Opportunistic Network Coding for Video Streaming over Wireless

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Outline

- Introduction
- System Overview
- Coding Algorithms
- Performance Evaluation
- Summary

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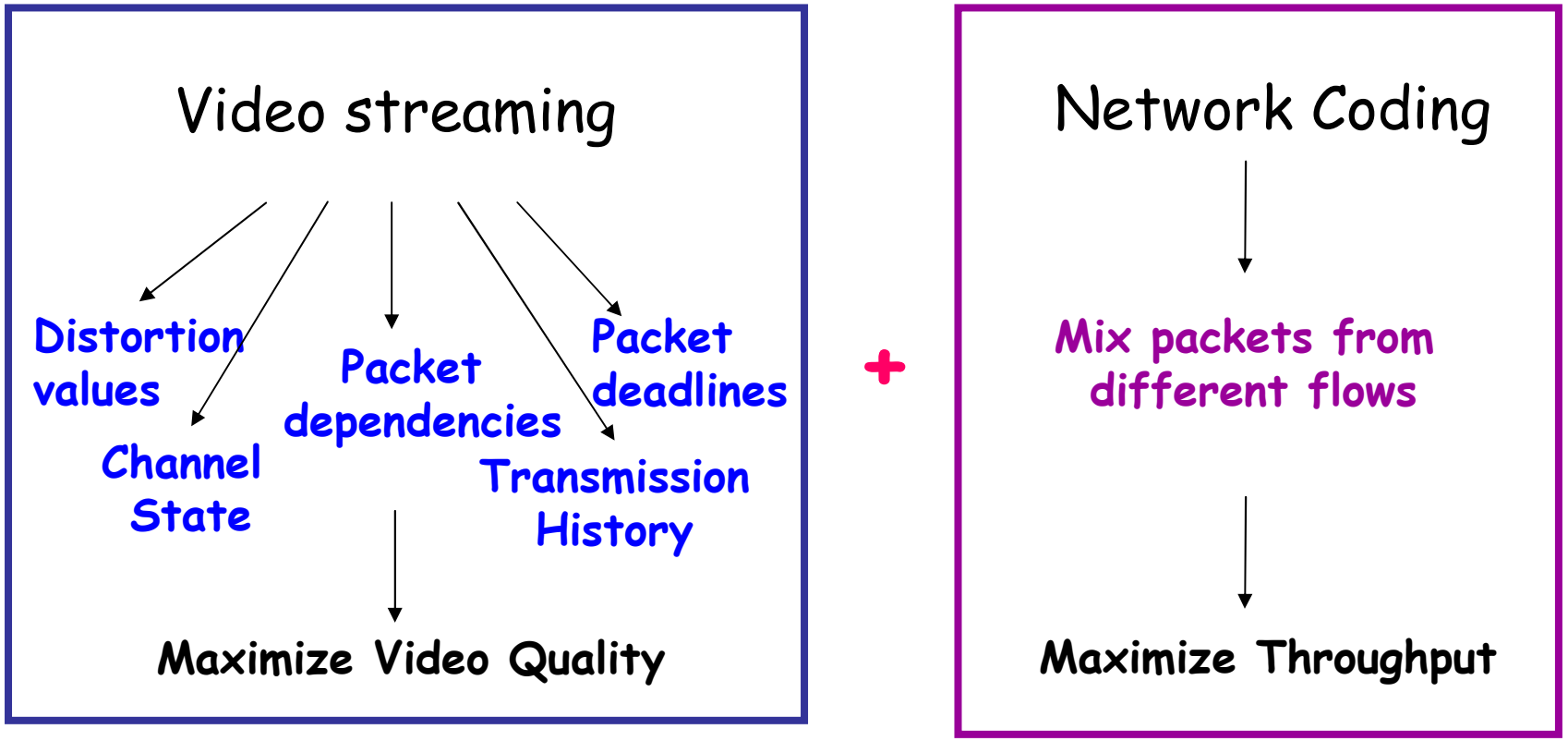
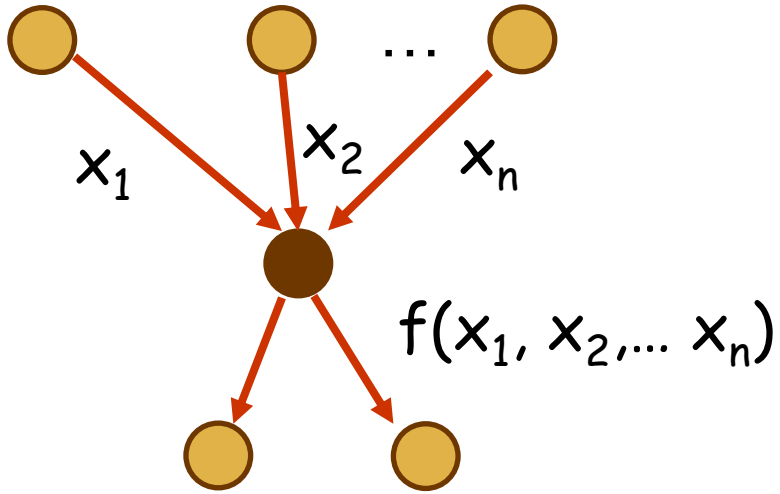
Motivation



