Channelization for Network Coding in Wireless Networks

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Outline

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Introduction

- Network coding gains can arise from one of two reasons – multi-path and independent errors at destinations.
- Network coding gains vary with link error rates (LER), collisions, maximum number of coded packets.

Introduction

- The contributions of this paper are:
  - Providing an analysis of potential network coding gains under congested conditions.
  - Design of selective channelization policies.
  - Simulation results to show gains.

Related Works

- Network coding may achieve larger capacity in multicast links.
- COPE (XORs in The Air, SIGCOMM '06) proposed a method of combining packets in wireless networks.
- Another way to improve network capacity is through scheduling and spatial reuse of channels.

Gain Analysis

- At high collision error rate, even with network coding, the number of transmissions for data delivery may reach unacceptable levels.
- The gain g_h achieved over a single hyperarc h is $g_h = r_h / n_h \ \forall h \in H$ where r_h is the number of total transmissions without network coding, and n_h is the total number of transmissions with network coding.

Gain Analysis

- The expected number of transmissions

$$T(N,B)_{scheme} = B(p_i^N)^B + \sum_{l=0,m=B-l}^{B-1} \binom{B}{l} X_1 + \sum_{l=0}^{B-1} \binom{B}{l} X_2 \quad (2)$$

$$X_1 = (B + T(N,m))(p_i^N)^l (p_b^N)^m \quad (3)$$

$$X_2(l,j,k) = p_i^{Nl} \sum_{j=0}^{B-l-1} p_b^{Nj} [1 - p_i^N - p_b^N]^k \binom{B-l}{j} X_3(l,j,k) \quad (4)$$

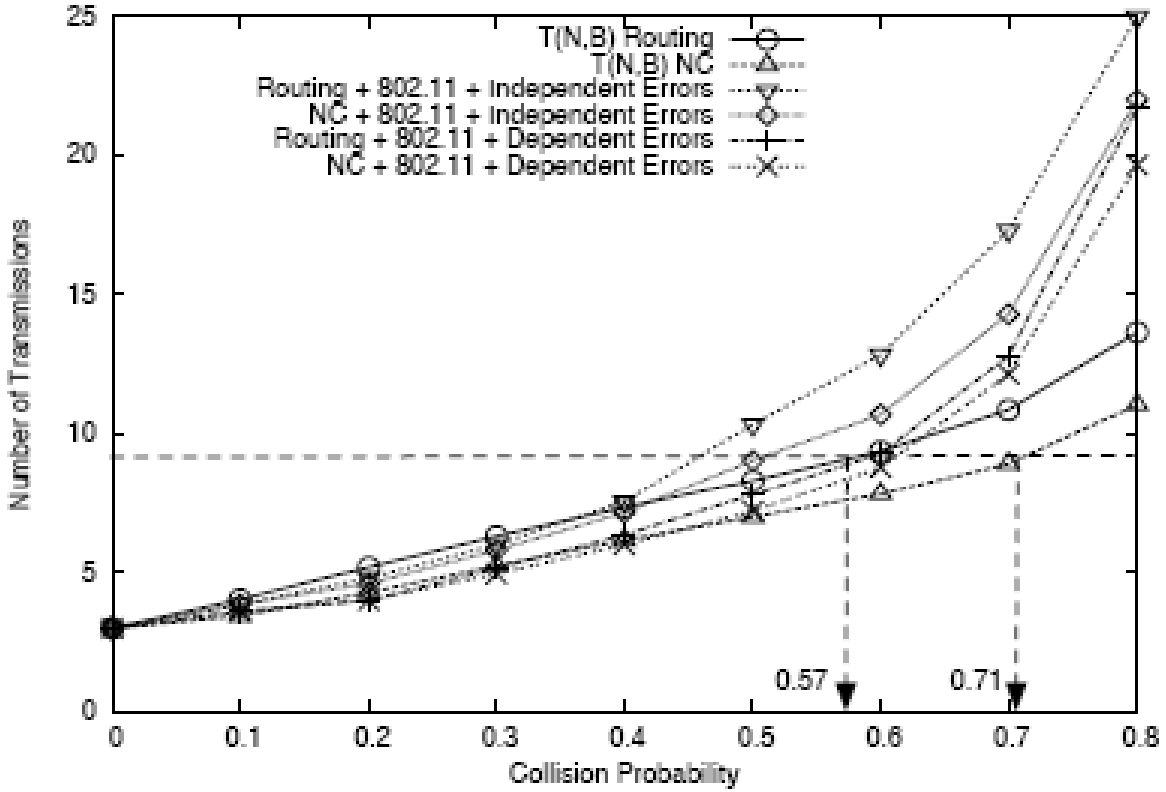
B: number of packets need to be delivered p_i: prob. of receiving correctly

