Distributed Rate Control for Video Streaming with Intersession Network Coding

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Outline

- Introduction
- General Rate Control over NC
- Video Rate Control over NC
- Performance Evaluation
- Summary

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- Introduction
  - Motivation
  - Problem Statement
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Motivation

Video Streaming

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Maximize video quality

- Transmission history
- Packet deadlines
- Distortion values
- Packet dependencies
- Channel state

Network Coding

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Mix packets from different flows

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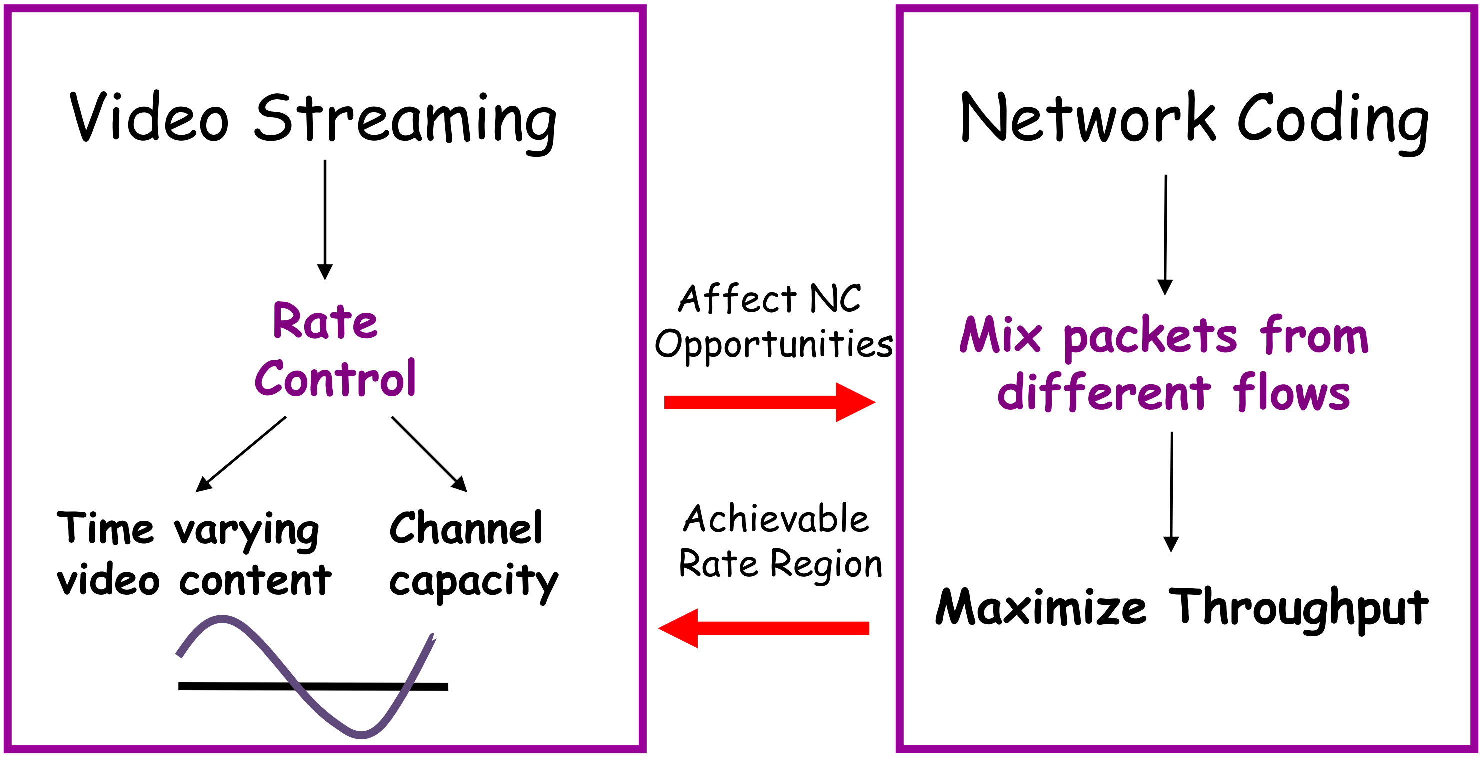
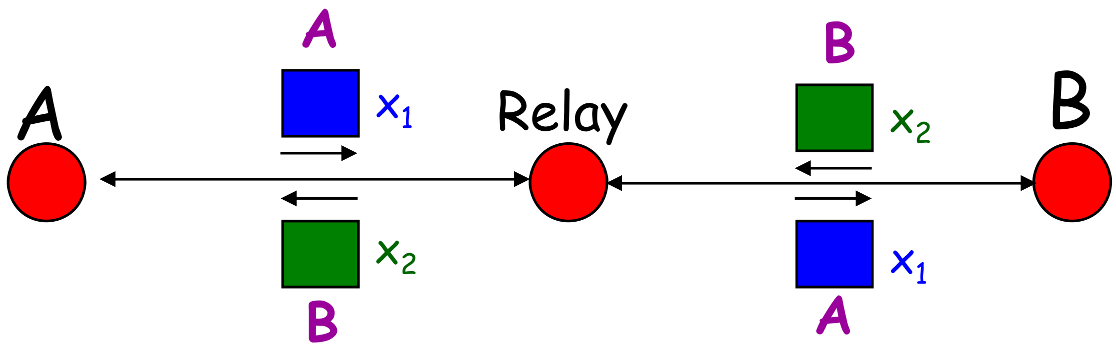
Maximize Throughput