= Video-aware network coding schemes
to optimize Video Quality and Throughput

The Network Coding Paradigm

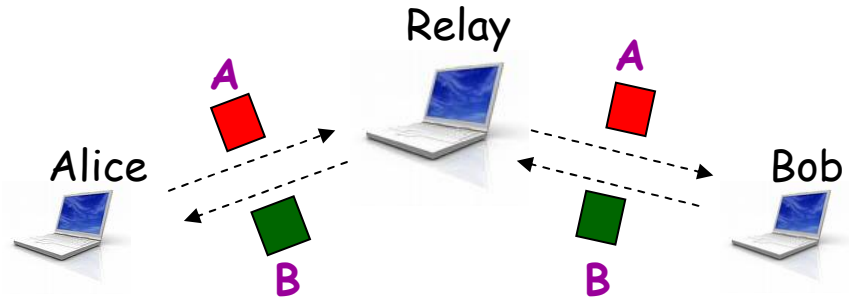
- Idea: allow intermediate nodes to combine incoming packets before forwarding them



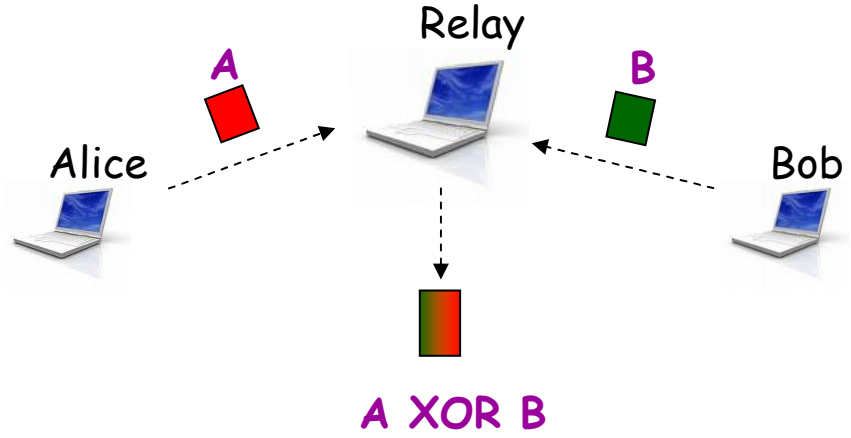
- Benefits in throughput and distributed scheduling
- Applications in p2p and wireless mesh networks

Network Coding for Wireless (broadcast)

