Efficient Symbol-Level Transmission in Error-Prone Wireless Networks

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Agenda

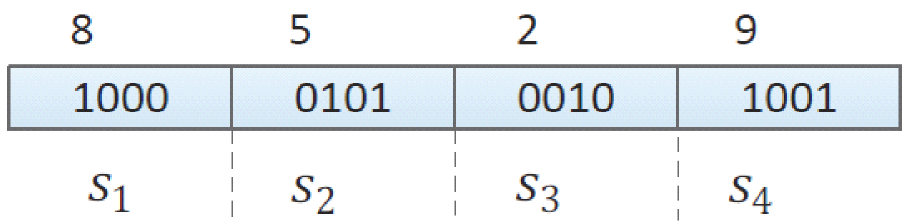
- Introduction
- Motivation
- Setting
- Proposed methods
  - Single packet
  - Multiple packets
  - Multiple packets with network coding
- Simulation results
- Conclusion

Introduction

- Broadcasting in wireless networks
  - Disseminating data and control messages

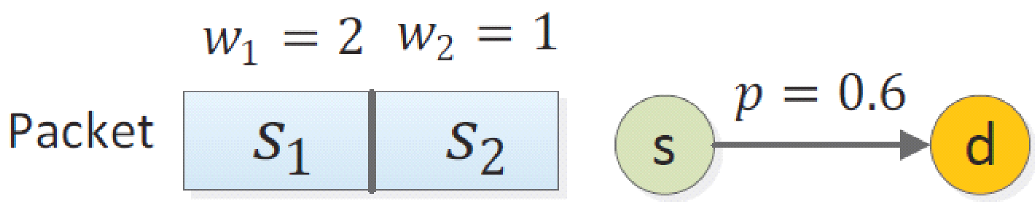
- Error-prone wireless links
  - Provide reliability
    - ARQ
    - Hybrid-ARQ
    - Erasure codes
    - Fountain codes (rateless codes)

Introduction



- Errors in packets
  - Not binary
- Numeric data
  - Like sensed data by sensor nodes
  - The important of the symbols (bits) are different
    - The importance of the symbols should be considered
- Choices
  - Reliable transmissions
  - Maximizing the expected gain with a fixed given number transmissions

Motivation



$$u = w_1 \times (1 - p^{x_1}) + w_2 \times (1 - p^{x_2})$$

x_1	x_2	Utility
2	0	1.28
1	1	1.2
0	2	0.64

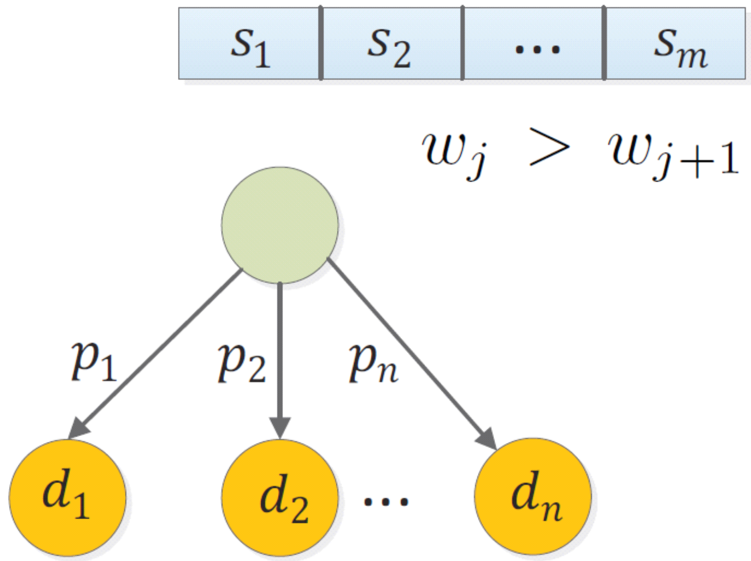
2 transmissions

x_1	x_2	Utility
3	0	1.568
2	1	1.68
1	2	1.44
0	3	0.78

3 transmissions

Setting and Objective

- One-hop network
- Lossy links
- Transmission window size
  - t slots for a packet