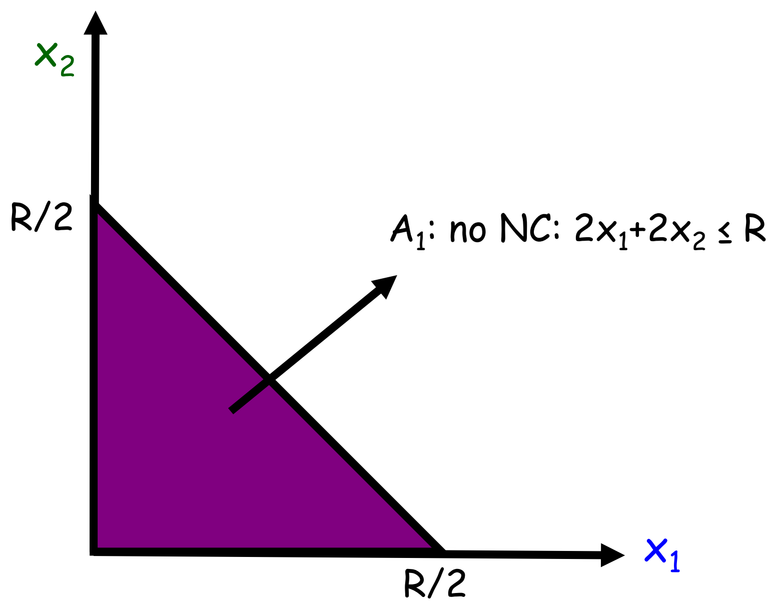
Motivation



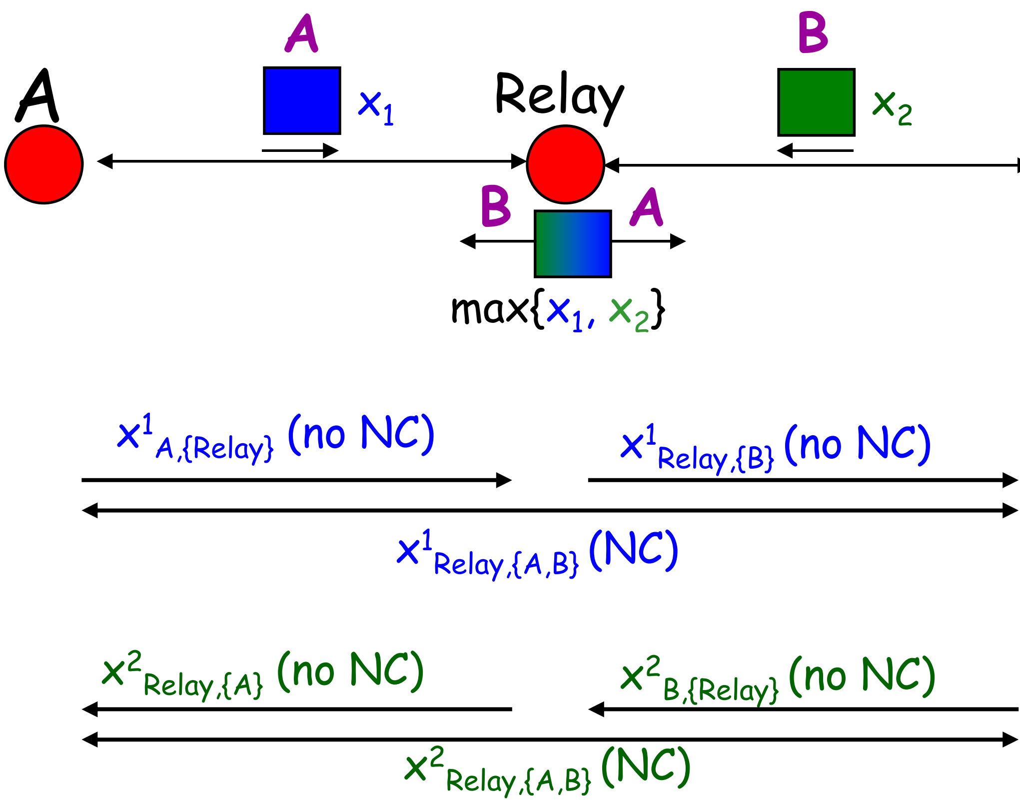
Interaction of rate control and network coding

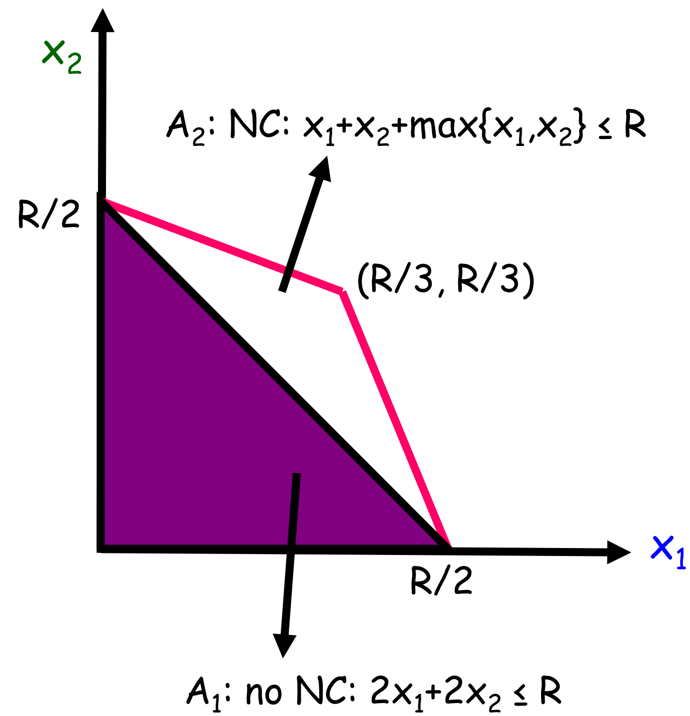
No Network Coding
(achievable region)