Current Approach



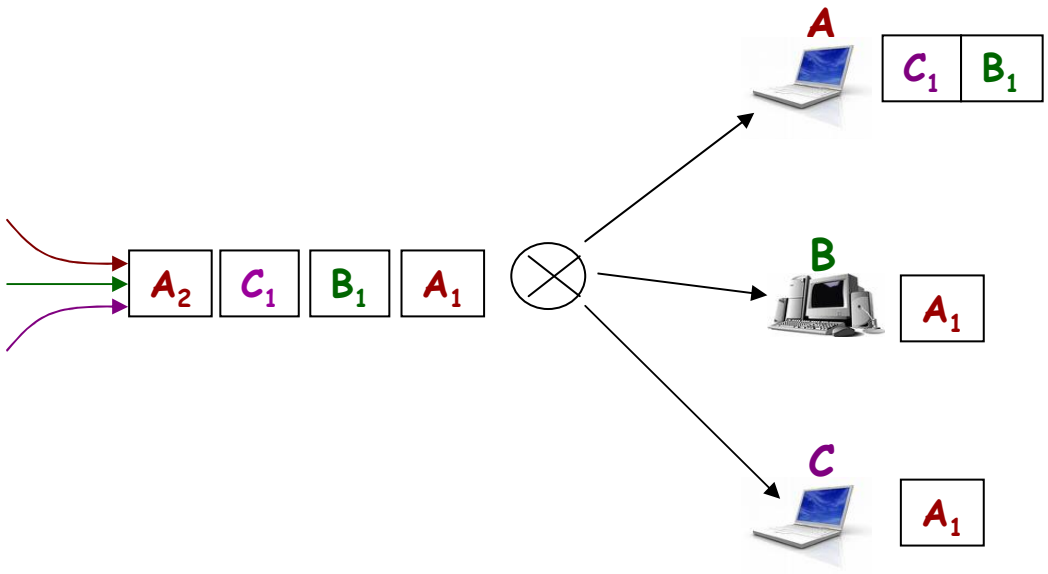
Network Coding



Network Coding for Wireless Mesh

["COPE:XORs in the Air", Katti et al., Sigcomm 06]

- Mix packets from different flows to increase information per packet



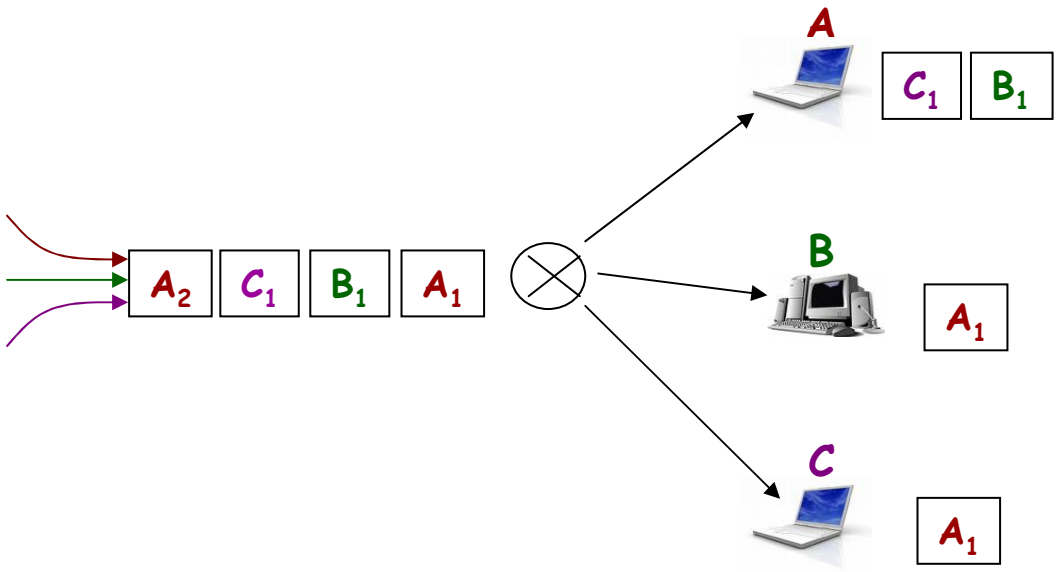
Network Codes	Decodability
$c_1 = A_1$	only A decodes
$c_2 = A_1+B_1$	A and B decode
$c_3 = A_1+C_1$	A and C decode
$c_4 = A_1+B_1+C_1$	only A decodes

c_2

- COPE maximizes the number of receivers that decode.