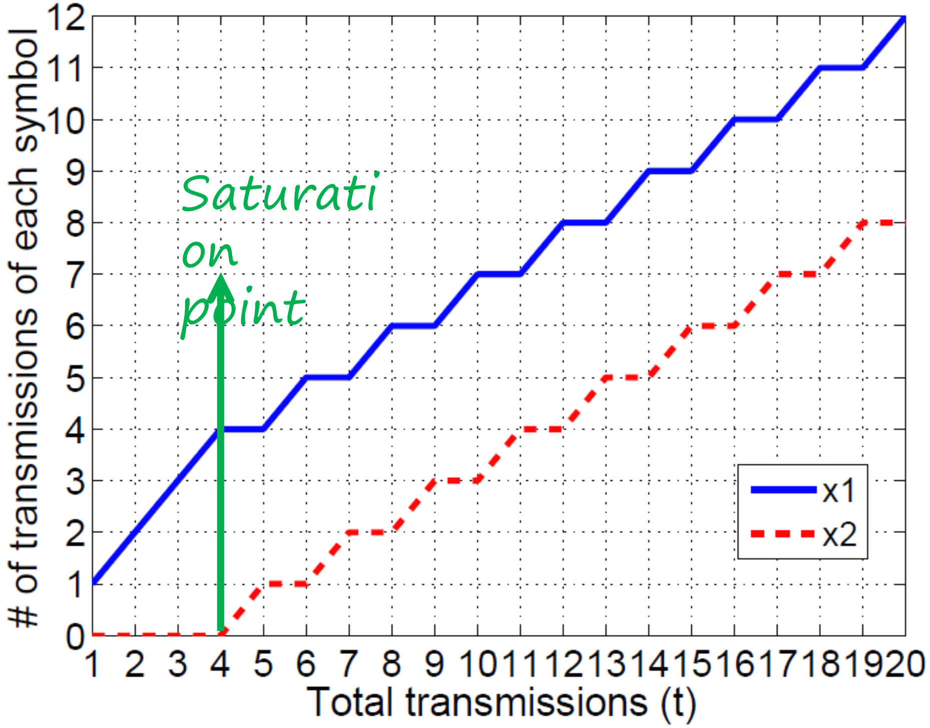
- <u>Objective</u>: maximizing the total weight of the received symbols

Single Packet (One Destination)

- The case of a packet size equal to 2 symbols

$$u = w_1 \times (1 - p^{x_1}) + w_2(1 - p^{x_2})$$

$$st. \quad x_1 + x_2 = t$$



$$w_1 = 5$$

$$w_2 = 1$$

Single Packet (One Destination)

- We consider the problem in rounds of transmissions
- The first time we should increment x_2 is when

$$p^{x_1} < \frac{w_2}{w_1}$$

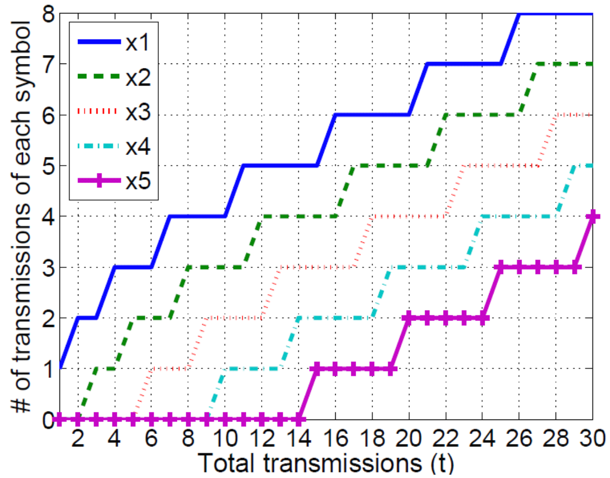
- After the saturation point, the distribution of the transmissions has a *round-robin* incrementing pattern
- The proof of optimality is provided in the paper

Single Packet (One Destination)

- Generalizing to *m* symbols
  - We assign the transmissions to x_1 until $p^{x_1} < \frac{w_2}{w_1}$
  - Then, we distribute the transmissions between x_1 and x_2 until $p^{x_1} < \frac{w_3}{w_1}$ and $p^{x_2} < \frac{w_3}{w_2}$
  - After this point, we continue the round-robin pattern among x_1, x_2, and x_3

