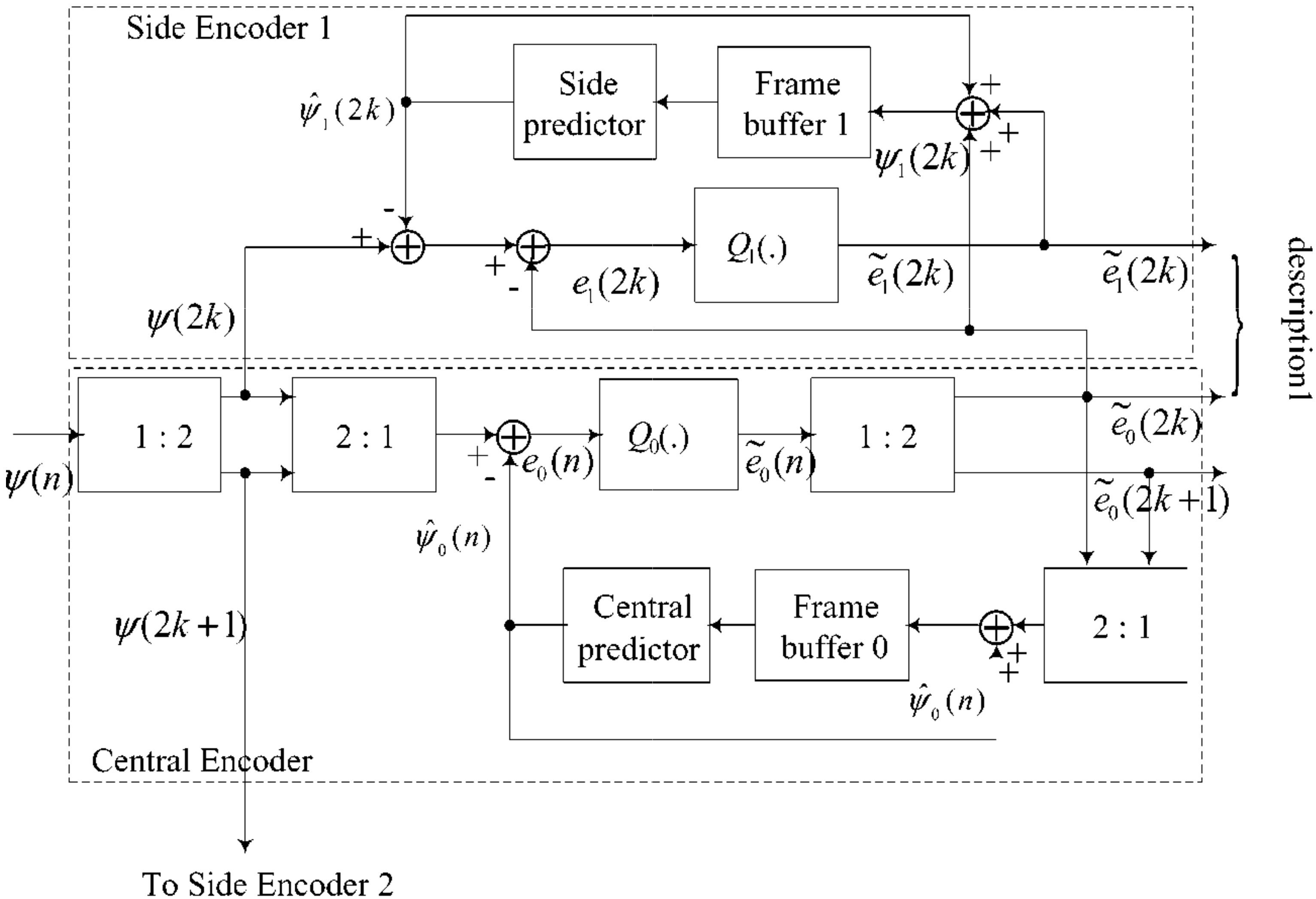
Scheme 3: MDMC

- Even/odd frames sent on separate paths
- No feedback channel required
- Each frame predicted from previous 2 frames – can reconstruct missing frame
- Mismatch in prediction coded explicitly (quantizing error between original and predicted is sent along with other information in frame n)
- Redundancy controlled by predictor and quantizer for mismatched signal – adjust based on channel loss