Network Coding for Video

- Key observation: the content (not only the number) of packets matters



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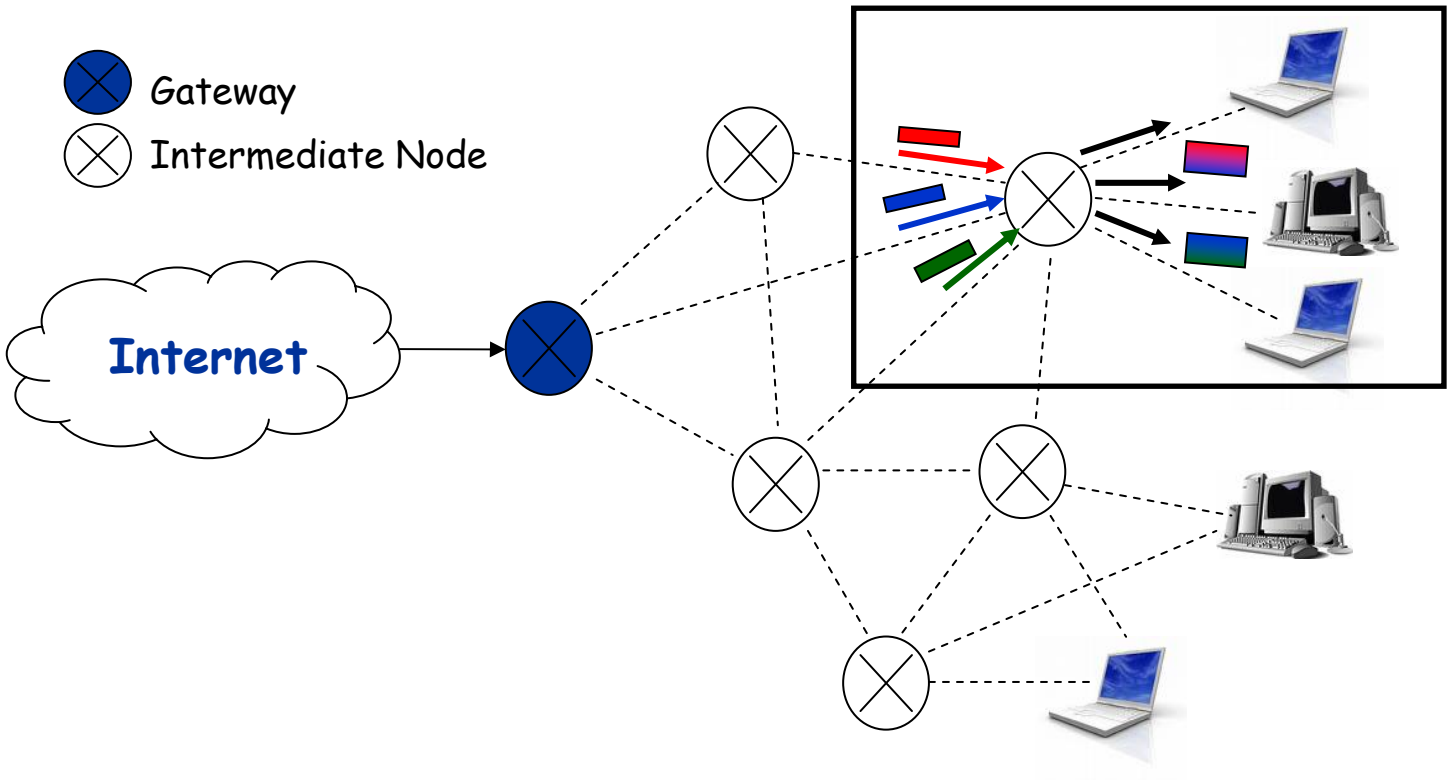
c_2 or c_3 ?

- Consider packet distortion, deadline, dependencies to maximize video quality and throughput.

