Graduate Research

Rate Analysis of Multiuser Random Access Protocols as Codes

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Overview

Motivation

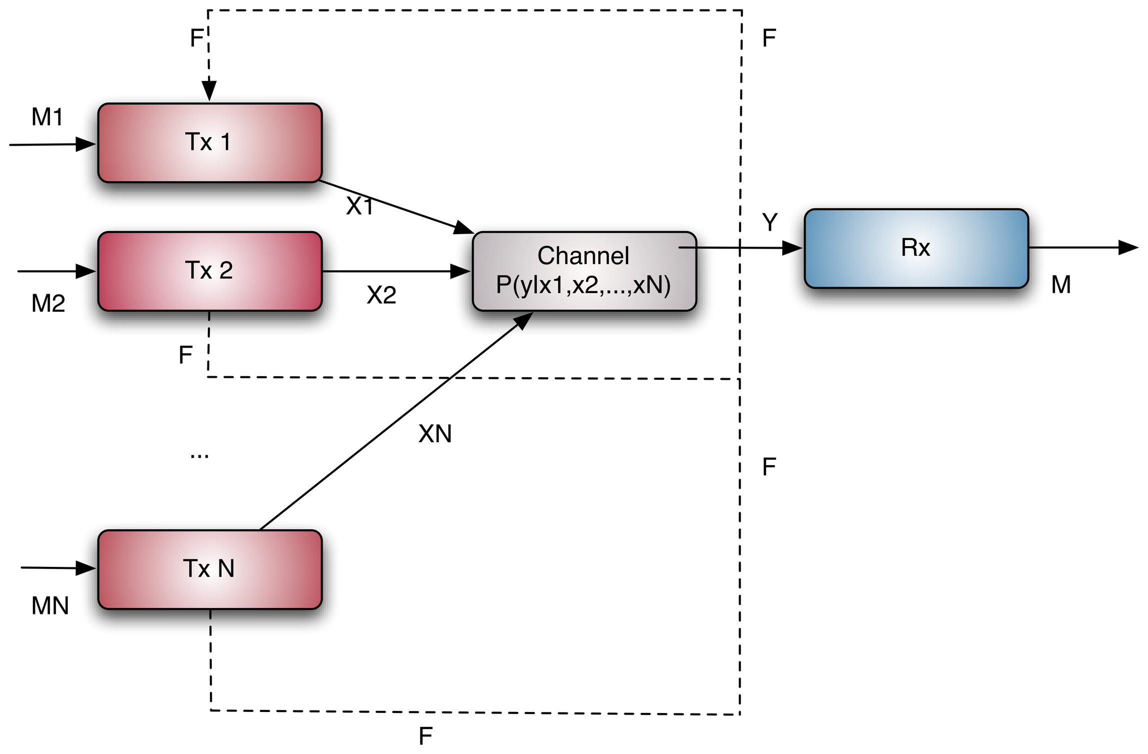
- 802.11 is a random access protocol with significant overhead
- To improve, we need to reverse engineer the problem it is trying to solve
- Use analysis tools and techniques from Information Theory to improve on performance
  - Where are gains coming from?
  - How can they be maximized?

Contributions

- Define 802.11 as a multiple user coding scheme for a compound MAC channel with feedback
- Devise a valid metric to compute the coding rate of the *802.11 code*
- Compare 802.11 rate to optimal strategy
- Demonstrate gains with respect to a collision channel with out feedback

802.11 As A Code

Channel Model



- The channel is a collision channel with 3 input symbols and 4 output symbols

$$f : \{0, 1, \emptyset\} \rightarrow \{0, 1, \emptyset, c\}$$

where f is the encoding function, {0, 1} are bits, c is a collision, and ∅ is silence

Coding Scheme

- ***Encoding***
  - Each encoder i generates a codeword

$$\mathbf{x_i} = (x_i^1, x_i^2, ..., x_i^{L_i})$$

each composed of the following elements:

- A waiting vector (depends on backoff level)

$$\mathbf{u_i} = (u_i^1, u_i^2, ..., u_i^w) = (\emptyset, \emptyset, ..., \emptyset)$$