MDMC block diagram



(a)

MDMC – further info

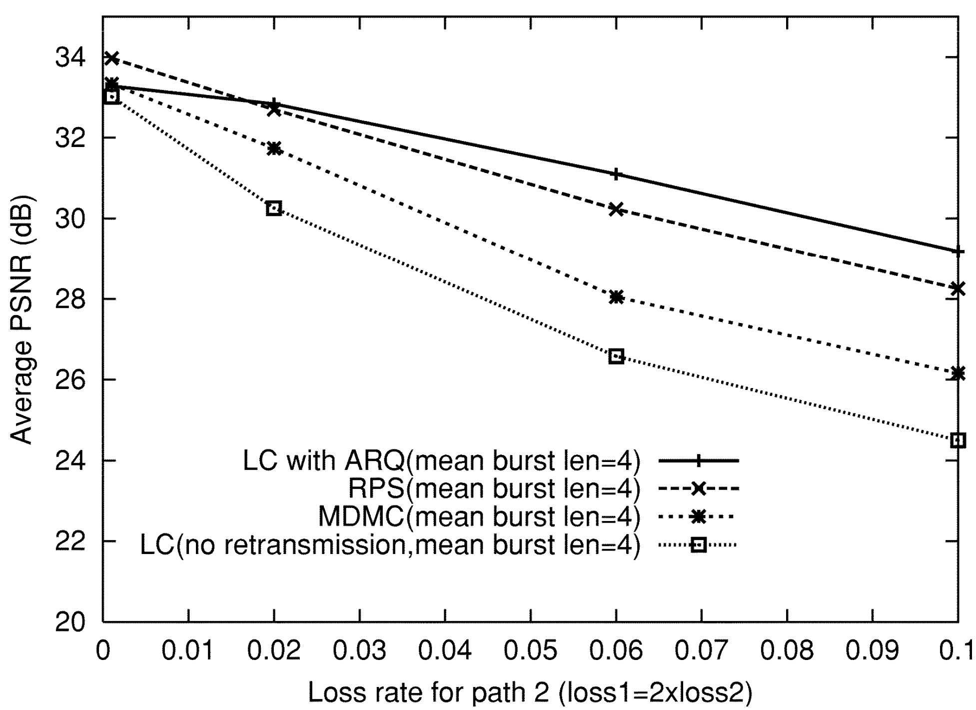
- Encoder uses three prediction loops
  - central prediction loop
  - two side prediction loops
- Mimic three possible scenarios at the decoder
  - both descriptions are received
  - description 1 alone
  - description 2 alone is received.
- The central predictor uses both even and odd past samples for prediction
- side predictor uses only even or odd samples to produce predicted values