Problem Statement:

Network coding for video over wireless mesh



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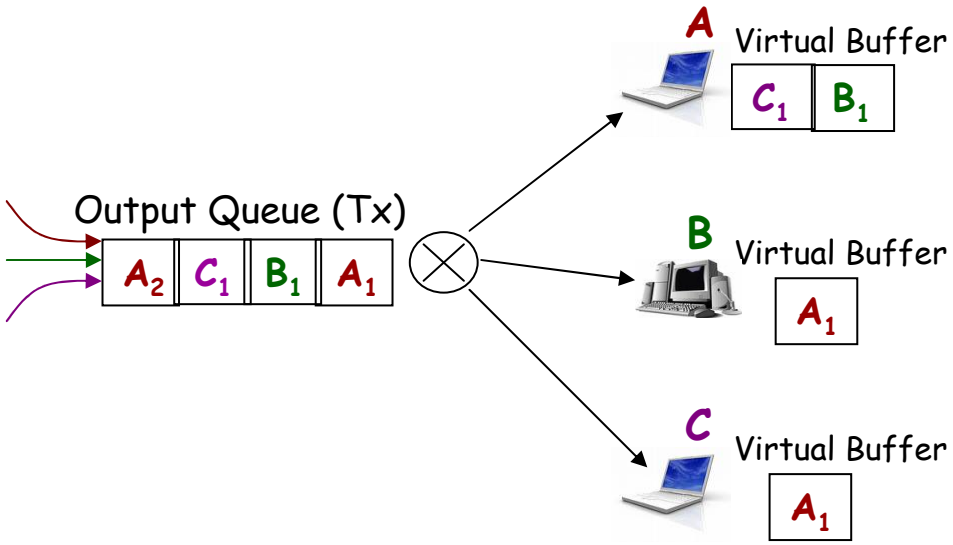
  - NCV Algorithm: Network Coding for Video
  - NCVD Algorithm: looking into the queue in Depth
- Performance Evaluation
- Summary

System Overview



➔ Only video packets

➔ Intermediate nodes combine different flows and broadcast.

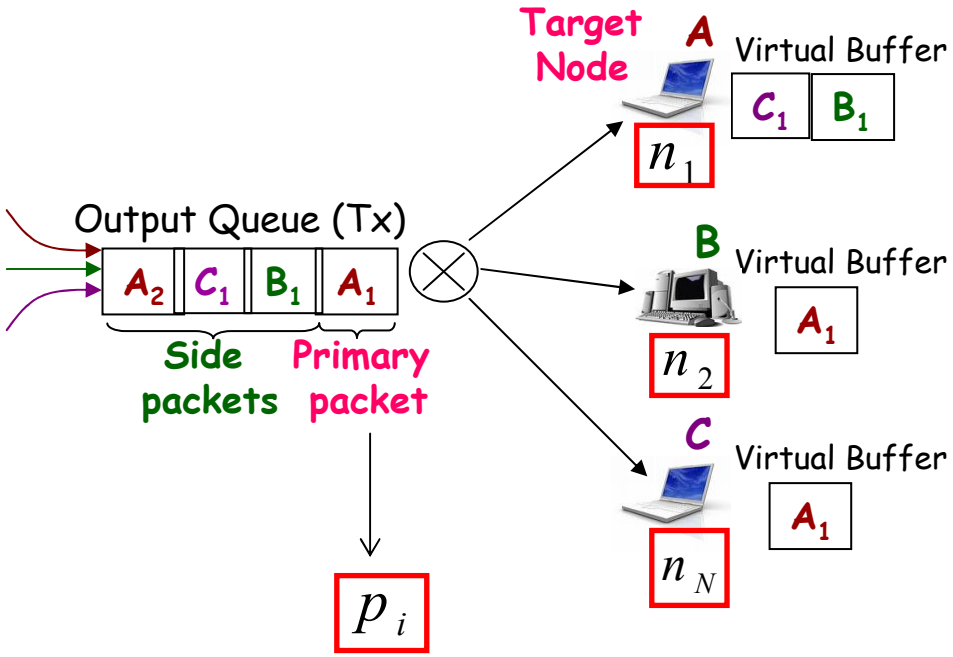
➔ Nodes can overhear all transmissions in their neighborhood.

➔ Knowledge of contents of virtual buffers.

➔ Active – inactive packets.