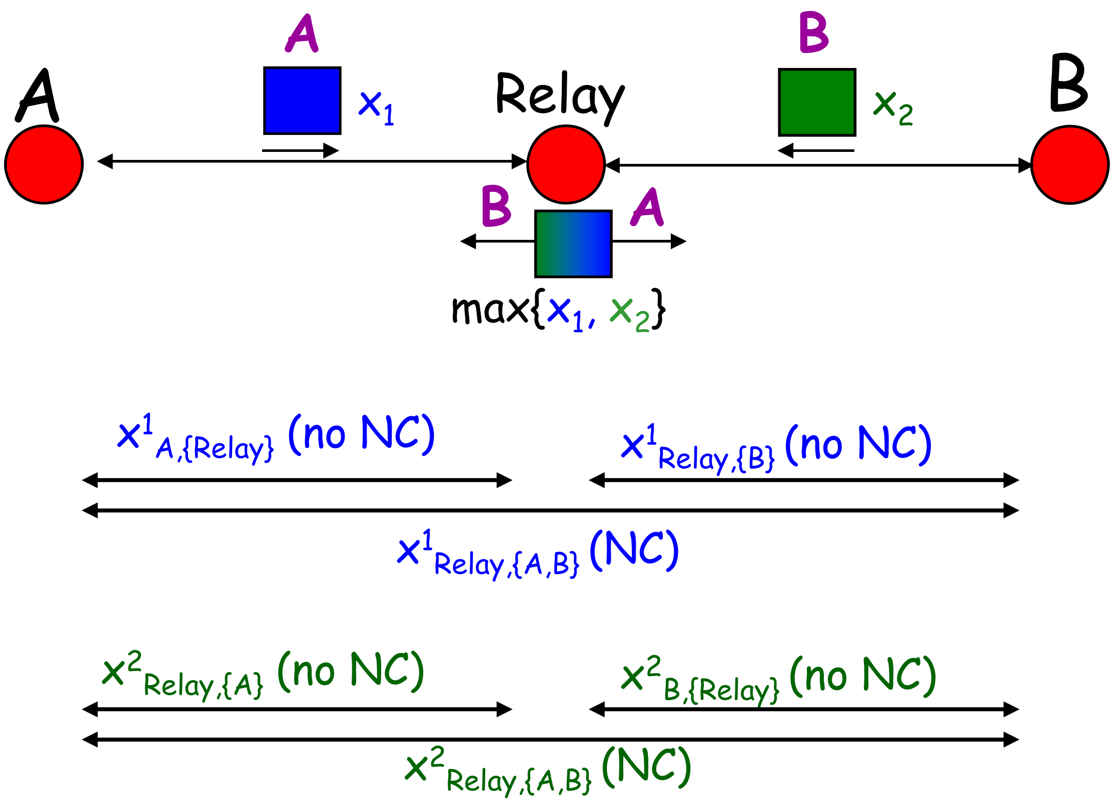


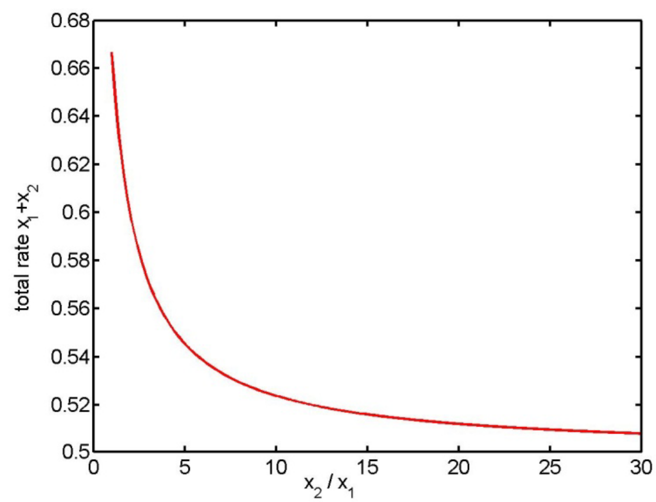
Network Coding for Wireless
(achievable region)





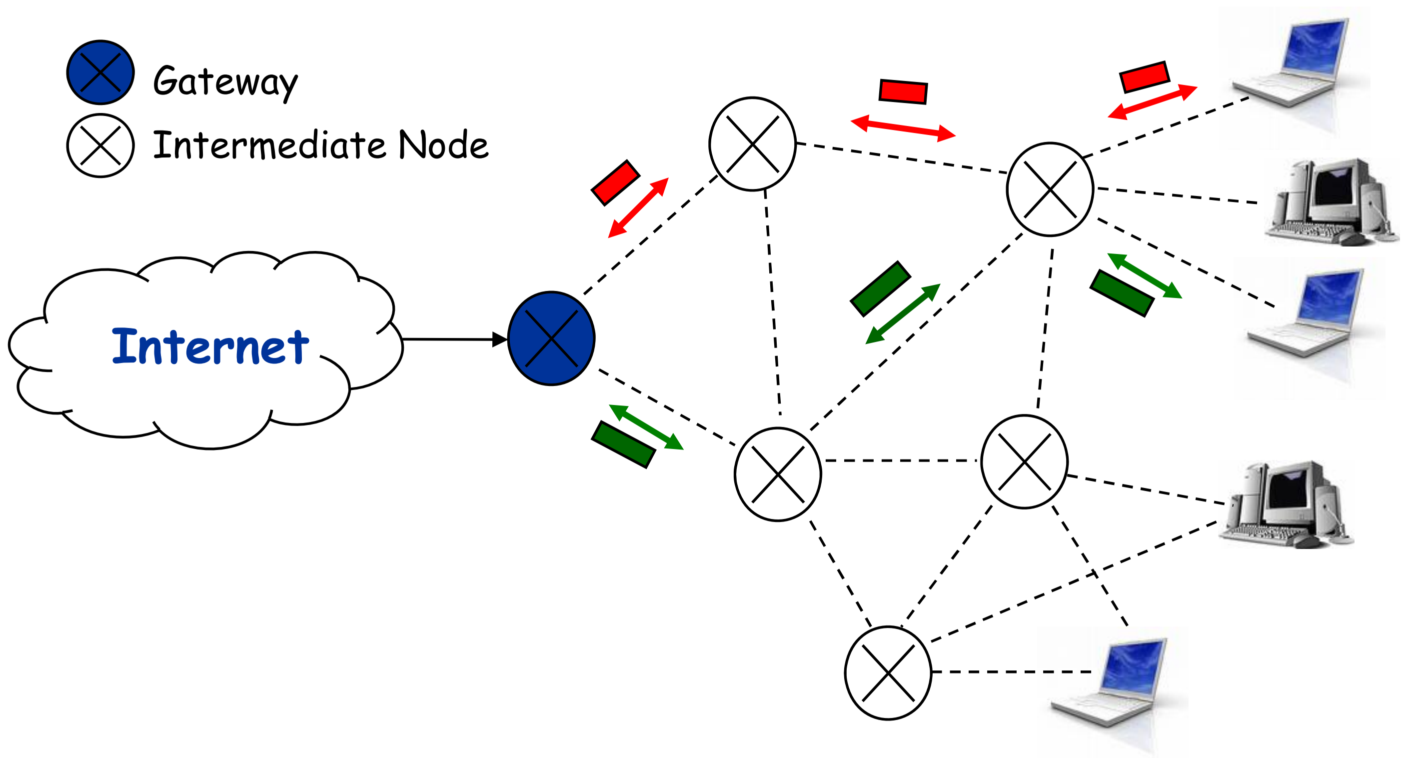
Network Coding for Wireless
(achievable region)