In general, we start incrementing x_j when:

$$p^{x_i} < \frac{w_j}{w_i} \quad \forall i : 1 \le i \le j-1$$



The proof of optimality: in the paper

Single Packet (Multiple Destinations)

- In the case of different transmission error rates, the round-robin pattern does not exist
- Iterative algorithm
  - We assign the transmissions to the symbols in *t* rounds

$$\Delta_{x_i} = w_i \times \sum_{l=1}^{n} \left[1 - p_l^{x_i+1} - (1 - p_l^{x_i}) \right] = w_i \times \sum_{l=1}^{n} \left[p_l^{x_i} - p_l^{x_i+1} \right]$$

- At each iteration we assign the current transmission to the symbol with maximum Δ_{x_i}

Multiple Packets

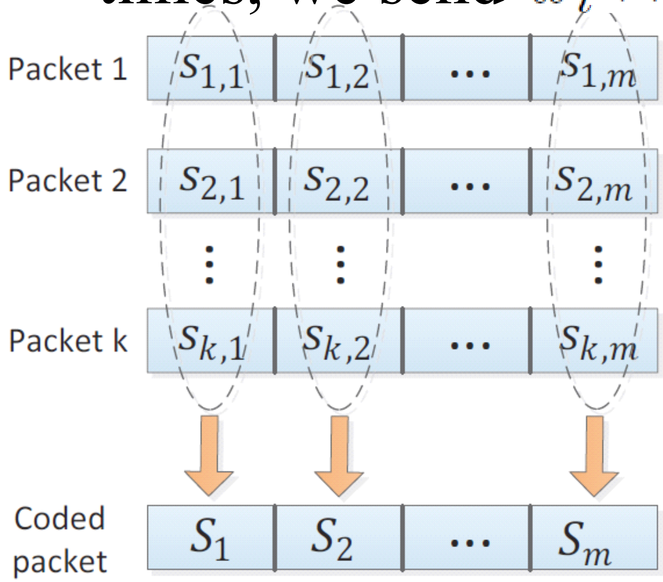
- Our model
  - The size of the packets are equal
  - The weights of the i-th symbols in different packets are the same

- The problem of sending k independent packets becomes k similar problems with the same solution

- We can solve the problem for a single packet, and repeat it for any packet

Multiple Packets- with Network Coding

- We first find the optimal x_i
- We code all of the *i*-th symbols of the *k* packets together
  - Instead of sending the *i*-th symbols of each packet x_i times, we send $x_i \times k$ coded symbols



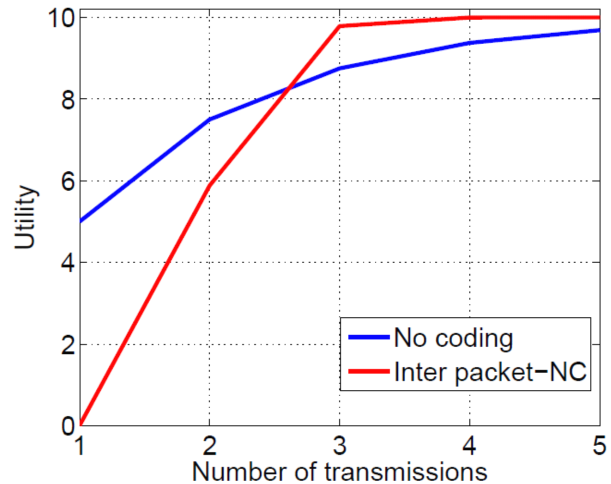
$$S_i = \sum_{j=1}^{k} \alpha_j \times s_{j,i}$$

Multiple Packets- with Network Coding

- Using network coding might increase or decrease the gain
  - Since partial decoding is not possible
  - For each set of the *i*-th symbols we compare the gain of coding and non-coding

$$u_i^{NC} = w_i \times k \times \sum_{l=1}^{n} \left[\sum_{j=k}^{x_i \times k} \binom{k \times x_i}{j} \times (1-p_l)^j \times p_l^{x_i \times k - j} \right]$$