➔ ACK mechanism is employed.

Code Construction



Candidate Codes:

$c'_1 = A_1$
$c'_2 = A_1+B_1$
$c'_3 = A_1+C_1$
$c'_4 = A_1+B_1+C_1$

$$S_k^i \quad k = 1,\ldots,2^{\Psi i}$$

$$c_k^i = p_i \oplus S_k^1$$

$$k = 1,\ldots,2^{\Psi_1}$$

Which code to choose to maximize total quality and throughput?

Coding Algorithm I: NCV

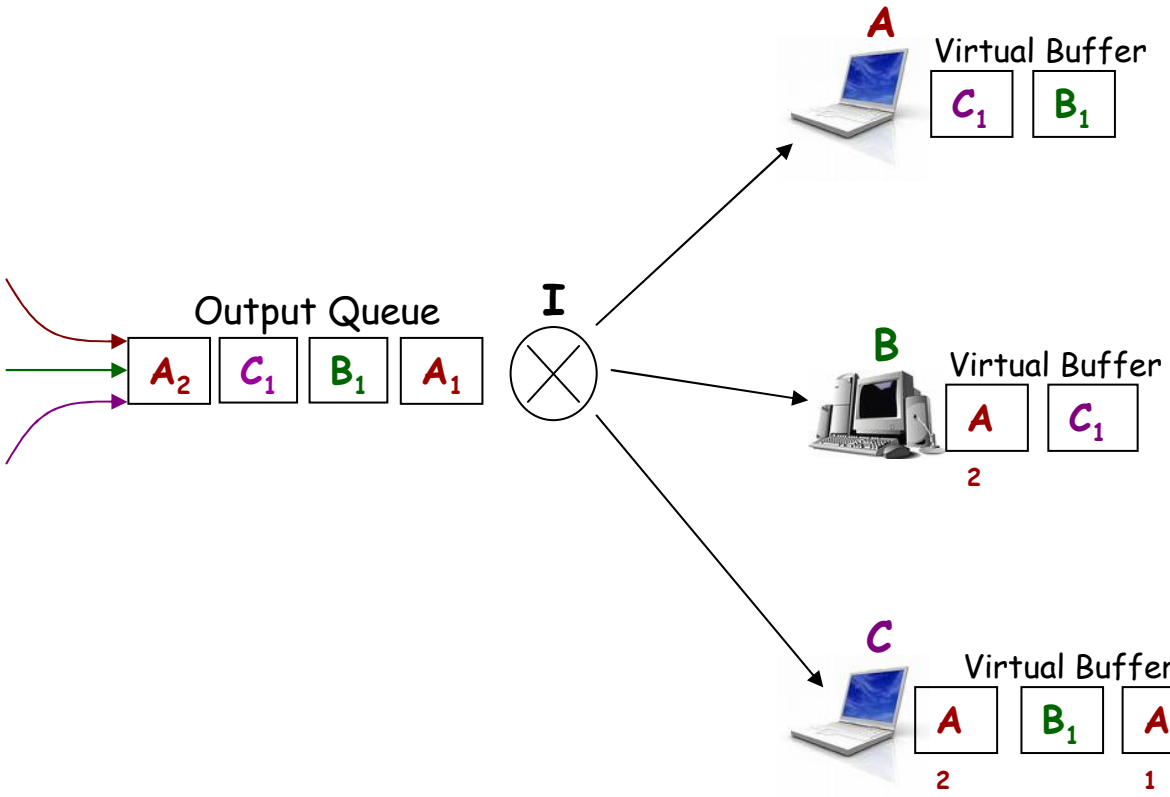
- Choose code c_k^i to maximize improvement I_k^i

$$\max_k I_k^i = \sum_{n=1}^{N} I_k^i(n)$$

$$I_k^i(n) = \sum_{l=1}^{L_k} (1 - e_l^k)\Delta_l^k g_l^k d_l^k$$

- Number of packets in code
- Probability of error due to channel noise or delay
- Distortion value
- 1 if packet is useful
- 1 if code is decodable

