PRIORITITY-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 importance 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


- $S_i$ : symbol $i$
- $x_i$ : number of transmission of symbol
- $w_i$ : weight of symbol

Motivation

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

<table>
<thead>
<tr>
<th>$x_1$</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>$x_2$</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>$u$</td>
<td>9.984</td>
<td>10.72</td>
<td>10.56</td>
<td>8.992</td>
<td>0.9984</td>
</tr>
</tbody>
</table>

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
The case of a packet size equal to 2 symbols

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

\[ s.t. \quad x_1 + x_2 = t \]

\[ w_1 = 5 \]
\[ w_2 = 1 \]

Saturation point \( p^{x_1} < \frac{w_2}{w_1} \)
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 $\Delta_{x_i}$
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
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

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

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

- 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

\[
\begin{align*}
G & \quad 1-q & & 1-q \\
q & & & 1-q \\
B & & & 1-q \\
1-r & & & 1-q \\
\end{align*}
\]
Simulations

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

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

\[ r = 0.24, \quad q \in [1, 0.24] \]
Simulations

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

$r = 0.12, \ q \in [0.05, 0.12]$
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 videos: the base layer
- We can encode the coefficients of the network coded packets
Questions

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