PRIORITY-BASED BROADCASTING OF SENSITIVE DATA IN ERROR-PRONE WIRELESS NETWORKS

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Agenda

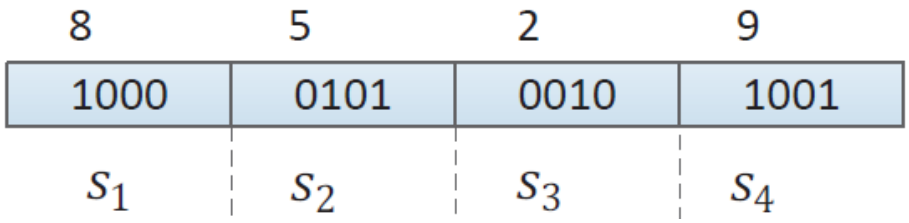
- Introduction
- Motivation
- Setting
  - Error model
- Priory-based data transmission
- Simulation results
- Conclusion

Introduction

- Broadcasting in wireless networks
  - Disseminating data and control messages
- Error-prone wireless links
  - Provide resilience
    - ARQ
    - Erasure codes
    - Hybrid-ARQ
    - Fountain codes (rateless codes)

Observations

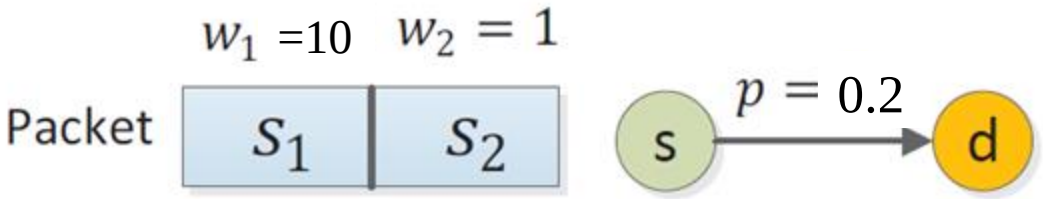
- Errors in packets
  - Not binary



- 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 for *resilient communication*
  - Reliable transmissions
  - Maximizing the expected gain with a fixed given number transmissions

Motivation

- s_i : symbol i
- x_i : number of transmission of symbol
- w_i : weight of symbol



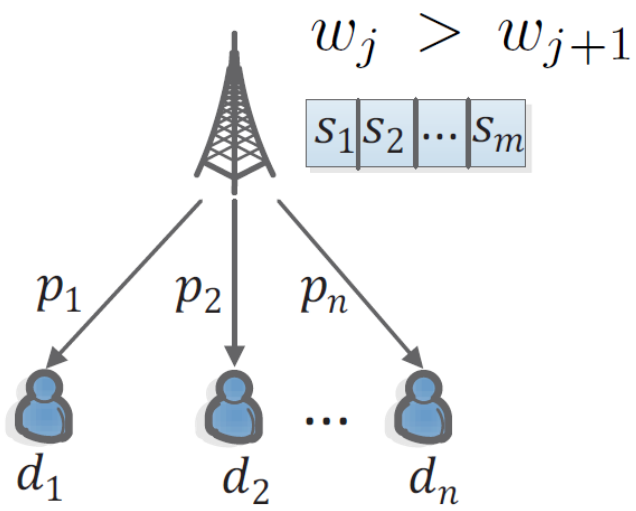
$$u = w_1 \times (1 - p^{x_1}) + w_2 \times (1 - p^{x_2})$$