Problem Statement:

Rate control for video with network coding



Optimal e2e rate and network coding in the core !

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- Introduction
- General Rate Control over NC
  - Formulation
  - Distributed Solution
  - Convergence
- Video Rate Control over NC
- Performance Evaluation
- Summary

General Rate Control over NC

Formulation

$$\max_{x,\tau} \sum_{s\in S} U_s(x_s)$$

→ Optimize total utility

s.t.

$$x_s = \sum_{\{J|(i,J)\in A, i\in I_s\}} x_{i,J}^s$$

→ Flow Conservation

$$z_{i,J}^k = R_{i,J}\tau_{i,J}^k$$

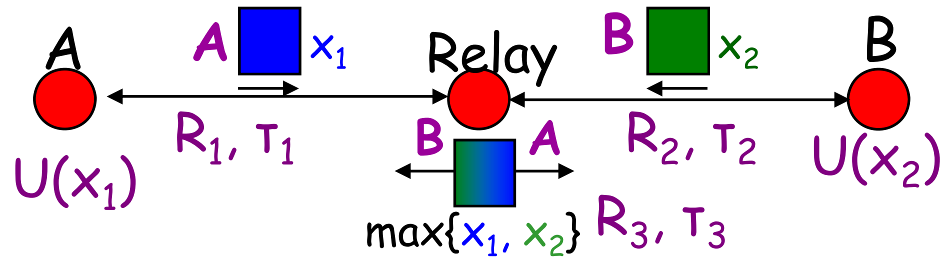
→ Available Capacity

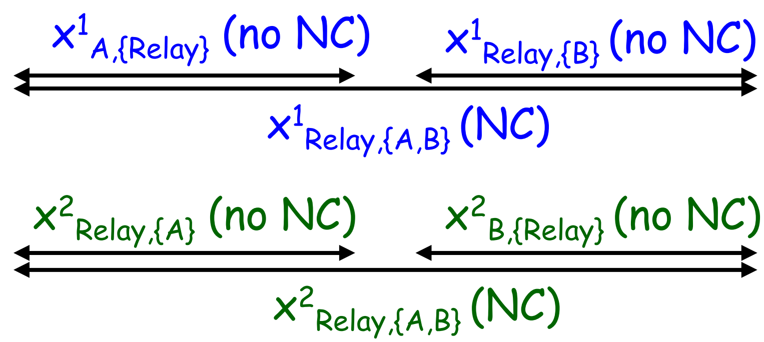
$$\sum_{(i,J)\in A_c^q} \sum_{k\in K} \tau_{i,J}^k \le \gamma$$

→ Interference

$$H_{i,J}^s x_{i.J}^s \le z_{i.J}^k \xi_{i,J}^s$$

→ Capacity constraint





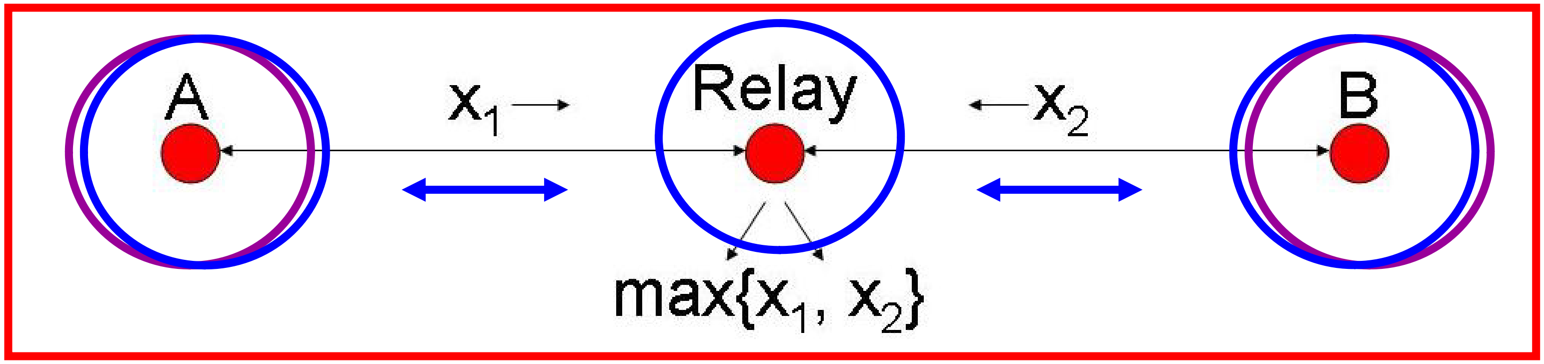
$$\max U(x_1) + U(x_2)$$

$$x_1 = x^1_{A,\{Relay\}} = x^1_{Relay,\{B\}} + x^1_{Relay,\{A,B\}}$$

$$x_2 = x^2_{B,\{Relay\}} = x^2_{Relay,\{A\}} + x^2_{Relay,\{A,B\}}$$

General Rate Control over NC

Distributed solution



Rate Control

$$\max_{x_s} \quad U_s(x_s) - \sum_{i \in I_s} \sum_{\{J | (i,J) \in A, i \in I_s\}} q_{i,J}^{\eta_{i,J}(s),s} H_{i,J}^s x_{i,J}^s$$