- A message vector

$$\mathbf{b_i} = (b_i^1, b_i^2, ..., b_i^{\lceil \log M \rceil})$$

- Hence creating the needed codeword

$$\mathbf{x_i} = (x_i^1, x_i^2, ..., x_i^{L_i}) = (\mathbf{u_i}, \mathbf{b_i})$$

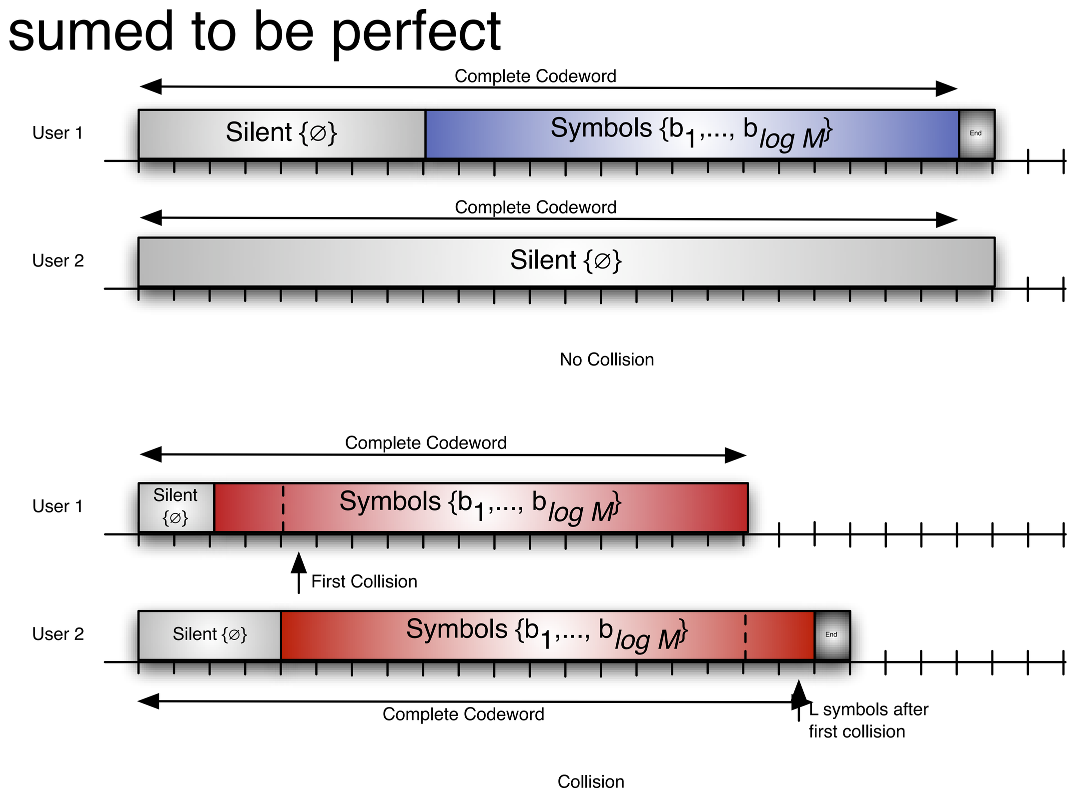
where w is the backoff level chosen uniformly from the contention window {0, 1, ... W-1}, and the message is chosen from M possible messages

Decoding

- The decoder uses $g(\mathbf{y})$ to provide estimates on the sent messages. Since the channel is a collision channel, the message will be recovered perfectly when no collision occurs
- In a system with carrier sensing multiple access with collision avoidance (CSMA/CA), a collision only occurs if both users choose the same backoff level w

Feedback

- Feedback is binary, {*ACK, NACK*}, and is assumed to be perfect



Coding Rate

- Since this is a variable length code, rate is defined as *number of payload bits transmitted/ units of time required to transmit*, or:

$$R_k \triangleq \frac{\log M}{L_k}$$

- The average rate of the code is found by finding the expected value of R_k over L_k

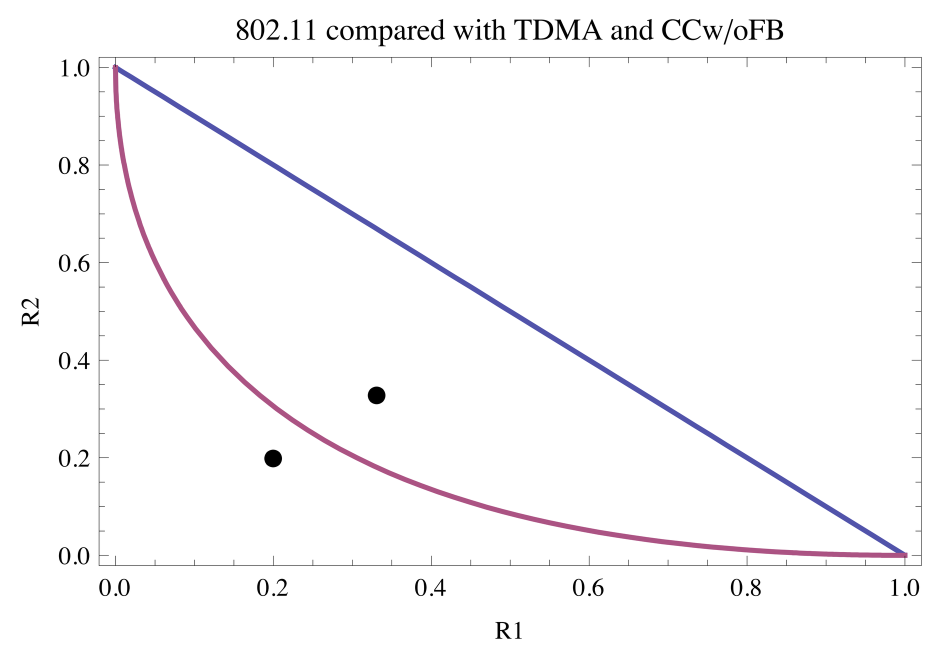
$$R_k = p_s(W_0)\Gamma(W_0, l) + p_c\{p_s(W_1)\Gamma(W_1, l) + p_c\{...\}\}$$

where

$$\Gamma(W, l) = \frac{l}{Q_{nc} + l} = \frac{l}{W - 1 + 2l}$$

p_s and p_c are the probabilities of successful transmission and collision, respectively.

- Important notes about the rate formulation:
  - Allows the analysis of the effect of exponential growth of contention window size
  - Provides helpful bounds
  - Permits asymptotic analysis



Future Work

- Characterize rate for no-CSMA case
- Deterministic channel model
- Effects of more feedback

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Center for Multimedia Communication