N: number of destination p_b: prob. of collision

l: number of packets delivered to all destinations

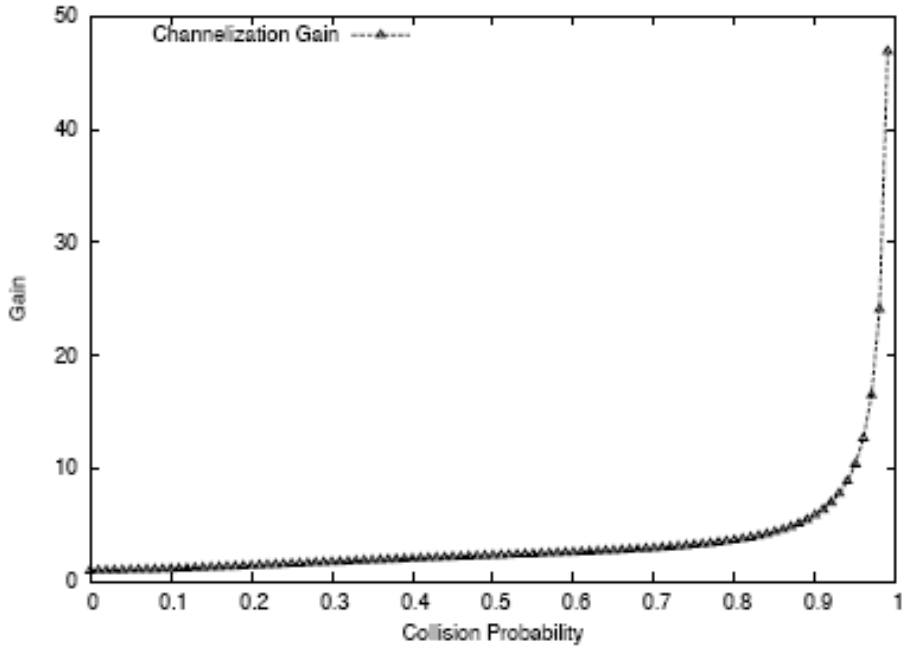
j: number of packets lost k: B-l-j

Gain Analysis



(a) Avg. Number of Transmissions Per Packet with Perfect Feedback: N=3, B=3, Packet Size = 512 Bytes

Gain Analysis



(b) Channelization Gain over Network Coding

Channelization

- IEEE 802.11 does not protect multicast traffic by performing an RTS/CTS exchange before transmission.
- Channelization is to define channels as TDMA slots, and at least one channel is reserved for its use among its two hop neighbors.

Channelization

- For example, assume a frame includes 10 slots, and a node has data to send.
- Without channelization:
  - Send in each slot with probability 0.1 until the queue is empty.
- With channelization:
  - The node has one time-slot reserved for each frame, so its neighbors contend for the other 9 slots in each frame.

Channelization

- The channels may be not sufficient for channelization every time, so a selective channelization is proposed.
- Channelization with network coding will reduce the required (re)transmissions, and the authors focus on determining when to trigger channelization.

When to channelize

- A node takes channelization if the number of transmissions required to successfully deliver packets exceeds a threshold.
- There are two channelization scheme:
  - Count-based channelization
  - Model-based channelization using network coding estimate

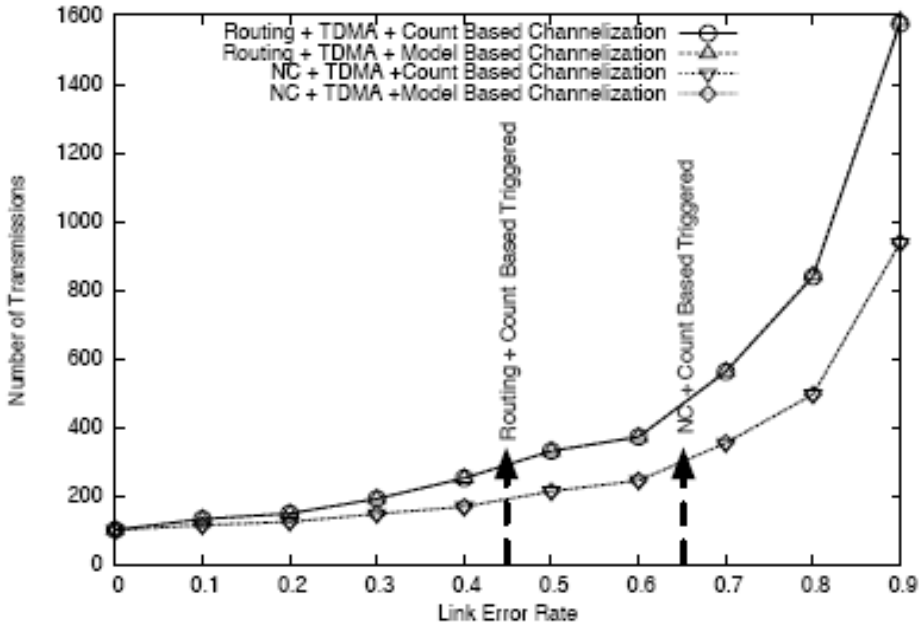
Channelization schemes

- Count-based channelization
  - A node maintains an average of the number of transmissions required to successfully deliver a packet.
  - When this average becomes larger than a threshold, it triggers channelization.
  - However, it can not distinguish between collisions and link errors.