$$u_i = w_i \times k \times (1 - p_l^{x_i})$$



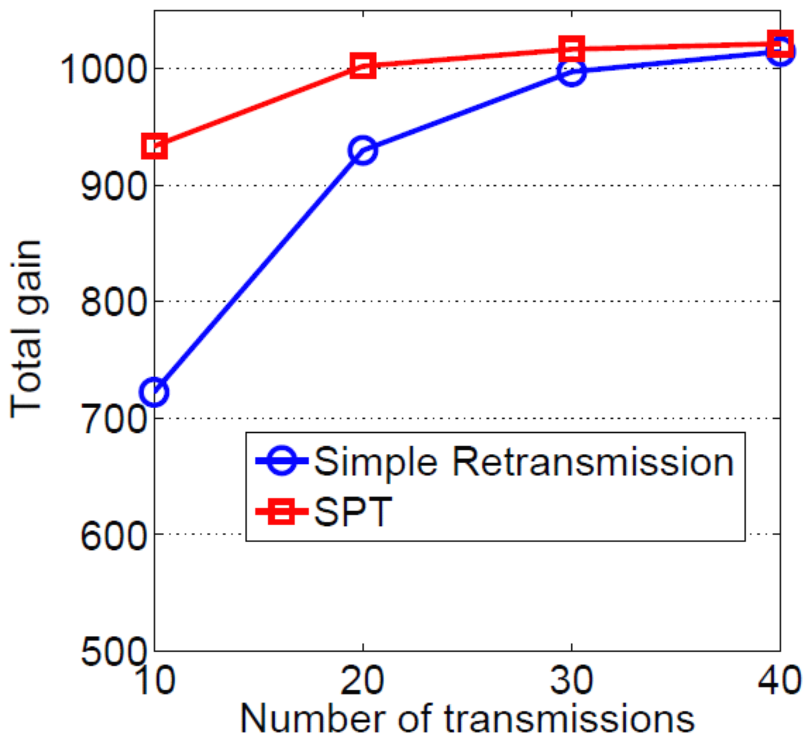
  - We turn off coding if it decreases the gain

Simulations Setting

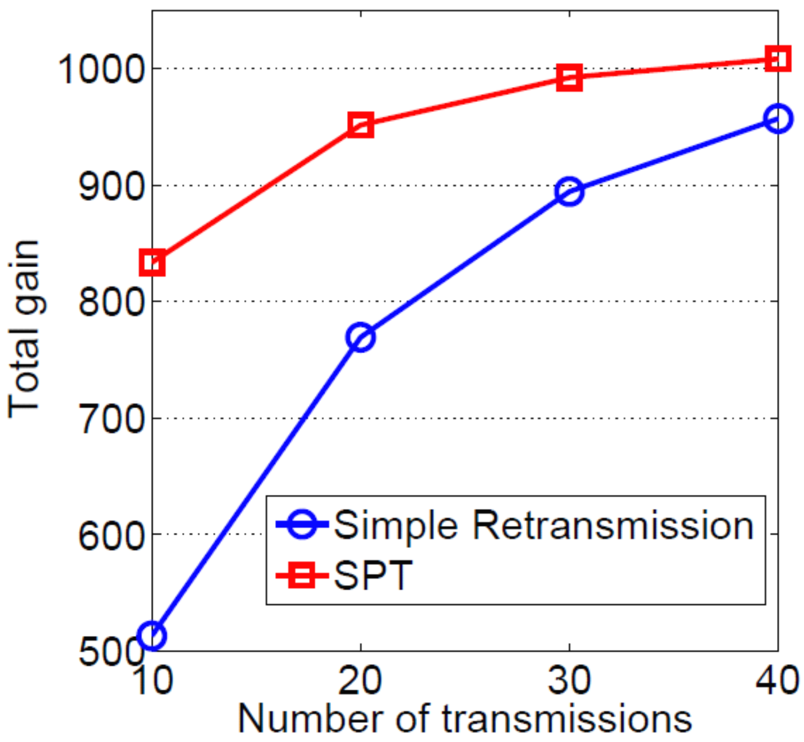
- MATLAB environment
- 1,000 random topologies
  - Different links' error rates
- Weight of the i-th symbol: 2^{m-i}
- Compare with simple retransmission method
  - Distribute the transmissions evenly to the different symbols of the packets

Simulations- (Single Destination)