$$s.t. \quad x_s = \sum_{\{J | (i,J) \in A, i \in I_s\}} x_{i,J}^s, \quad \forall s \in S$$

$$x_s, x_{i,J}^s \geq 0, \quad \forall (i,J) \in A$$

Scheduling

$$\max_{\tau} \quad \sum_{(i,J) \in A} \sum_{k \in K} R_{i,J} \tau_{i,J}^k Q_{i,J}^k$$

$$s.t. \quad \sum_{(i,J) \in A_c^q} \sum_{k \in K} \tau_{i,J}^k \leq \gamma, \quad \forall A_c^q \in A_c$$

$$\tau_{i,J}^k \geq 0, \quad \forall k \in K, \forall (i,J) \in A.$$

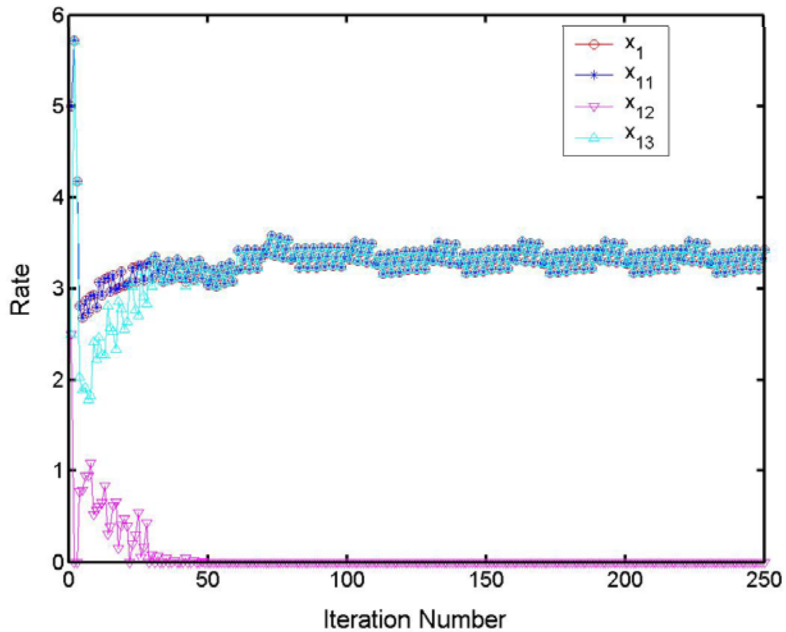
Parameter Update

$$q_{i,J}^{k,s}(t+1) = \left\{ q_{i,J}^{k,s}(t) + \beta_t \left[H_{i,J}^s x_{i,J}^s - z_{i,J}^k \xi_{i,J}^s \right] \right\}^+$$