Channelization schemes

- Model-based channelization using network coding estimate
  - Set the threshold which is based on $T(N,B)_{nc}$ from Equation 2.
  - Trigger channelization when the required number of transmissions is larger than the threshold.

Simulation



(a) Varying LER: Number of Background Flows = 0

Fig. 2. Number of Transmissions: Number of Flows = 1, Number of Packets = 100, Packet Size = 512 Bytes

Simulation

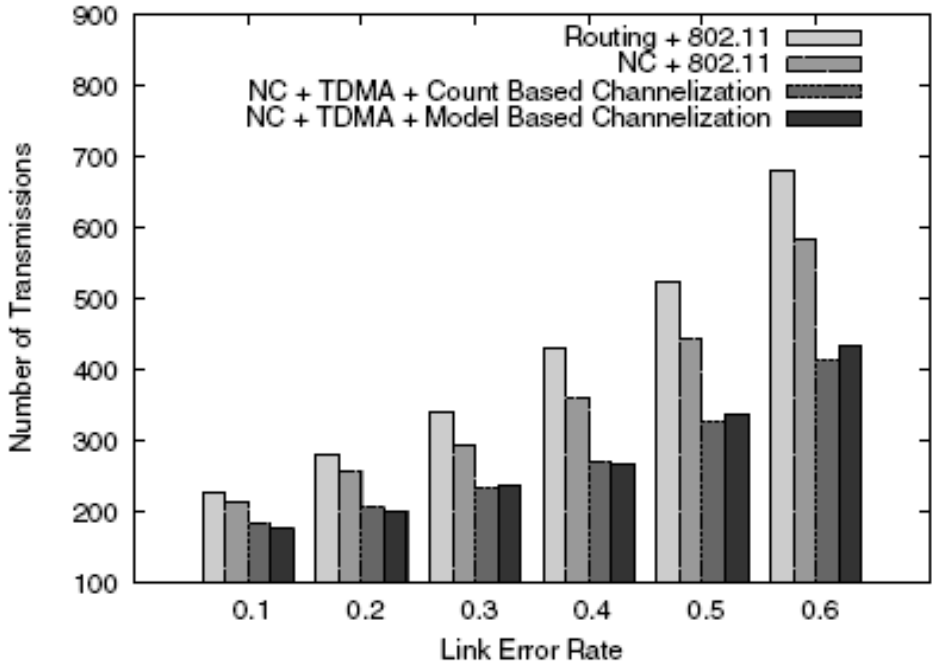


Fig. 3. Varying Link Error Rate: Number of Flows = 1, Number of Packets = 50, Packet Size = 512 Bytes

Simulation

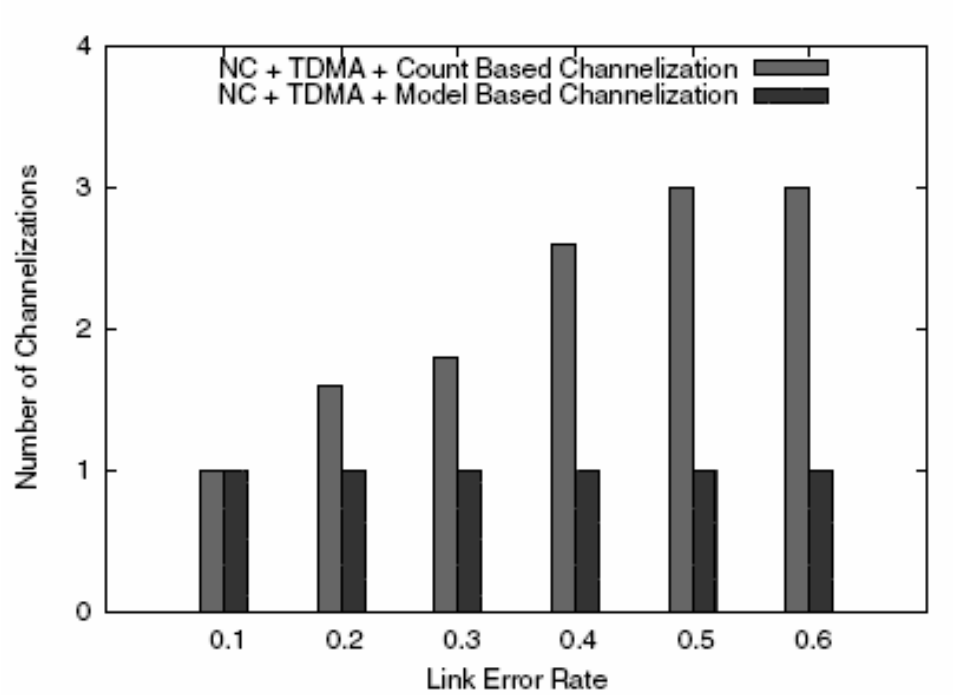


Fig. 3. Varying Link Error Rate: Number of Flows = 1, Number of Packets = 50, Packet Size = 512 Bytes

Conclusion

- Even when network coding is employed, under highly congested circumstance, the number of transmissions may become prohibitive.
- Base on the analysis, the authors propose a selective channelization scheme to prevent performance degradation in high collision circumstance.