Experimental Study of the Interplay of Channel and Network Coding in Low Power Sensor Applications

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Sensor Networks and their Applications

- Sensors: collect information and reliably transmit it to a sink/processing hub
- They operate under strict energy constraints..
- ... and usually in harsh environments!!
Increasing Data Reliability

Methods to increase data reliability in sensor networks:

• Higher transmission power
• Use of PHY FEC schemes

• Use of packet-level erasure codes

Q: How do these methods perform/interact in low power and interference-heavy sensor networks?
Outline of the Talk

• Packet-level erasure coding schemes
• Implementation considerations
• Experimental setup
• Measurement results
• Joint channel-network coding scheme
• Summary
Packet-level Erasure Coding Schemes

• Several associated advantages:
  – Delay, outage probability, goodput, etc
• Usually implemented at higher layers of the stack
• Plethora of such schemes proposed in the literature
  – Reed-Solomon codes: not rateless
  – Fountain codes (*i.e.* Raptor): non-zero coding overhead ($\varepsilon$)
• Our design choice: random linear network coding
  – Rateless and zero coding overhead
  – Higher complexity in general for the decoding process
  – Re-encoding packets on the fly, w/o decoding first
RLNC and Implementation Considerations

- Delay and memory constraints dictate $K$ to be small ($K=4$)
- Coefficients are generated by LFSRs
- Galois field size $2^8$ is used
- Encoding is critical for low power sensors
- Re-encoding is performed by the same process
Experimental Setup I

- Custom 2.4GHz transmitter - commercial receiver
Experimental Setup 1

- Custom 2.4GHz transmitter - commercial receiver

![Diagram showing Custom Sensor Node, FPGA, Matlab, and CC2511 Commercial RX connected by RF signals and data flow.](image)
Experimental Setup I

- Custom 2.4GHz transmitter - commercial receiver

![Diagram of experimental setup]
Experimental Setup 1

- Custom 2.4GHz transmitter - commercial receiver
Coding Schemes Supported in the System

• PHY FEC code
  – Convolutional code at rates 3/4, 1/2 and 1/3
  – Interleaver and hard Viterbi decoding
• Packet-level erasure code
  – Rates 4/5, 4/6 and 4/8
• FSK modulation and coherent demodulation
• Transmission data rate 500Kbps
• Packet format

<table>
<thead>
<tr>
<th>Preamble</th>
<th>Sync word</th>
<th>Seq. num.</th>
<th>Coeffs</th>
<th>Payload</th>
<th>CRC</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 bytes</td>
<td>8 bytes</td>
<td>1 byte</td>
<td>4 bytes</td>
<td>Up to 64 bytes</td>
<td>2 bytes</td>
</tr>
</tbody>
</table>
Measurements – PHY FEC only

• Use of PHY FEC codes improves reliability
• 2.25dB coding gain at $10^{-2}$ PER
Measurements – RLNC only

- 3.4dB coding gain at $10^{-2}$ PER
- Much steeper slope compared to PHY FEC curves
Can we further improve performance?

- PHY FEC codes: can approach capacity of a fixed-SNR AWGN channel
- Packet-level erasure codes: optimal performance in an erasure channel
- Realistic wireless indoors channels lay between the two extreme models
- Low SNR $\rightarrow$ noise effects dominate $\rightarrow$ better corrected by PHY FEC codes

A combination of the two coding schemes would considerably improve performance
Joint Channel and Network Coding (JCNC)

• JCNC achieves greater coding gain for the same effective coding rate

• Its PER curve hits the saturating barrier at a lower SNR
Summary

• Low power sensors need to communicate information reliably and under strict energy limits
• A custom 2.4GHz ISM flexible transmitter is designed
• A testbed is built for performance evaluation of different coding schemes
• RLNC is studied as a packet-level erasure code
• Nature of indoors channel motivates a combination of the two coding methods
• JCNC scheme can efficiently increase performance of low power sensor networks
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• Questions?