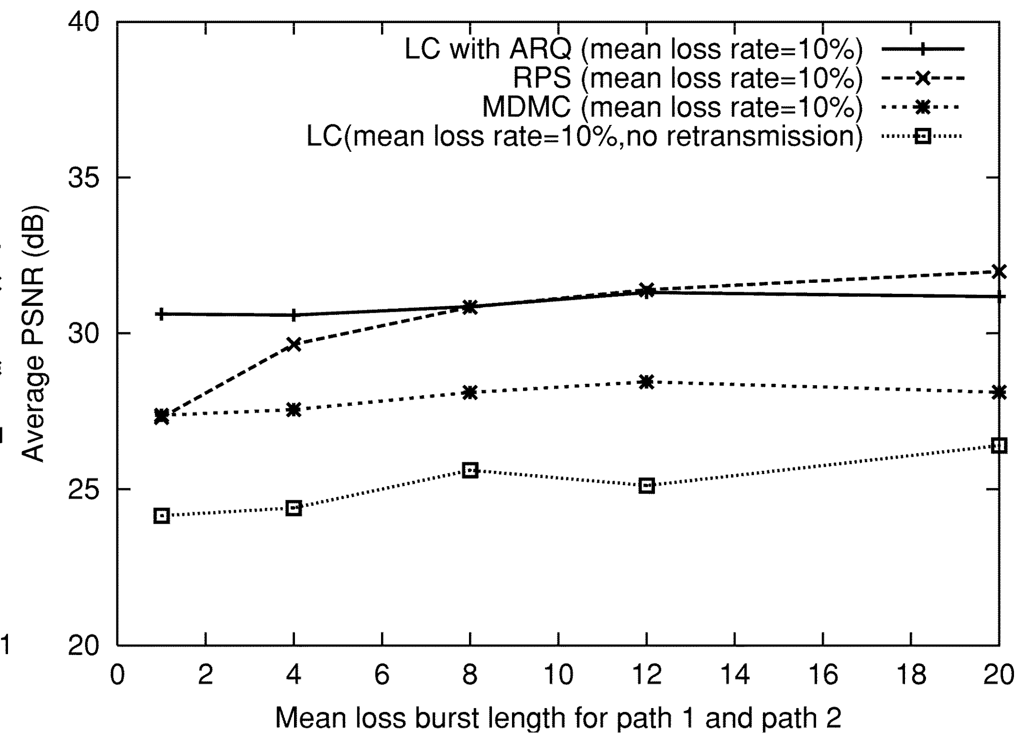
Evaluation

- Mathematical Markov process model
  - Reference Picture Selection
  - Layered coding with ARQ
  - Multiple Description Motion Compensation
- Simulation with OPNET
  - Evaluate Multipath DSR (MDSR)
  - Multiple Description Motion Compensation
- Testbed 4x802.11 nodes in a building
  - Layered coding with ARQ
  - Multiple Description Motion Compensation

Markov channel model

- 3 state Markov model - good (p=1), bad (p=[0.001,0.2]), down (p=0)
- Every 2s link chosen randomly from pool