- Single packet- 10 symbols



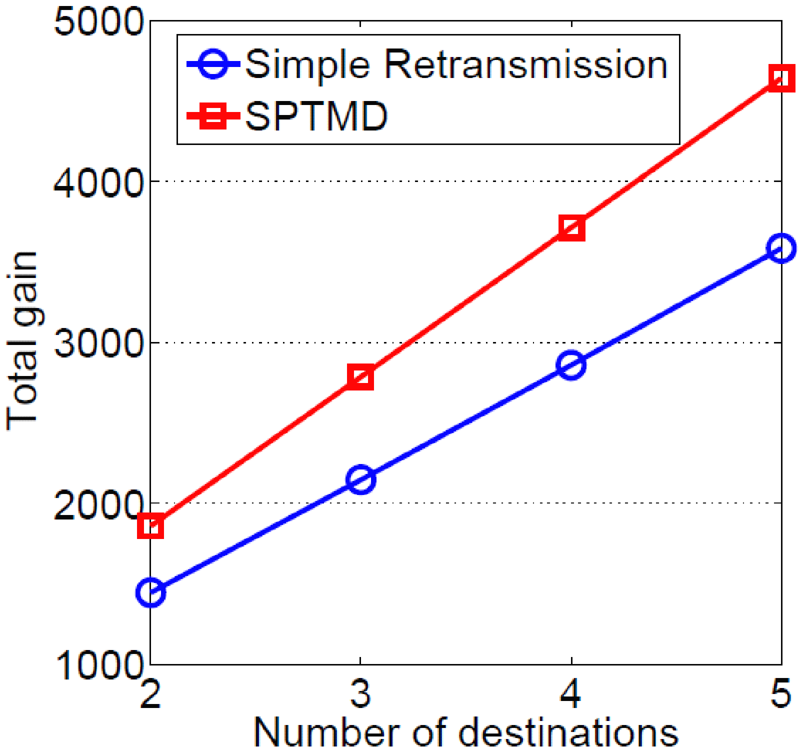
$p = 0.3$



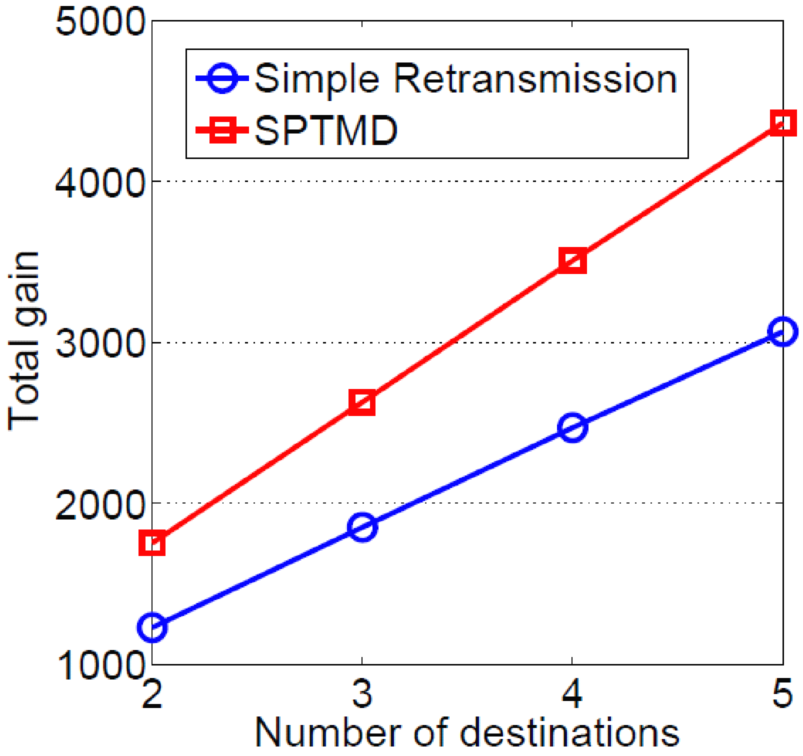
$p = 0.5$

Simulations- (Multiple Destinations)

