Channelization for Network Coding in Wireless Networks

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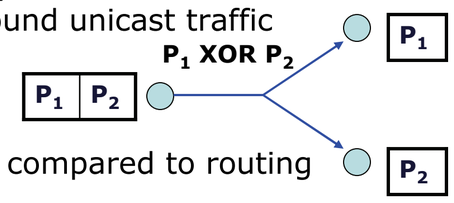
Network Coding

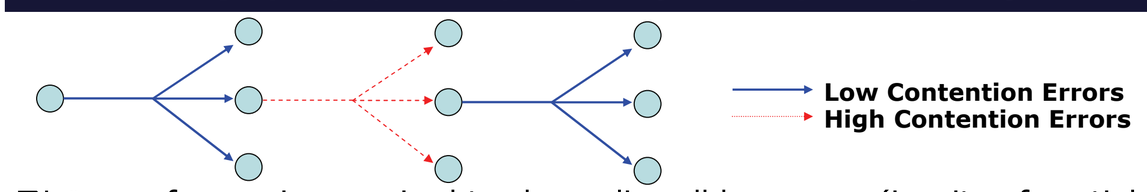
- Network: Nodes with single radio and 802.11 Phy
- Load: Multicast traffic in the presence of background unicast traffic
- Channels: TDMA Slots



- Network Coding (NC) increases channel capacity compared to routing
  - COPE [Katti et. al.] like NC used
- At high load, NC unable to prevent performance degradation

- Objective: Overcome congestion by combining network coding and channelization (i.e., allocation of TDMA slots)
- Goal: Reserve as few resources as possible while maintaining performance target
- Approach: Channelize when expected number of collisions passes a threshold

Selective Channelization



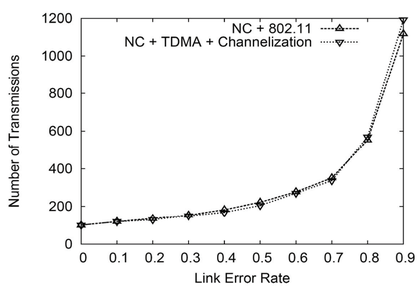
- Large frame size required to channelize all hyperarcs (inspite of spatial reuse) - unacceptable
- At reasonable levels of contention (moderate collision rates), NC recovers nicely
  - No need for channelization
- At high levels of contention, NC outperforms routing, but performance still degrades
  - Channelization removes degradation for flow with channelized link
  - Others may experience lower contention
- Benefits of Selective Channelization
  - Simpler channelization protocols possible
  - Little impact on remainder of the network

Observations

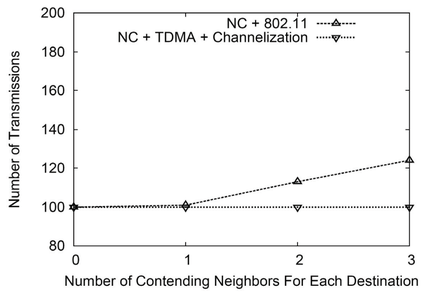
- Channelization assists in overcoming high congestion (collisions)
  - It does not assist in overcoming high link error rates

- Network Coding reduces congestion by reducing transmissions
  - Makes need for channelization occur at higher loads than routing

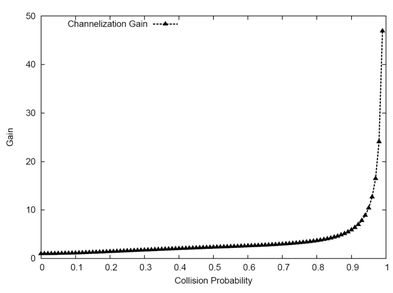
- NC + Selective Channelization
  - Channelization used only during very high congestion
    - Avoids drawbacks of exhaustive channelization
  - Network coding continues to achieve gains for other reasons (e.g., multipath)



Varying LER



Varying Contention



Channelization Gain over NC

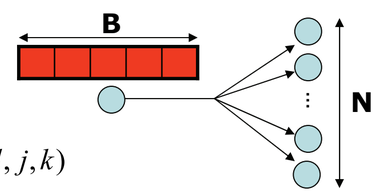
Analysis

- Expected number of transmissions, T, to deliver B packets to N destinations over 1 hop
  - p_b denotes probability of a destination receiving a transmission successfully

$$T(N,B) = B[(1-p_b)^N]^B + \sum_{l=0,m=B-l}^{B-1}\binom{B}{l}X_1 + \sum_{l=0}^{B-1}\binom{B}{l}X_2$$

$$X_1 = (B+T(N,m))((1-p_b)^N)^l(p_b{}^N)^m$$

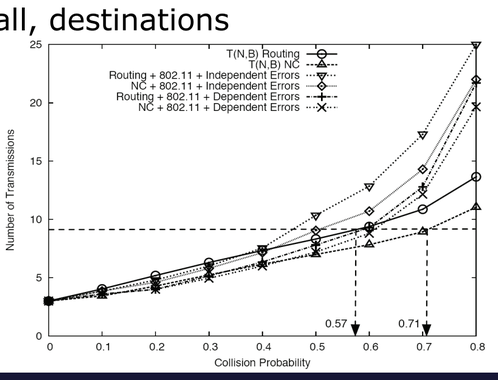
$$X_2(l,j,k) = (1-p_b)^{Nl}\sum_{j=0}^{B-l-1} p_b{}^{Nj}[1-(1-p_b)^N - p_b^N]^k\binom{B-l}{j}X_3(l,j,k)$$