Coding Algorithm II: NCVD



A_1 is primary packet

Network Codes	Decodability
$c_1 = A_1$	only A decodes
$c_2 = A_1+B_1$	only A decodes
$c_3 = A_1+C_1$	A and C decode
$c_4 = A_1+B_1+C_1$	A and C decode

B_1 is primary packet

Network Codes	Decodability
$c'_1 = B_1$	only B decodes
$c'_2 = B_1+C_1$	B and C decode
$c'_3 = B_1+A_2$	A and B decode
$c'_4 = B_1+C_1+A_2$	A, B, C decode

Primary packet – {A_1 or B_1}?

$$\max_{p_i} \max_{k} (I_k^i)$$

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Performance Evaluation
Scenario

- System Model:
  - One hop downlink transmission with 3 receivers
  - Downlink 300 kbps
  - Delay budget 100 ms. Random delay in forward ch., avg= 4ms
- Wireless Channel Model
  - Model I: iid – loss rates from 1% to 20%
  - Model II: Rayleigh fading channel modeled with Gilbert-Elliot – 3 dB to 9 dB (loss rates from 1% to 35%)
- Video Sequences
  - Carphone, Foreman, Mother&Daughter
  - H.264/AVC, 1I:9P frames
  - 70 kbps, 30 fps, 250B packets on average.

Performance Evaluation
Baseline Algorithms

- NoNC: FIFO with improvements
  - ARQ is employed
  - Active-inactive packets
  - Late packets are dropped from the output queue
- NCT: COPE with improvements
  - Active-inactive packets
  - Late packets are dropped from the output queue.
  - Consider all packets as eligible packets instead of just head-on packets

Performance Evaluation
Video quality

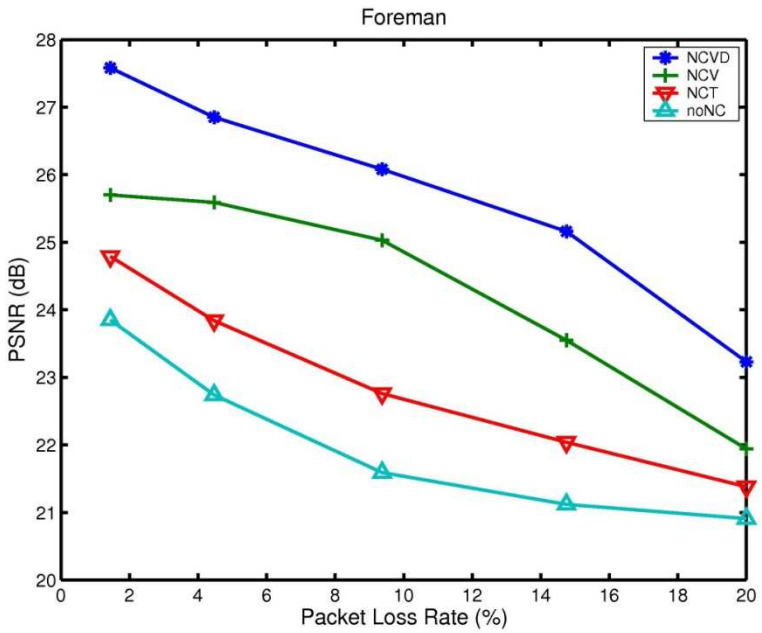
Average PSNR for iid model with
9.4% Loss Rate, 100 ms Playout Deadline

avg PSNR (dB)	Carphone	Foreman	Mother&Daughter
No Error	29.95	28.70	40.74
NCVD	26.32	26.08	32.87
NCV	23.99	25.03	32.62
NCT	22.40	22.76	30.81
noNC	22.08	21.59	26.92