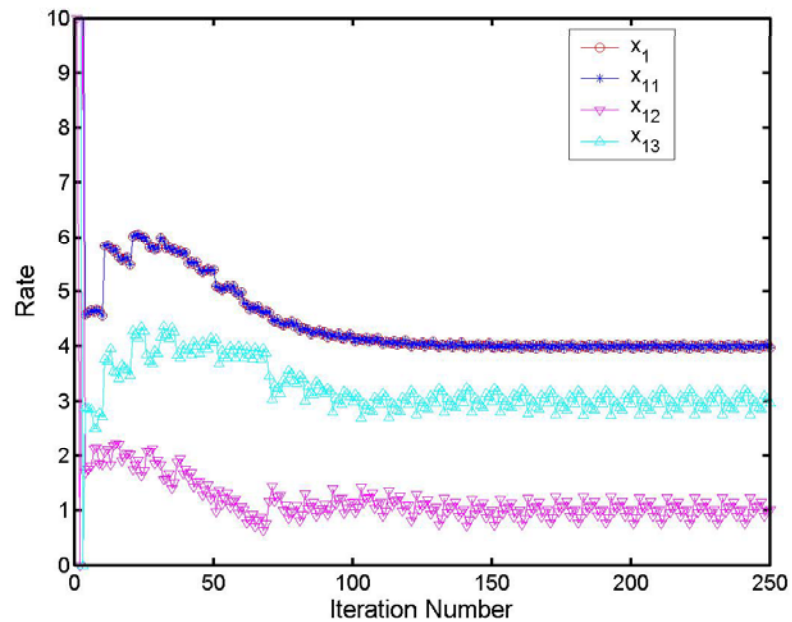
General Rate Control over NC

Convergence

Case I: $U_1(x_1) = \log(x_1)$, $U_2(x_2) = \log(x_2)$



Case II: $U_1(x_1) = 4\log(x_1)$, $U_2(x_2) = \log(x_2)$



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  - Key Observations
  - Formulation
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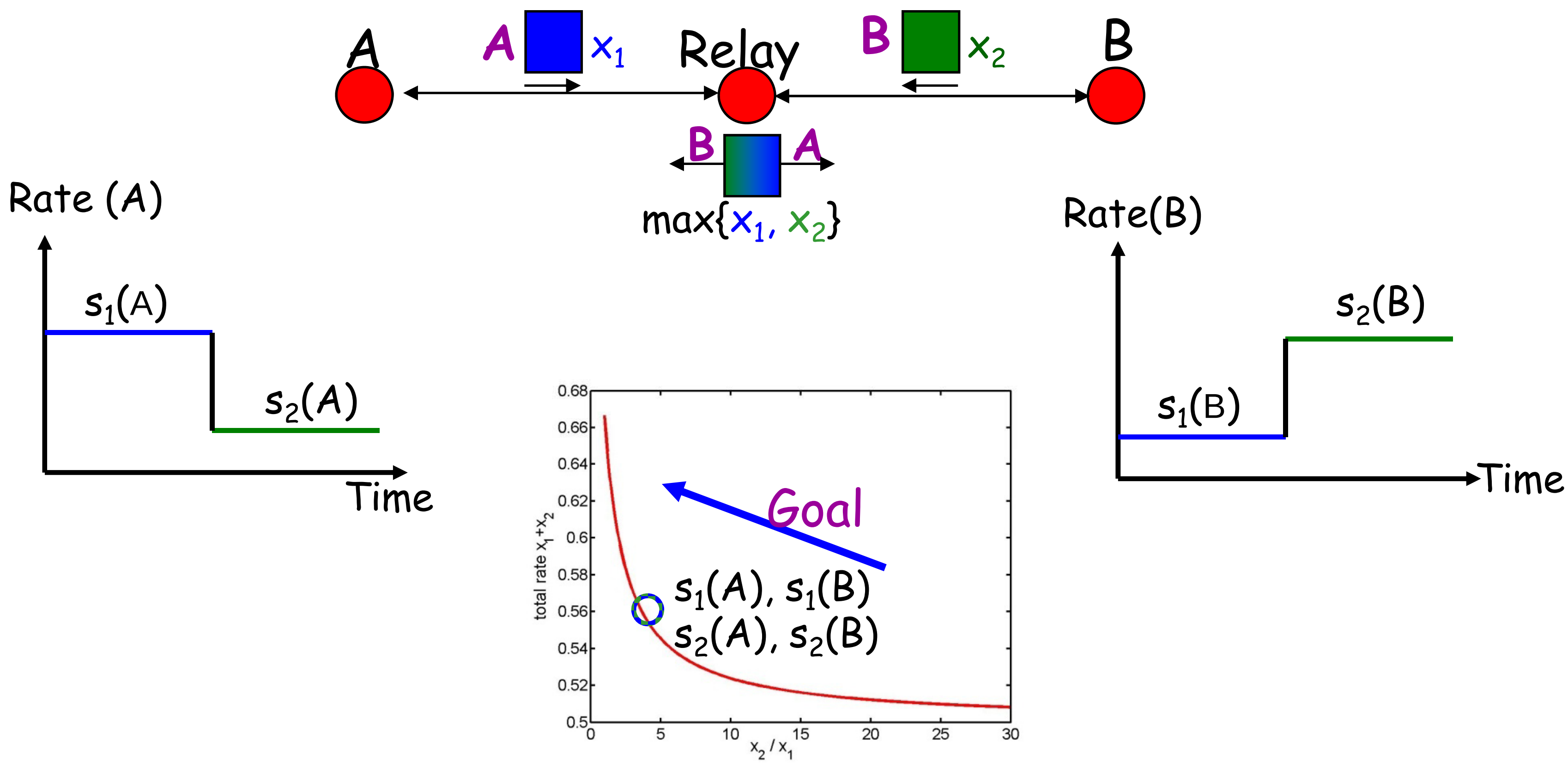
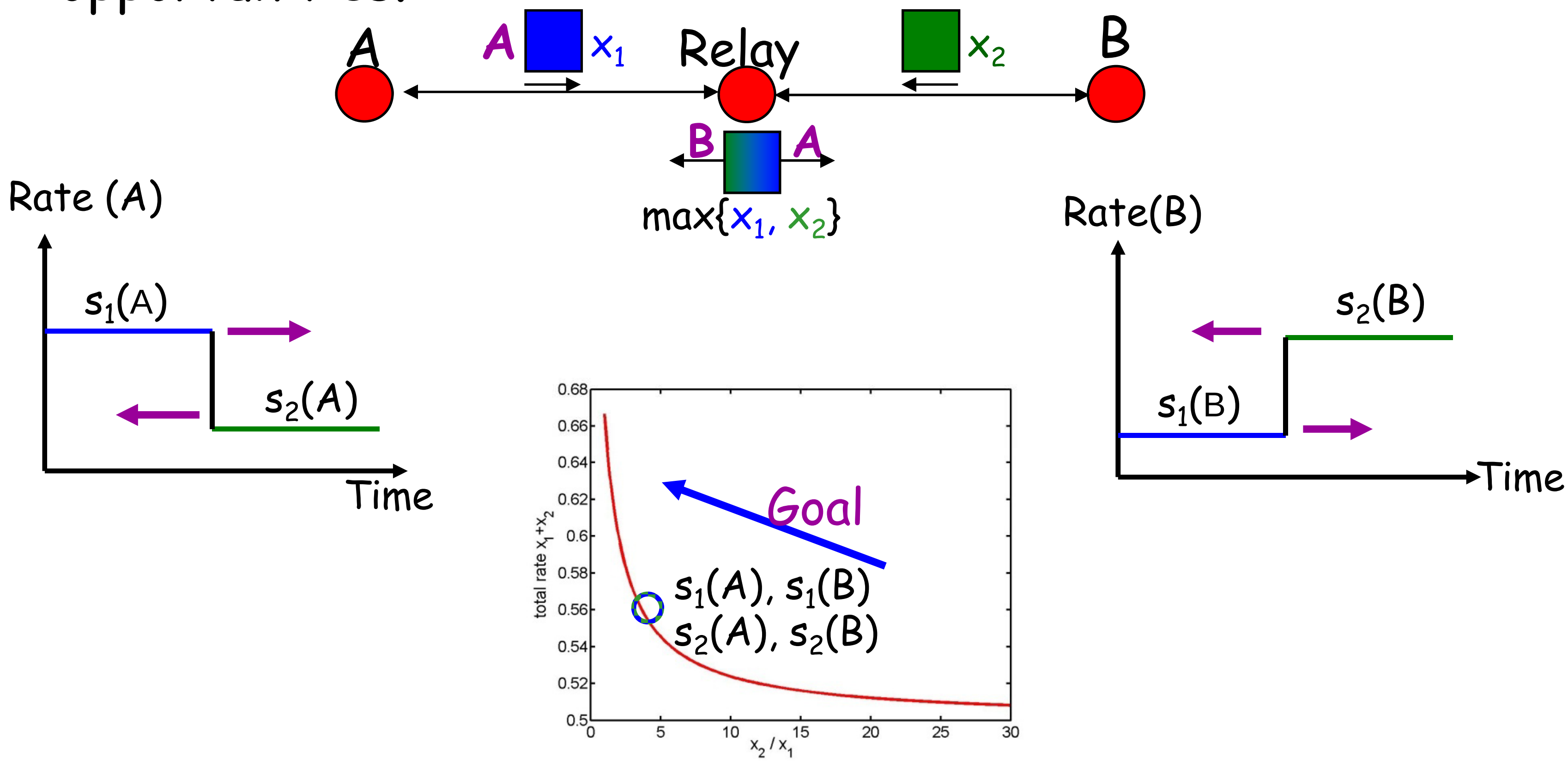
Video Rate Control over NC
Key observations

- **Key observation I:** Video rate requirements affect the underlying network coding opportunities.