- Single packet- 10 symbols
- 10 transmissions



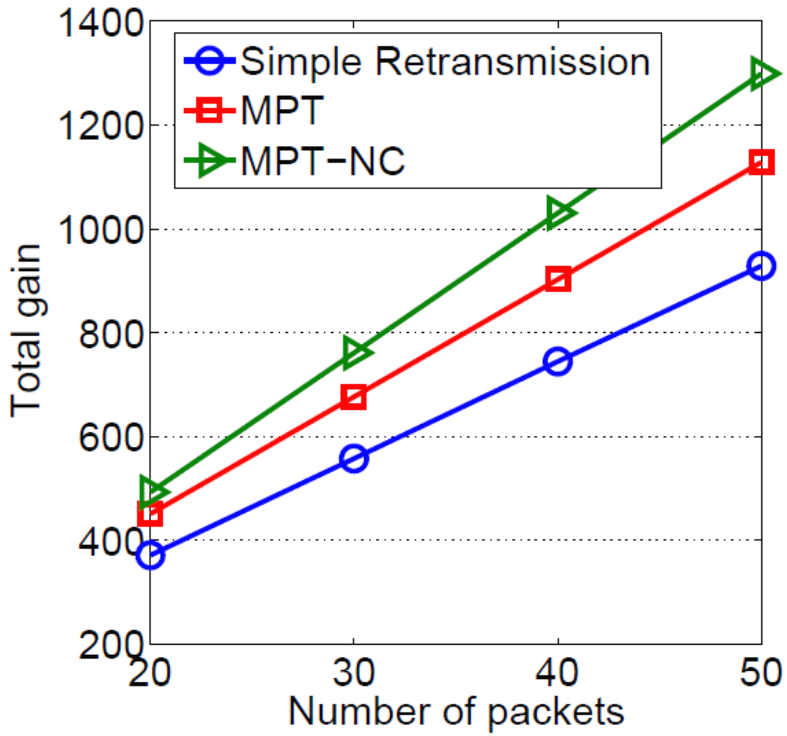
$p \in [0.2, 0.4]$

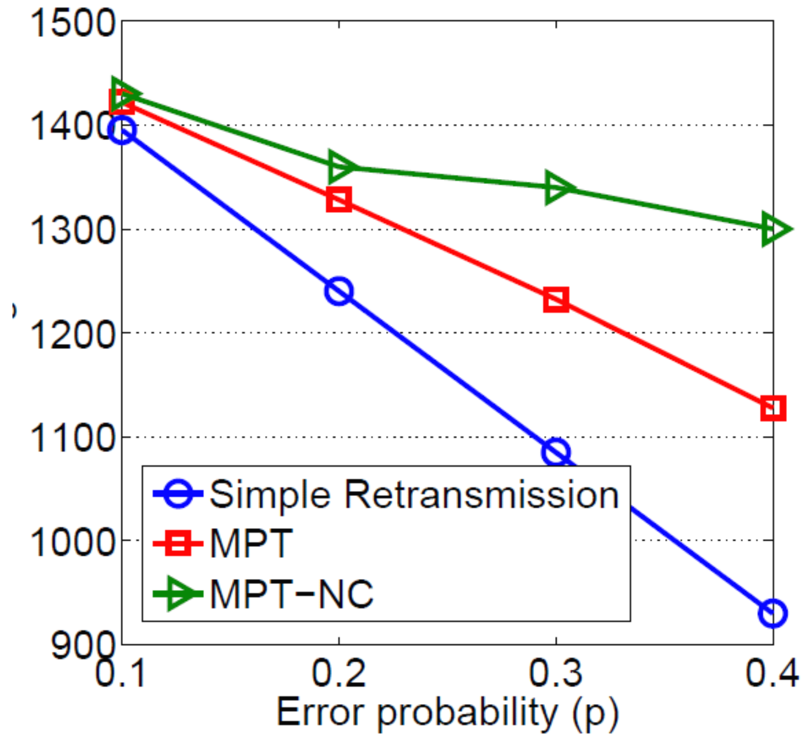


$p \in [0.2, 0.6]$

Simulations

- Packet size: 5 symbols





10 transmissions

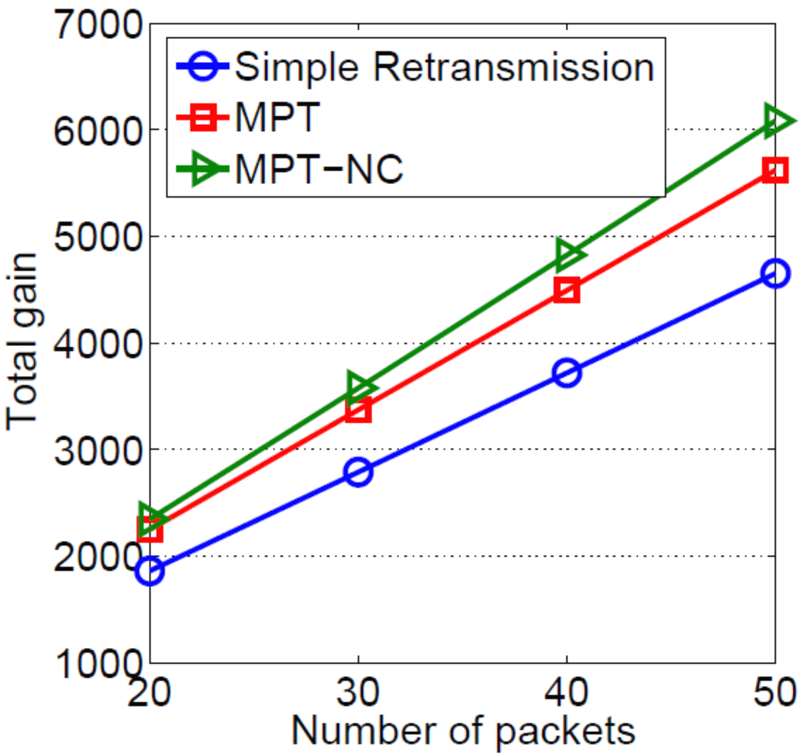
$p = 0.4$

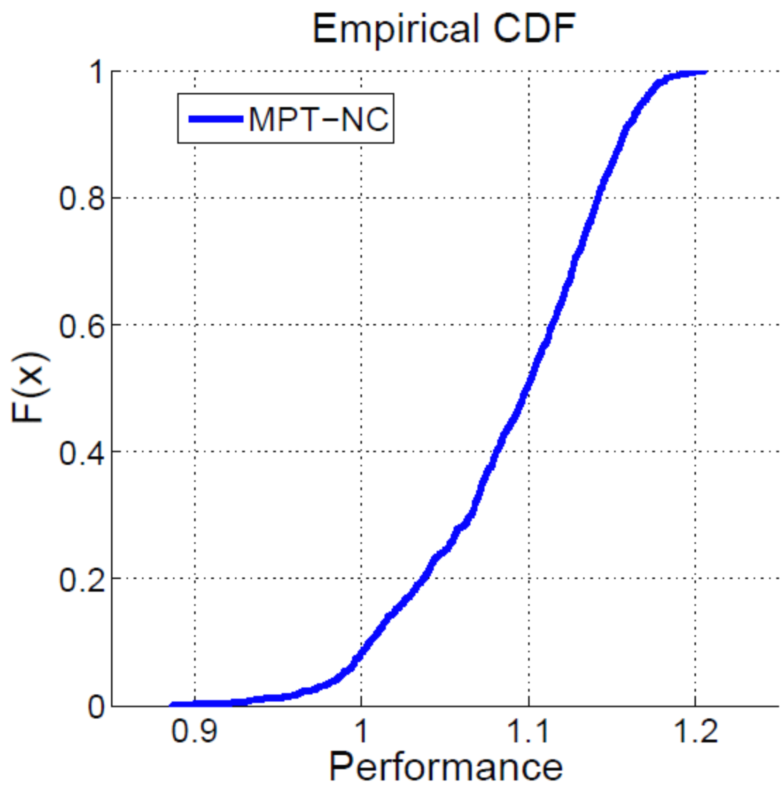
50 packets

Simulations

- Packet size: 5 symbols
- 5 destinations

$p \in [0.3, 0.5]$





Simulations Summary

- Our proposed MPT mechanism can increase the gain up to 22% compared to that of a simple retransmission mechanism

- Our network coding scheme enhances the expected total gain up to 45% compared to the simple retransmission mechanism

Summary

- There is much work on reliable transmissions over error-prone wireless channels
- We propose a novel transmission scheme which is based on the importance of the symbols (bits)

- Proposed methods
  - Single packet
  - Multiple packets
  - Multiple packets with network coding

Questions