- X_3 - enumerates possible received combinations and accounts for those that result in coding gains
- l – no. of packets received by all destinations
- j – no. of packets delivered to no destinations
- k – no. of packets delivered to some, but not all, destinations

- Observations
  - If k > 1, network coding may help
  - If l dominates, little coding needed
  - If j dominates, channelization will help

- Model is reasonably accurate for our purposes



Algorithms

- Set threshold, T, of number of transmissions per packet (due to collisions)
  - If threshold exceeded, trigger channelization

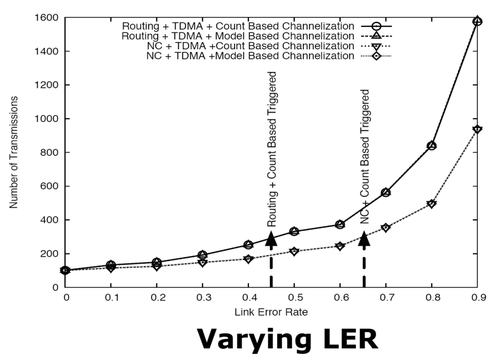
- COUNT: Nodes simply count transmissions
  - Will include gains of coding
  - Will NOT separate loss due to link errors vs. collisions
  - May "over-channelize"

- Model-based
  - Calculate target p_b from model
  - Calculate experienced p'_b from neighbor backlog information
    - 1-bit in headers
  - If $p'_b > p_b$, channelize
  - Will account for coding gains
  - Will separate link loss vs. collisions

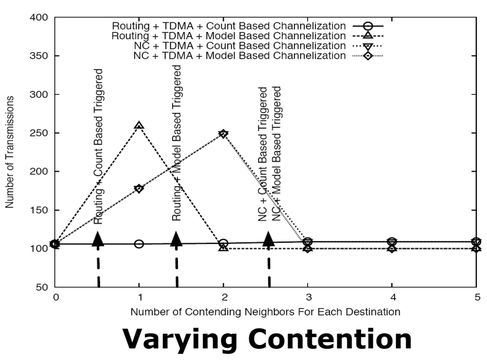
- Requirement for minimum threshold
  - Gain of network coding alone **<** Gain of network coding with channelization

Channelization Triggers

- Model-based algorithm does not experience false alarms
  - Count triggers when LER is high even if collisions are low
- Model-based algorithm is accurate in face of high collisions
  - Triggers at same point as COUNT with no link errors
- Network coding saves resources
  - Allows later trigger of channelization

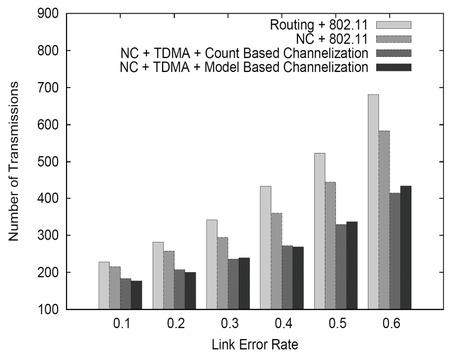


Varying LER

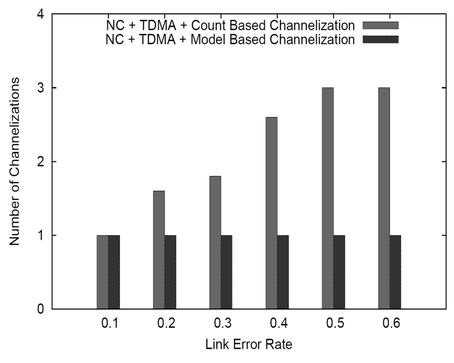


Varying Contention

Varying Link Error Rate

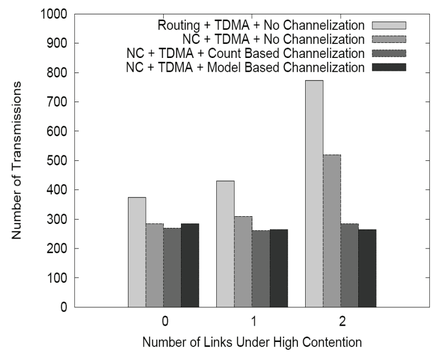


Number of Transmissions



Number of Channelizations

Varying No. of Links Under Contention



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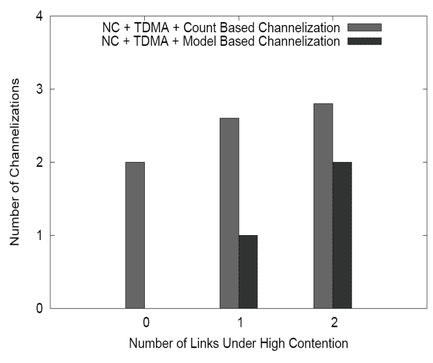

Number of Channelizations

Conclusions

- Selective channelization in conjunction with Network Coding is an effective scheme to prevent widespread performance degradation with few resources
- Model-based scheme performs comparably to COUNT-based scheme
- Model-based scheme requires less resources compared to COUNT-based scheme

- **Future Work :** "Cooperative Channelization" – Performance of hyperarcs does not degrade in isolation. As a result, the impact on interfering hyperarcs will be taken into consideration before channelization.

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