Video Rate Control over NC
Key observations

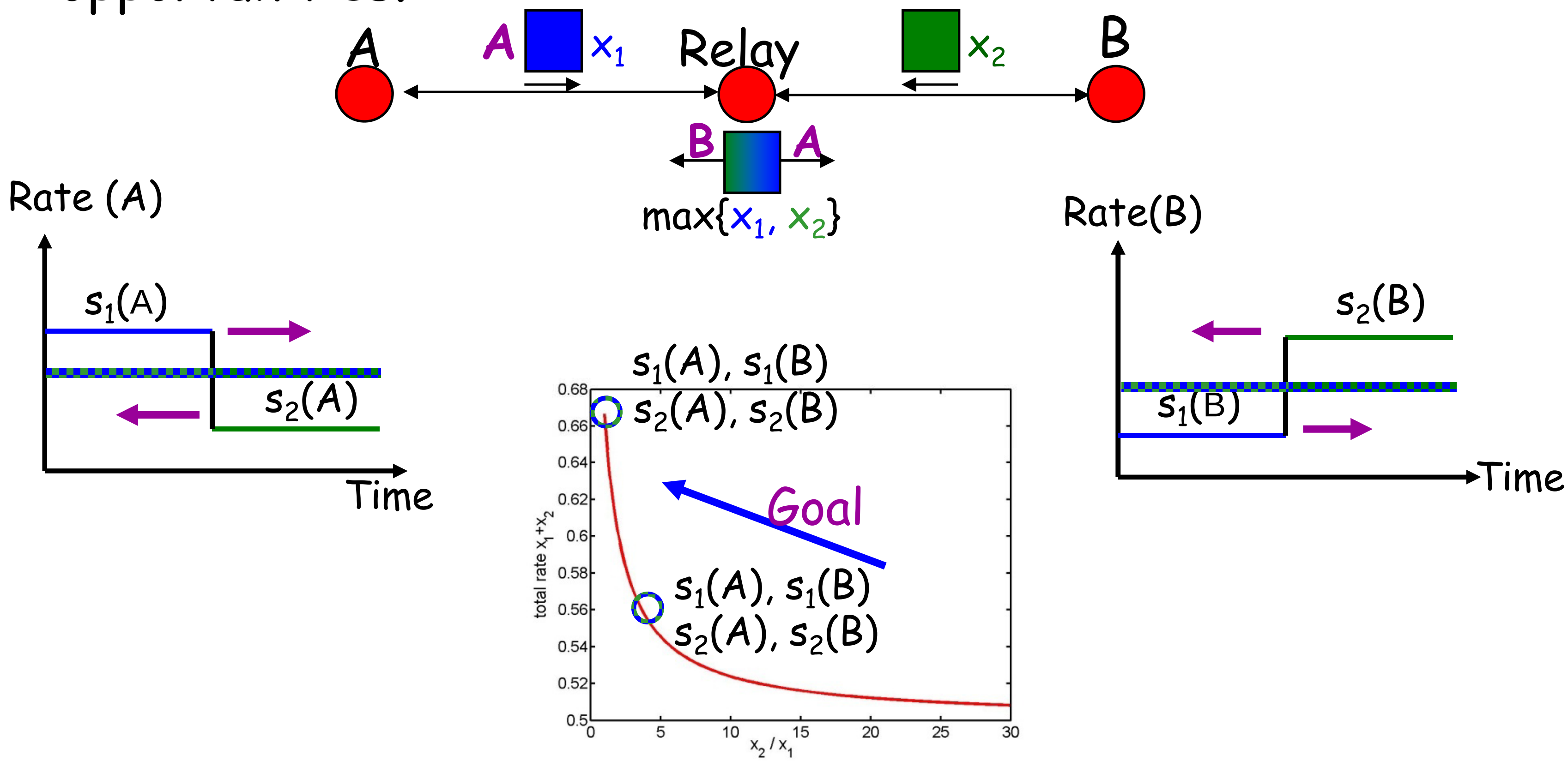
- **Key observation II:** Delaying some scenes and optimizing the rate allocation create more network coding opportunities.



Video Rate Control over NC

Key observations

- **Key observation II:** Delaying some scenes and optimizing the rate allocation create more network coding opportunities.