x_1	4	3	2	1	0
x_2	0	1	2	3	4
u	9.984	10.72	10.56	8.992	0.9984

4 transmissions

Setting and Objective

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



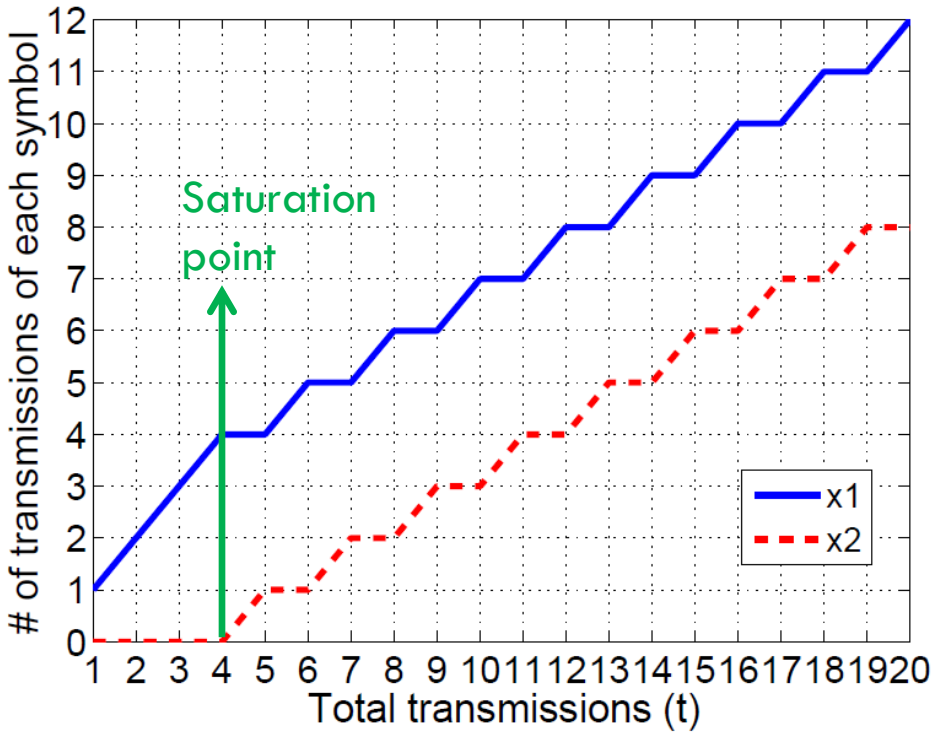
- Objective: maximizing the total weight of the received symbols

Single Packet (Homogeneous Destinations)

- The case of a packet size equal to 2 symbols

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

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



$$w_1 = 5$$

$$w_2 = 1$$

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

Single Packet (Heterogeneous 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

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

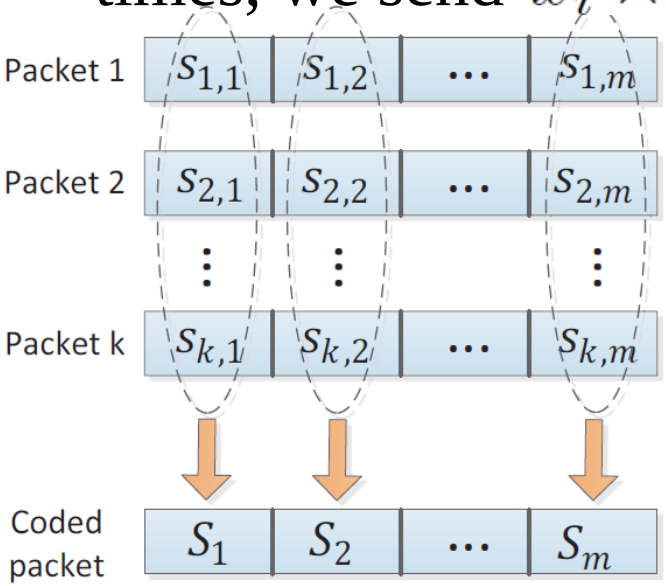
- At each iteration we assign the current transmission to the symbol with maximum Δ_{x_i}

