Intelligent Resource Allocation in Wireless Networks with Network Coding

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Selective Channelization

- Network Coding: Combine Packets Before Forwarding
  - Approaches multicast capacity of networks
  - Per-hop encoding and decoding employed
- Scenario: Congestion of multicast traffic
- Approach: Use TDMA MAC
  - Let network coding repair characteristics address low congestion
  - Channelize hyperarcs facing performance degradation
- Shortcomings:
  - Does not consider other characteristics of congested wireless networks - backoff, delays, queue occupancy, etc.
  - Does not take neighborhood into account before channelization

Cooperative Channelization

- Observation: Congestion arises out of competition for medium access in a neighborhood
- Define *health* metric using following components
  - Expected No. of Transmissions Due to Collisions
  - Expected No. of Media Access Attempts for Transmission
  - Network Coding Opportunity
  - Impact on Next-Hop Downstream Hyperarcs
- Channelization Scheme
  - A hyperarc is considered sick if its health < Threshold
  - Channelize sickest hyperarc in a 2-hop neighborhood

Expected No. of Transmissions Due to Collisions

Probability of node u receiving a packet from node v

$$p_u^v = (1 - h'_u \cdot q_u) \cdot \prod_w (1 - h'_w \cdot q_w), w \in \gamma_1(u) - \{v\}$$

$$h'_u = \begin{cases} h_u, & \text{if } h_u < 1 \\ 1, & \text{otherwise} \end{cases}$$

Expected No. of Transmissions Due To Collisions

$$X_v^i = T(|\eta_v^i|, |\eta_v^i|, avg_{u \in \eta_v^i}(p_u^v))_{nc} / |\eta_v^i|$$

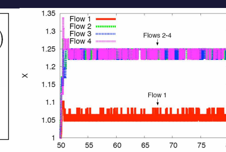
$$t_u = (1 - h'_u \cdot q_u) \cdot \prod_w (1 - h'_w \cdot q_w), w \in \gamma_1(u)$$

$$p_u^v = t_u / (1 - h'_v \cdot q_v)$$

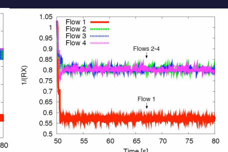
Expected No. of Media Access Attempts For Transmission

$$R_v^i = \begin{cases} d_v^i / (e_v^i + q_v^i \cdot |C_v|), & \text{if } d_v^i > (e_v^i + q_v^i \cdot |C_v|) \\ 1, & \text{otherwise} \end{cases}$$

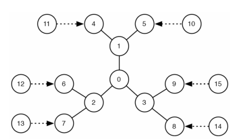
$$H_v^i = 1/(R_v^i \cdot X_v^i)$$



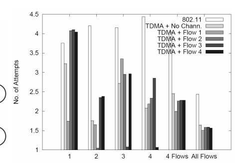
TDMA + No Chann. : X



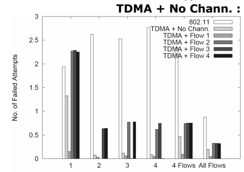
TDMA + No Chann. : H (=1/(RX))



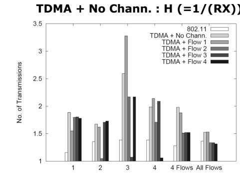
Deployment



Total Media Access Attempts



Failed Media Access Attempts



No. of Transmissions

Network Coding Opportunity

- Packets are coded using XOR
- No more than 1 packet can be decoded out of a transmission
- No more than number of destinations packets can be coded
- X provides performance estimate of network coding under current conditions
- G provides performance estimate of network coding under varying conditions

$$G_v^i = 1 + |\eta_v^i| / |\gamma_1|_{max}$$

η_v^i - Set of destinations of the hyperarc

$|\gamma_1|_{max}$ - Maximum number of 1-hop neighbors

$$H_v^i = G_v^i / (R_v^i \cdot X_v^i)$$

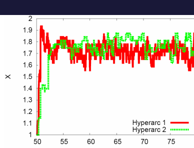
Impact on Next-Hop Downstream Hyperarcs

- Channelizing upstream hyperarcs may increase congestion on all downstream hyperarcs
- Channelize downstream hyperarcs first

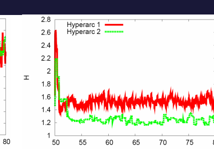
$$J_v^i = 1 + \rho_v^i / |\gamma_1|_{max}$$

ρ_v^i - Number of next-hop downstream hyperarcs for flow *i* in node *v*

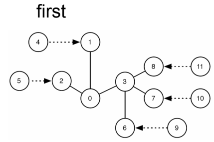
$$H_v^i = \frac{G_v^i \cdot J_v^i}{R_v^i \cdot X_v^i}$$



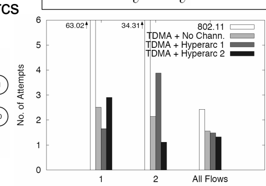
TDMA + No Chann. : X



TDMA + No Chann. : H (=1/(RX))



Deployment



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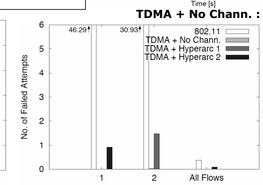

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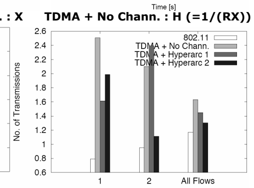
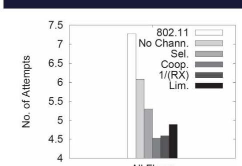


No. of Transmissions

Multi-Hop Results



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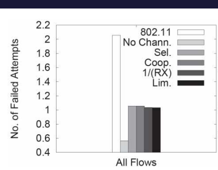

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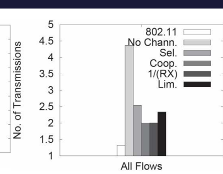

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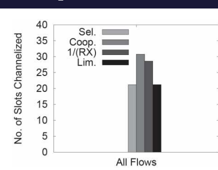
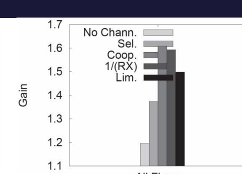
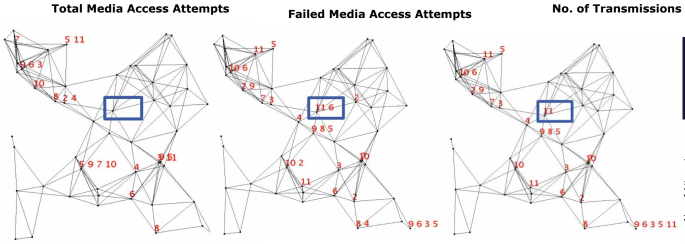


No. of Channelizations



Gains

- Improvement over 802.11
  - TDMA + No Chann.: 20%
  - Selective Channelization: 38%
  - Cooperative Channelization: 61%
  - 1.5x more gain than Sel. Chann.



Selective Channelization Cooperative Channelization Coop. Chann. + Lim

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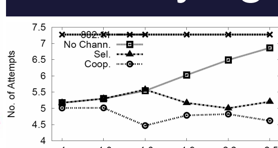
Varying Transmission Probability



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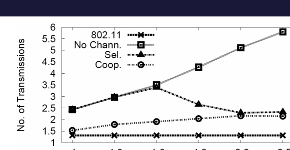

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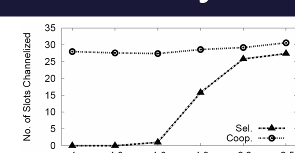

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