X-MAC: A Short Preamble MAC Protocol for Duty-Cycled Wireless Sensor Networks

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Purpose

• To minimize the preamble in MAC protocols
  – Reduce latency at each hop
  – Optimize energy consumption
  – Minimize energy consumption at non-target receivers
MAC Protocols

• Synchronous
  – Keeps an awake and sleep schedule
  – Reduces idle listening
  – Overhead associated with schedule

• Asynchronous
  – Low power listening a.k.a preamble
  – Reduce idle listening for receiver
  – Sender has to send preamble with length ≥ receiver sleep period
Asynchronous Duty Cycling

[Diagram showing the process of sending and receiving data with a long preamble and extended wait time.]
Why is a long preamble bad?

- Overhearing problem
- Sender Receiver has to wait
- Increased latency
Overhearing

• Problem: Receiver does not know if it is the target until preamble is complete
• X-MAC Solution: Embed address of target into preamble
Receiver Waiting

• Problem: Receiver has to wait until the preamble is finished wasting time and energy
• X-MAC Solution: Target receiver interrupts the preamble a.k.a strobing.
Sender Waiting

• Problem: Sender sends preamble packet and other senders stay awake until the channel is clear

• X-MAC Solution: Strobing allows for the insertion of a pause between preambles letting the receiver send an early ACK
X-MAC Design

X-MAC Sender (S)

X-MAC Receiver (R)

Short preambles with target address information

Receive early ACK

Send DATA

ACK

Recv DATA

Time & energy saved at S & R

R wakes up

Send early ACK
Results

• X-MAC reduces energy consumption while sending and receiving
• X-MAC reduces per hop latency
• X-MAC adapts to bursty and periodic traffic
• Can be implemented in software so applicable to packetized and bit stream radios
Evaluation

- Compared with LPL MAC because closest approximation supported by packetizing radio
  - Does not inspect preamble for target name
  - Sender sends the entire extended preamble and the receiver does not send an ACK
  - It’s not adaptable
  - Receiver can adjust sleep but sender will not know to adjust preamble length
# X-MAC Performance

<table>
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<th></th>
<th>X-MAC</th>
<th>LPL</th>
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<tbody>
<tr>
<td>Duty Cycle-No Contention, Single Sender</td>
<td>Remains constant with increasing network density</td>
<td>Increases with network density</td>
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<tr>
<td>Energy Use</td>
<td>Remains constant with increasing network density</td>
<td>Increases with network density</td>
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<tr>
<td>Duty Cycle-Contention</td>
<td>Remains constant with increasing network density</td>
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<tr>
<td>Fairness</td>
<td>More Fair</td>
<td>Less Fair</td>
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<tr>
<td>TX Success Rate</td>
<td>About 90% success for varying transmitters and sleep time</td>
<td>About 50% successful for 9 transmitters and 500ms sleep time</td>
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<tr>
<td>Latency</td>
<td>Latency increases with number of hops but 50% shorter than LPL</td>
<td>Latency increases with number of hops but 50% longer than X-MAC</td>
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X-MAC with Adaptation

• X-MAC has the option to adapt sleep time based on traffic load
• Algorithm calculates best sleep time
• When X-MAC is optimized to be adaptive it performs better than LPL and static X-MAC