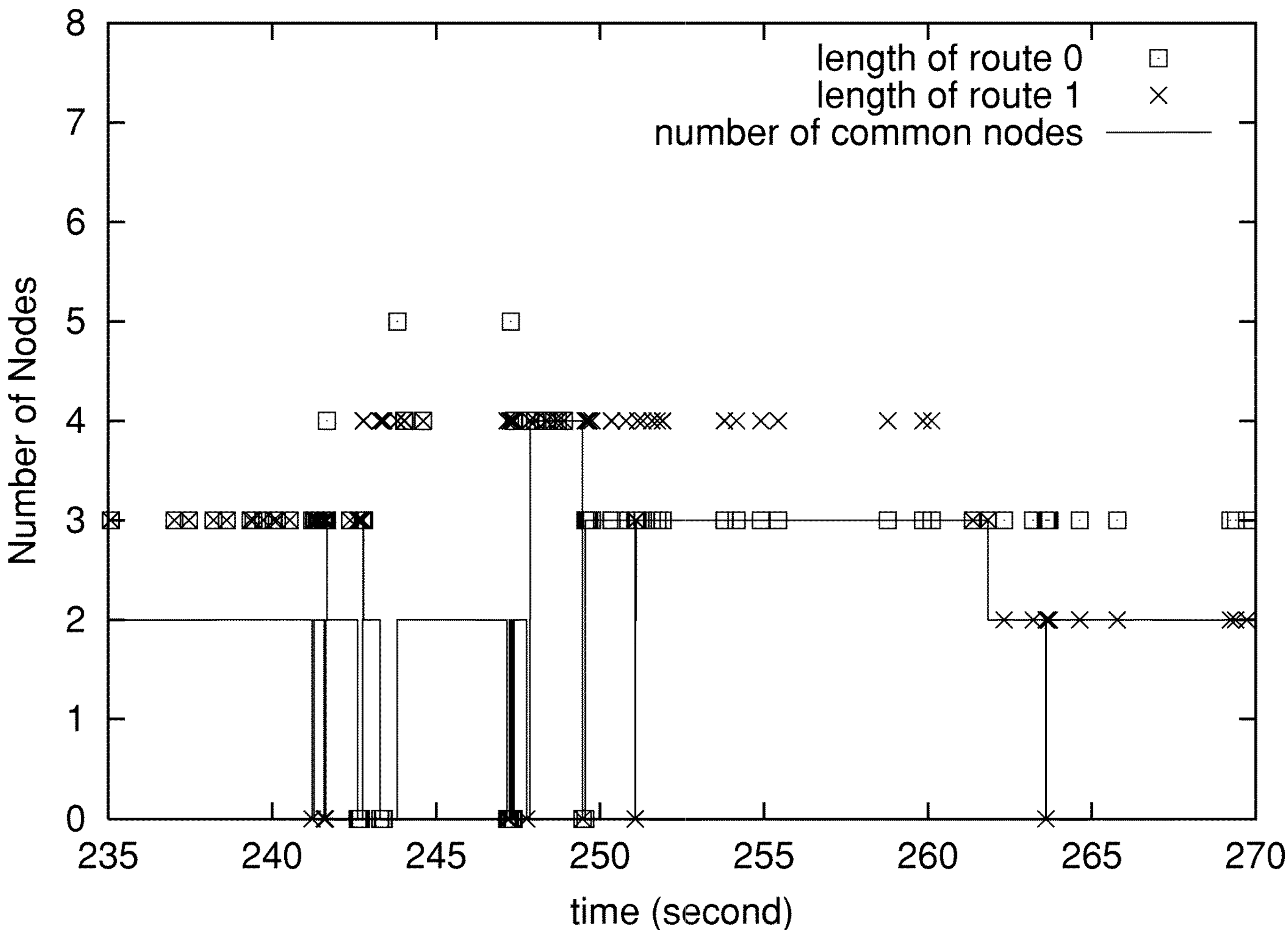
Markov channel model conclusions

- Video quality insensitive to path symmetry with all schemes (don’t need to worry about at least 1 high quality path)
- RPS best at low error rate due to best coding efficiency
- With retransmission allowed, LC with ARQ is the best performing overall
- But if no feedback allowed MDMC will perform only 1 to 3 db less than the others

OPNET Model

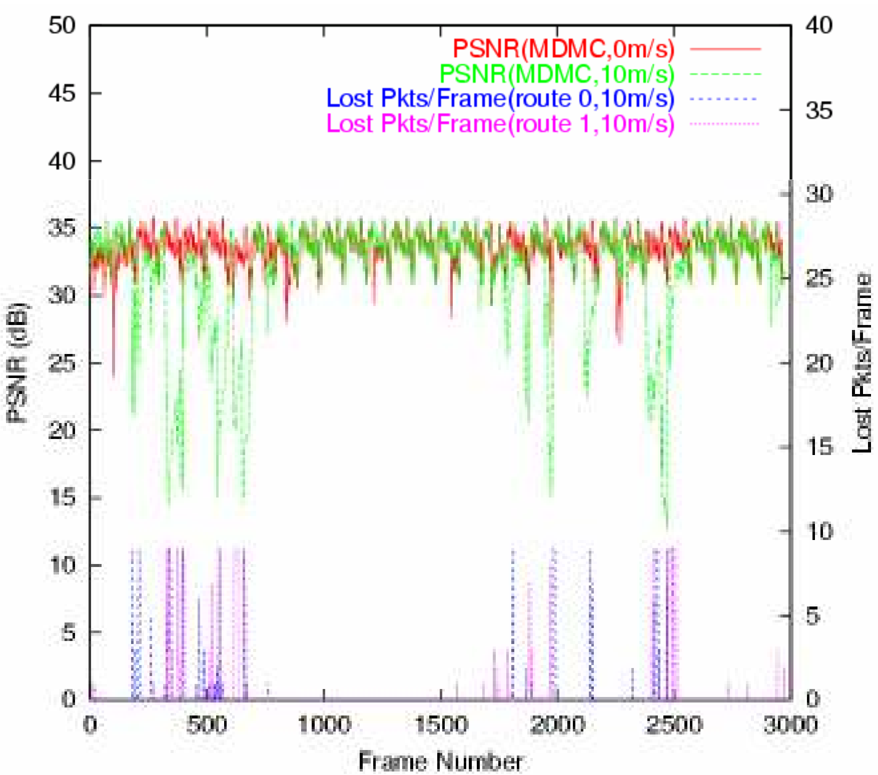
- Parameters
  - 16 nodes in 600m x 600m space
- Routing = Multipath DSR (MDSR)
  - Extension to Dynamic Source Routing protocol which maintain two maximally node-disjoint paths
- Radios = IEEE 802.11 MAC
  - No RTS/CTS, 7 retransmission allowed if there is collision
  - Range = 250m, lock to 1Mbps
- Mobility model
  - Random Waypoint with constant speed (no convergence problem which occurs with random speed) … up to 10m/s models pedestrians and vehicles