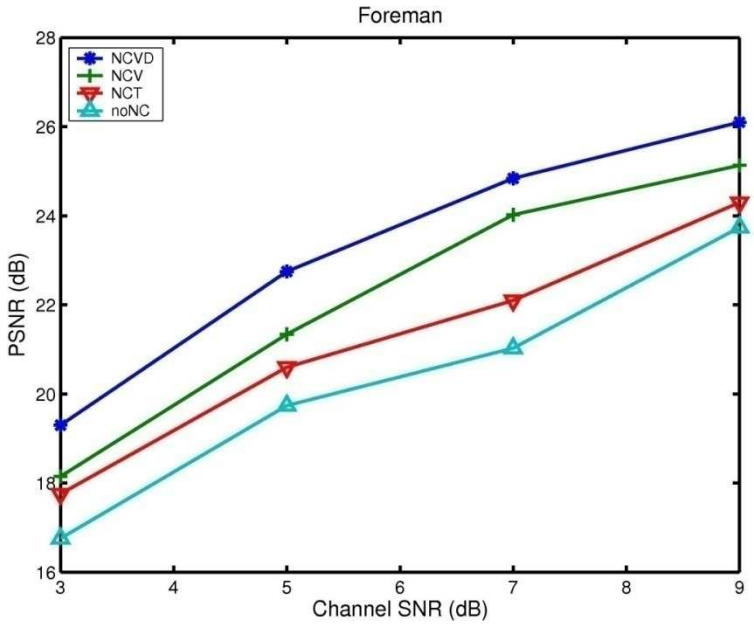
Performance Evaluation

Video quality

Avg. PSNR of Foreman, iid loss

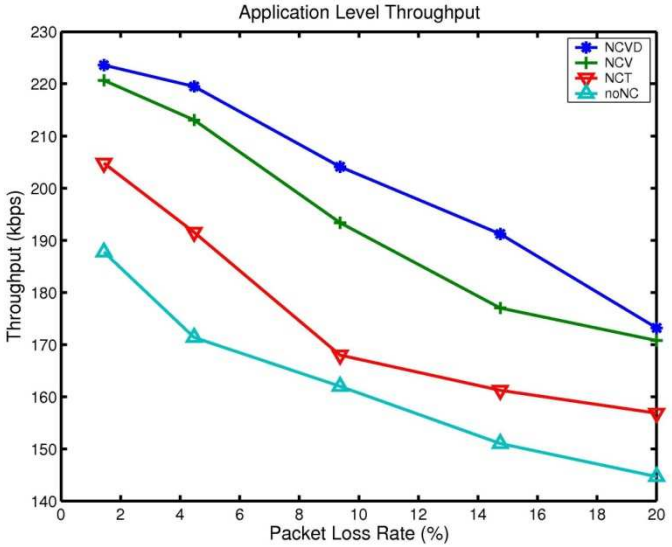


Avg. PSNR of Foreman, Rayleigh

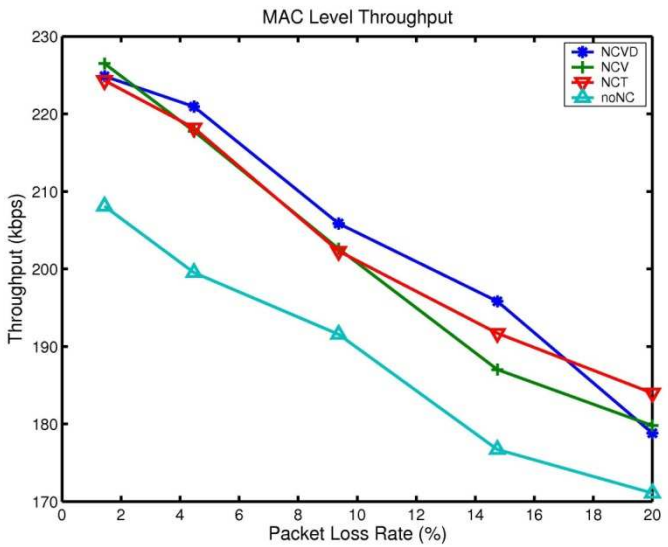


Performance Evaluation
Throughput

Application-level throughput



MAC-level throughput



- NCV and NCVD improve application level throughput
- MAC level throughput is similar for NCV, NCVD, and NCT

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Summary

- Proposed video-aware network coding schemes for wireless mesh networks
- Improved video quality up to 4-5 dB
- Improved application level throughput without hurting MAC throughput

- Ongoing work …

Thank you!

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