Video Rate Control over NC

Formulation

$$\max_{x,\tau} \sum_{s\in S} \sum_{f\in F_s} U_s(x_s(f))\delta(f)$$

→ Maximize total scene utilization

→ Scene duration

$$s.t.\quad x_s(f) = \sum_{\{J|(i,J)\in A, i\in I_s\}} x_{i,J}^s(f)$$

$$z_{i,J}^k = R_{i,J}\tau_{i,J}^k$$

$$\sum_{(i,J)\in A_c^q} \sum_{k\in K} \tau_{i,J}^k \le \gamma$$

$$\sum_{f\in F_s} H_{i,J}^s x_{i.J}^s(f) \le z_{i.J}^k \xi_{i,J}^s$$

→ Multiple scenes from a source

$$x_s(f) \ge x_s^{\min}(f)$$

→ Satisfy minimum rate requirement of each scene

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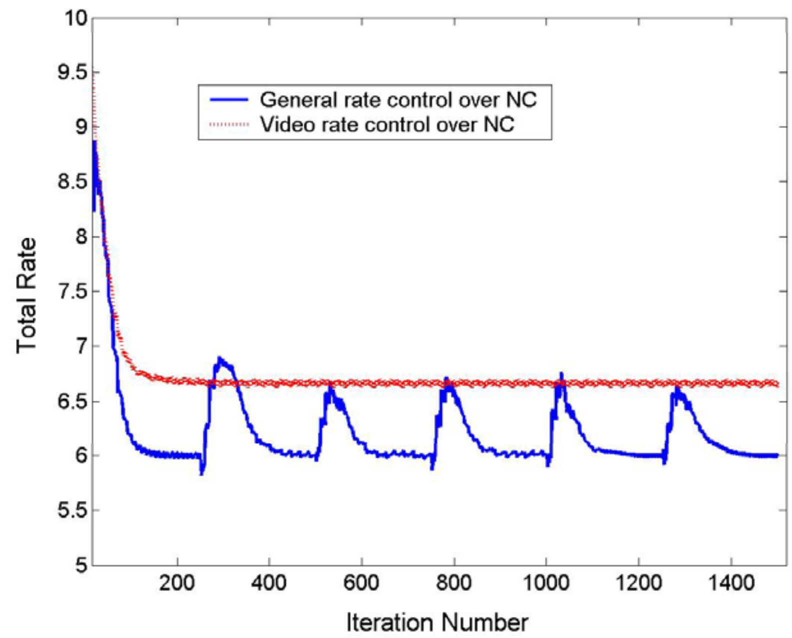
Performance Evaluation

Log utilities - setup

- A and B example
- Two sequences with six scenes
- Scenes consist of 250 packets
- Utility function of each stream;
  - U_1=[4logx_1(1), logx_1(2), 4logx_1(3), logx_1(4), 4logx_1(4), logx_1(4)]
  - U_2=[logx_2(1), 4logx_2(2), logx_2(3), 4logx_2(4), logx_2(4), 4logx_2(4)]
- Channel capacity of each link is considered as 10 packets/transmission

Performance Evaluation

Log utilities – results

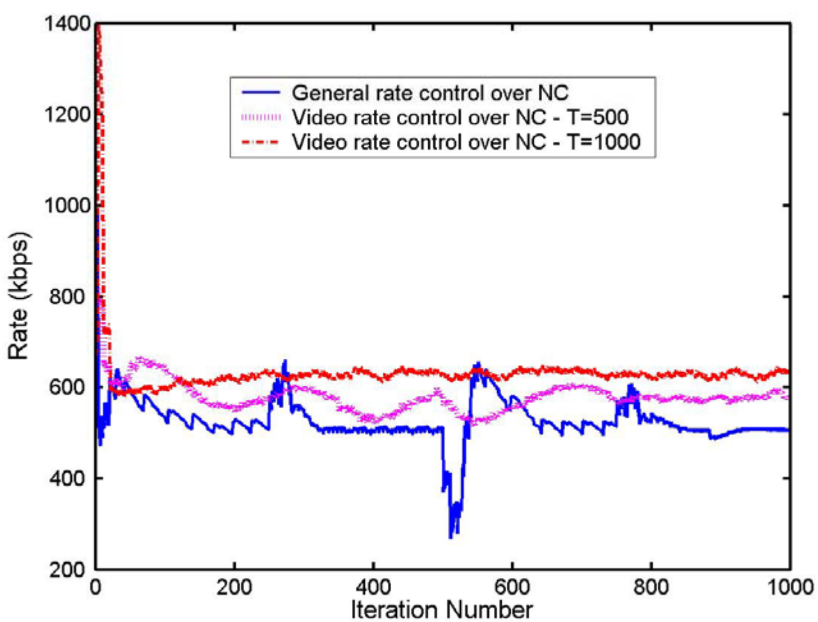


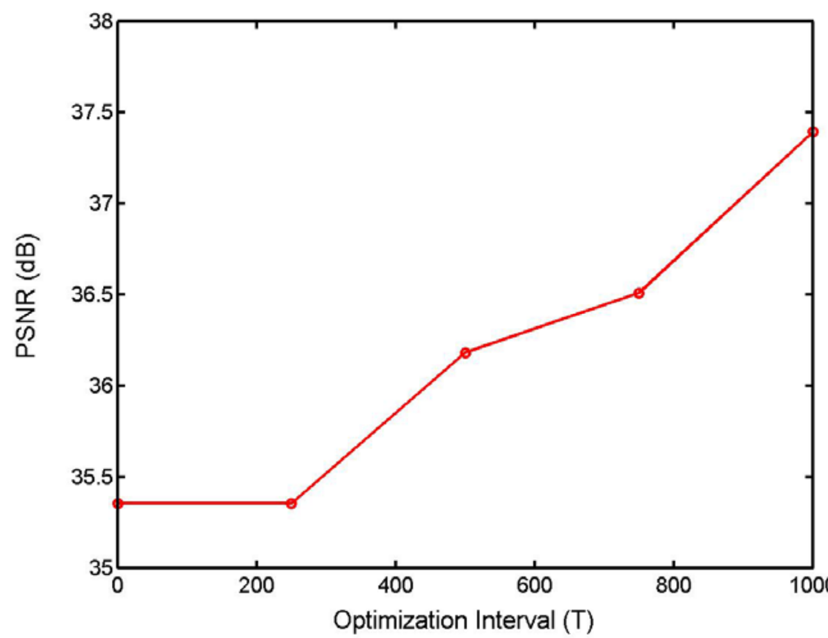
Scene Number	1	2	3	4	5	6
General Rate Control over NC	4.53	2.01	4.23	2.00	4.23	2.00
Video Rate Control over NC	4.98	2.04	4.66	2.00	4.66	2.00

Performance Evaluation
Real video - setup

- A and B example
- Two sequences with six scenes
- Scenes consist of QCIF size video sequences; Carphone, Foreman, Grandma, Mother & Daughter. 30 fps, IPP.. structure, average packet size is 1000B.
- Utility function of each stream determined according to DR curve and weighted according to content;
  - $\mathbf{w}_1$=[0.19, 4.45, 0.18, 3.57]
  - $\mathbf{w}_2$=[2.56, 0.19, 2.56, 0.14]
- Channel capacity of each link is considered as 1Mbps.

Performance Evaluation
Real video - results





Summary

- Proposed distributed rate control schemes for video streaming over wireless networks with intersession network coding.
- Improved total rate and video quality.

- Ongoing work…