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



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

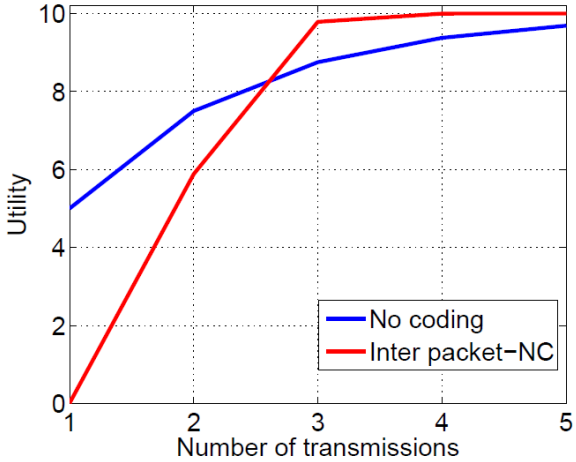
Multiple Packets- with Network Coding

- 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



Priority-based Transmission

- For each possible distribution:
  - Check the gain of the *i*-th symbols of the *k* packets in the case of coding and non-coding symbols
  - If coding does not increase the gain of the *i*-th symbols, do not perform coding
- Select the distribution with the maximum gain

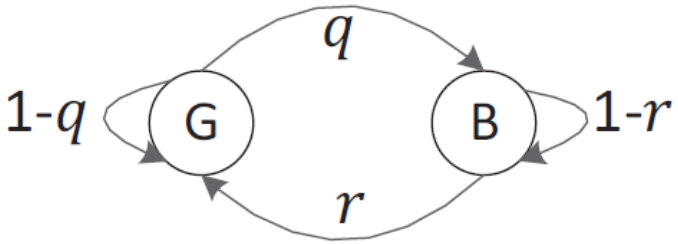
Bursty Errors

- Errors in wireless networks have burst pattern

- How to organize the symbols in the packets?
  - Serial
  - Round robin
  - Random