MDSR performance

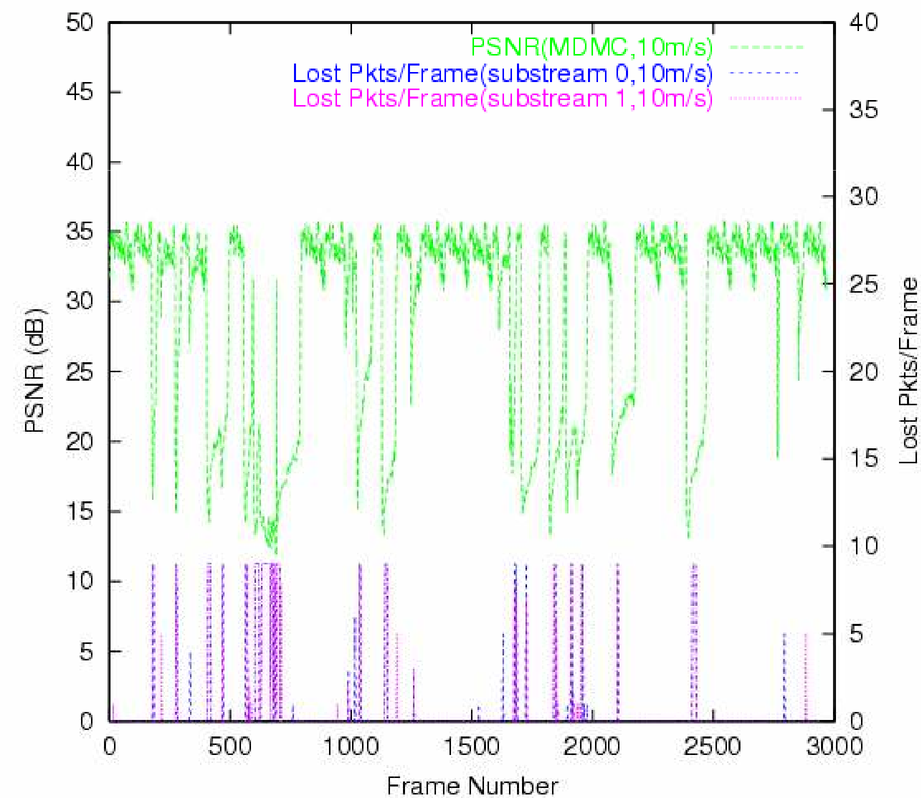


OPNET Simulation results

- 16 nodes, 600m by 600m, 0 or10m/s, range=250m

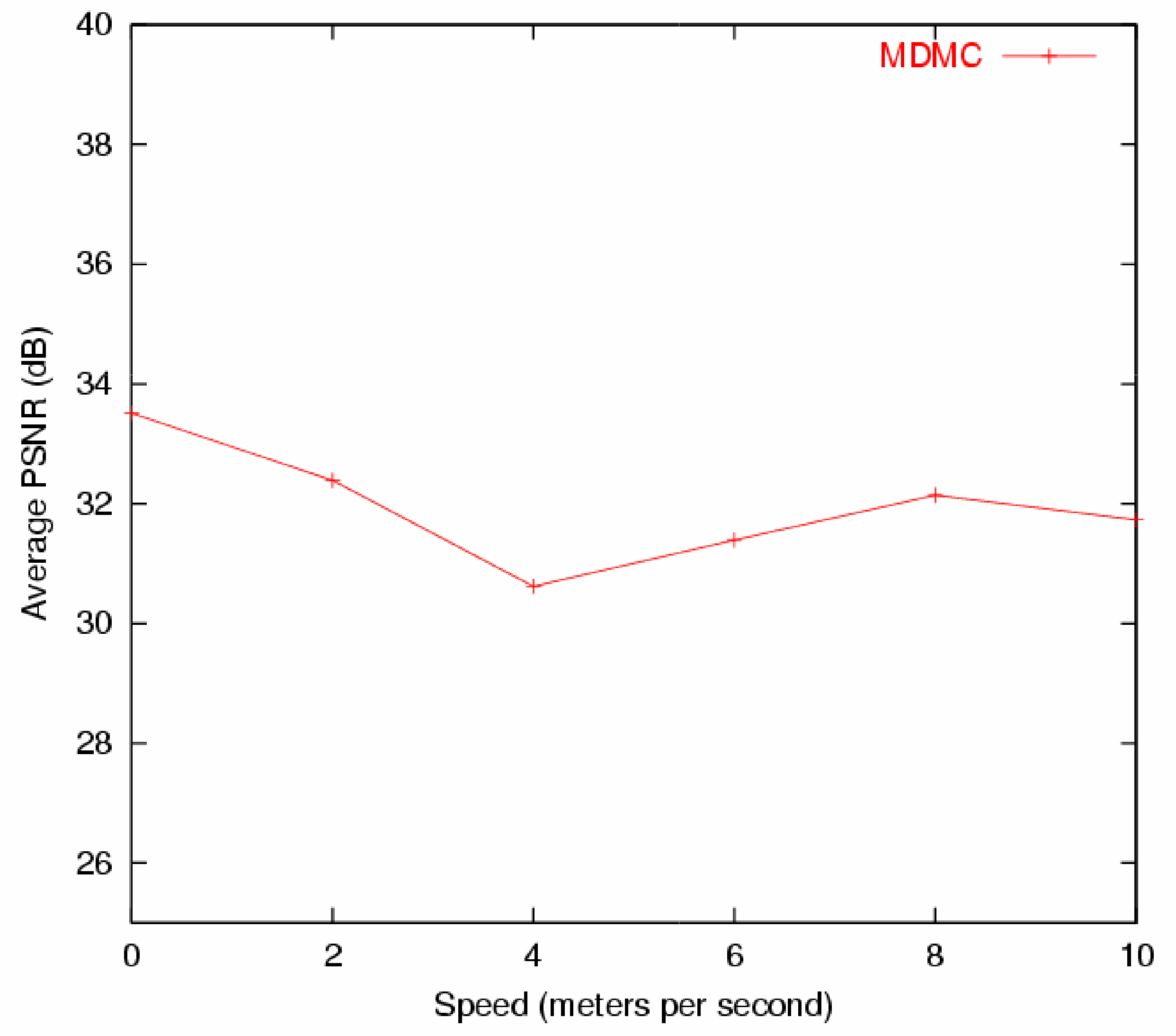


- Multipath DSR



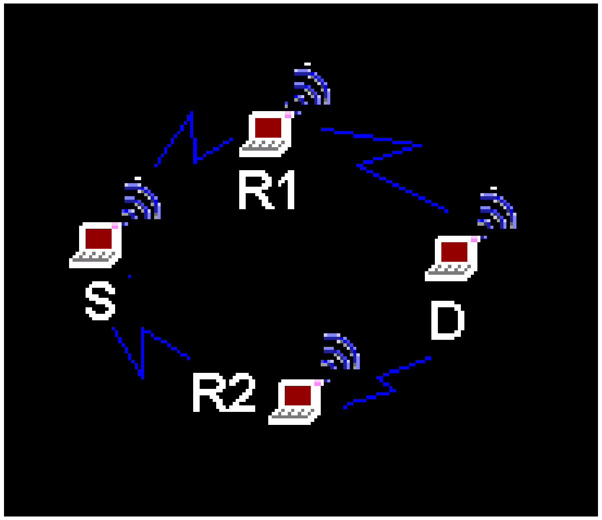
- Singlepath DSR

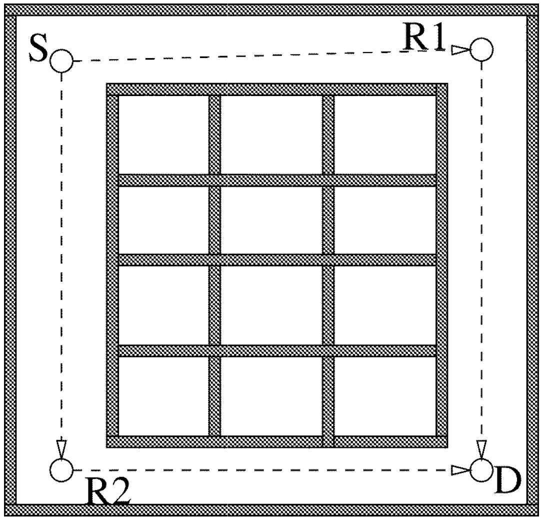
OPNET Simulation results

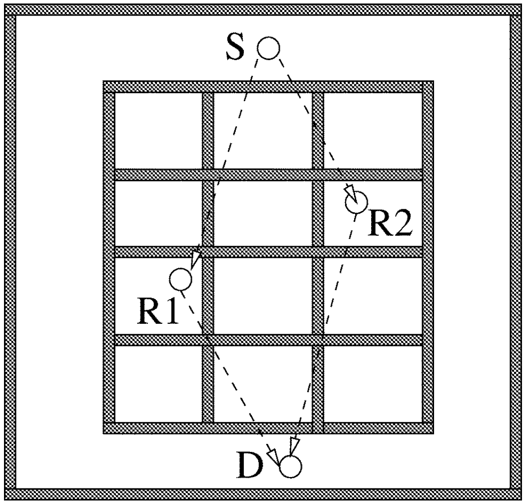


Multipath video streaming testbed

- 4 Notebook computers running windows
- One line of sight configuration (low loss) and one "behind the wall" configuration (high loss)







MDMC tested results

- MDMC testbed matches Markov simulation very well … ***very suspicious***
  - They even have audacity to say the difference is caused by difference in loss rate and testbed may not be Markovian

Line of sight Behind walls

Scenario	Fig.16(a)	Fig.16(b)	Fig.16(b)	Fig.16b)
Playout delay	2s	2s	2s	300ms
Pkt Loss rate 1	0.41%	6.14%	8.46%	8.13%
Pkt Loss rate 2	0.75%	11.96%	7.52%	7.97%
Burst length 1	1.75	3.79	3.67	6.08
Burst length 2	4.76	3.08	3.33	2.34
Ave. PSNR (testbed)	33.11 dB	27.53 dB	28.65 dB	28.16 dB
Ave. PSNR (sim)	33.08 dB	28.05 dB	28.65 dB	28.65 dB

LC with ARQ testbed results

- LC with ARQ testbed PSNR less than Markov model because Markov used perfect channel for feedback
- When error burst length >= playout delay only small portion can be successfully retransmitted

Line of sight | Behind walls

Scenario	Fig.16(a)	Fig.16(b)	Fig.16(b)	Fig.16(b)
Playout delay	2s	2s	2s	300ms
Ori. BL loss	0.06%	5.95%	7.98%	7.94%
BL loss	0.00%	2.49%	2.25%	5.37%
EL loss	0.38%	12.22%	8.14%	8.16%
Ori. BL Burst len.	3.64	4.80	3.94	4.25
BL Burst len.	0	10.23	6.33	8.58
EL Burst len.	3.29	4.18	3.94	3.16
ARQ succ. ratio	100%	58.0%	71.8%	32.4%
Ave. PSNR (testbed)	32.34 dB	30.64 dB	30.14 dB	30.13 dB
Ave. PSNR (sim)	N/A	31.10 dB	31.68 dB	31.68 dB

Conclusions

- Realtime media over a wireless medium is challenging - especially over ad hoc networks but path diversity can be exploited
- If Feedback available – RPS is best low delay option when losses are low
- If delay caused by retransmission is acceptable – LC with ARQ more suitable when losses are higher
- If feedback not available e.g. multicast than MDMC is best choice
- All assume that disjoint paths can be found using a multipath routing protocol like MDSR

Paper critique

- Average PSNR not always a good indication of user experience
- Should have compared all three schemes for markov, simulation, testbed
- Testbed too small
- Why use perfect feedback channel for Markov
- Don’t mention anything about I/P/B frames and ratios for specific PSNR discussed
- For LC with ARQ – When EL path becomes better than BL - should you switch or do route discovery?