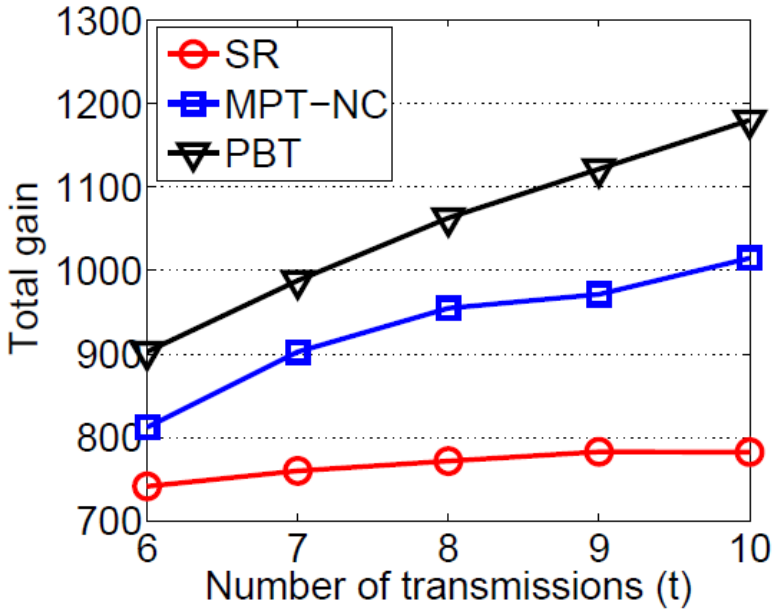
Simulations Setting

- 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
- Gilbert-Elliott model

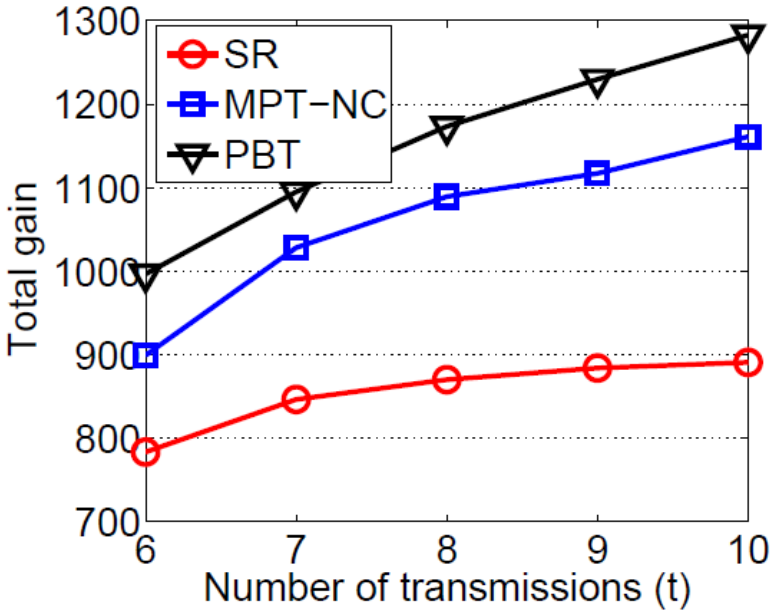


Simulations

- Packet size: 5 symbols
- 5 packets
- 10 destinations



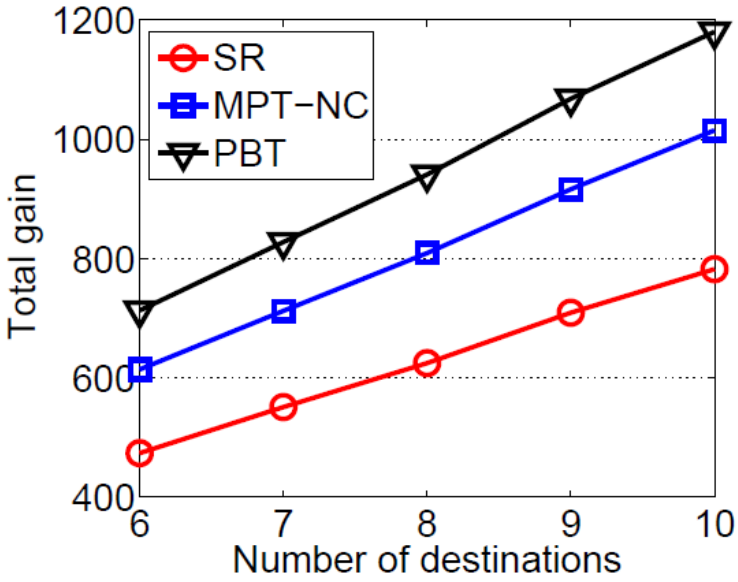
$r = 0.12,\ q \in [0.05, 0.12]$

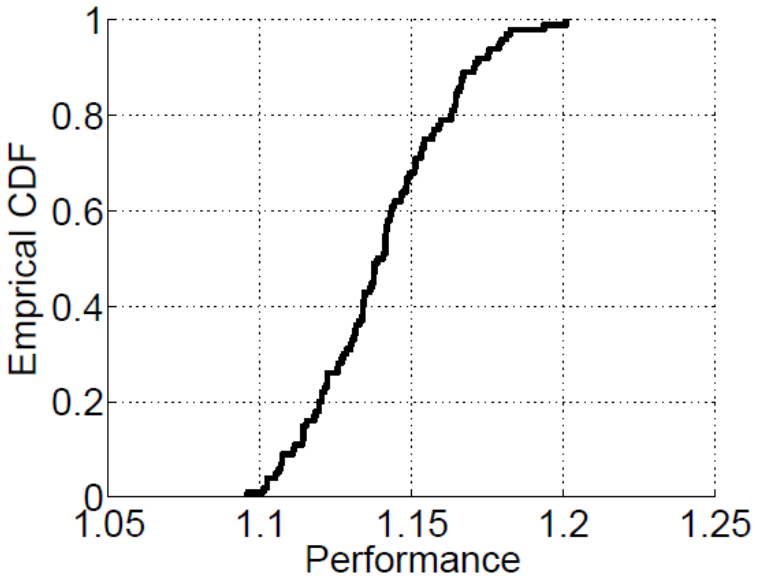


$r = 0.24,\ q \in [1, 0.24]$

Simulations

- Packet size: 5 symbols
- 5 packets
- 10 destinations



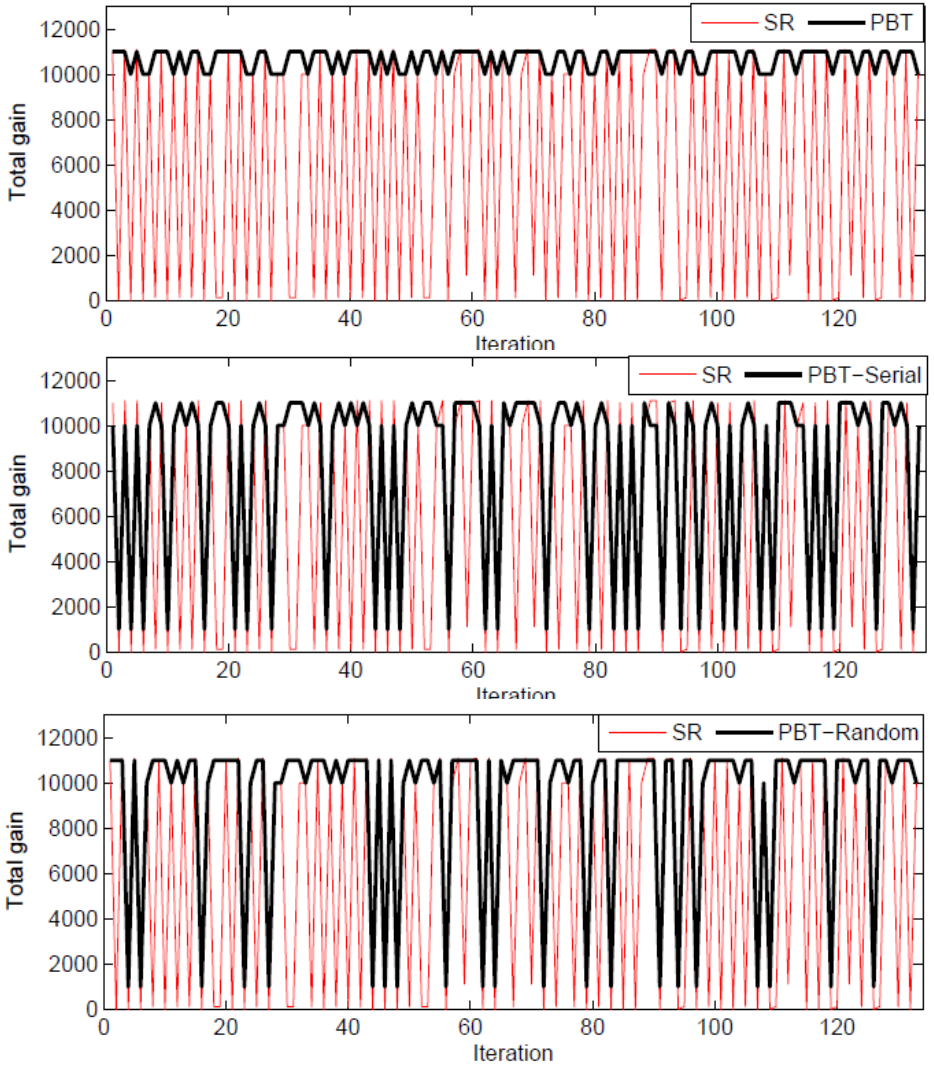


$r = 0.12,\ q \in [0.05, 0.12]$

10 destinations

Testbed- USRP devices

- 3 USRP devices
  - Sender
  - Receiver
  - Interference node
- Narrowband
- Central frequency: 1.26GHz
- Antenna gain: 20 db
- 5-digit BCD number



Conclusion

- There is much work on reliable transmissions over error-prone wireless channels
- We propose a transmission scheme which is based on the importance of the symbols (bits)
- Proposed methods
  - Network coding
  - Considering the bursty errors

Future Work

- Security
  - Encoding the whole data increase cost
    - Workload
    - Time complexity
- It is enough to encode the important parts of the data
  - Which symbols to encode?
    - Multi-layer vides: the base layer
- We can encode the coefficients of the network coded packets

Questions

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