**Paper presentation – Ultra-Portable Devices**

**Paper:**

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

- Introduction
- X-MAC protocol design
- Adaptation to traffic load
- Experimental evaluation
- Summary

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**Introduction**

- Major sources of energy waste
  - Idle listening
  - Overhearing
  - Control overhead
  - Collision

\[ \Rightarrow \text{duty cycle: Low power Listening (LPL)} \]

Disadvantages of LPL:
- Long preamble
- Overhearing
- Latency

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**X-MAC Protocol Design**

- Embedding target ID in preamble to avoid overhearing
X-MAC Protocol Design (Cont.)

- Reducing long preamble using strobing

![Diagram of X-MAC Protocol Design](image1)

Adaptation to Traffic Load Energy Model

- Assumption
  - Packet probability, $P_d(t)$, is known

$$E_t = (\text{preamble energy} + \text{energy per ACK listen})$$
  $$= (\text{expected preamble-listen iterations required})$$
  $$+ (\text{energy to send packet})$$

$$Lat = (\text{duration of preamble} + \text{ACK listen})$$
  $$= (\text{expected number of iterations required})$$
  $$+ (\text{duration to send packet})$$

Theorem 1: energy and latency minimized when preamble time and ACK listen time set to the lowest value.

Adaptation to Traffic Load Optimality

$$E_s = (\text{preamble energy} + \text{energy per ACK listen})$$
  $$= (\text{expected preamble-listen iterations required})$$
  $$+ (\text{energy to send packet})$$

$$Lat = (\text{duration of preamble} + \text{ACK listen})$$
  $$= (\text{expected number of iterations required})$$
  $$+ (\text{duration to send packet})$$

Theorem 1: energy and latency minimized when preamble time and ACK listen time set to the lowest value.
Adaptation to Traffic Load Optimality (Cont.)

Theorem 2:
Optimal Rx-sleep and Rx-listen for min Rx-sleep,Rx-listen\(f(\cdot)\) depends only on \(P_d(t)\).
\((f(\cdot): E_s, E_r, \text{Lat or combination of them})\)

Theorem 3:
min Rx-sleep,Rx-listen\(f(\cdot)\) can be found by convex optimization tech.

Adaptation to Traffic Load Optimality (Cont.)

• Motivation for approximation
  – Nonlinear minimization is a too demanding process.
  – Mapping is smooth enough to admit a lightweight approximation.

• Approximation
  – Linear interpolation

Model Validation

Energy-efficiency comparison of optimal and interpolated values

Mean difference: 0.45% 95th percentil difference: 1.3%
Evaluation and Experimental Setup

- X-MAC is implemented on top of Mantis OS.
- TelosB with chipcon CC2420 is deployed.
- CC2420 properties
  - 250 kbps
  - 2.4 GHz ISM band
  - Uses 8 MHz TI MSP430 processor with 1 MB external flash
- Processor energy consumption is ignored.
- Star topology, one RX and up to nine TX.

X-MAC Performance

- Duty cycle under no contention
  - Each node sends a pkt. every 9 sec.
  - Sleep period 500 ms
  - Preamble 500 ms

X-MAC Performance (Cont.)

- Energy usage
  - Oscilloscope is attached to one of transmitting node

X-MAC Performance (Cont.)

- Duty cycle under contention
  - One packet per second
  - One packet per ten second
X-MAC Performance (Cont.)

• Fairness
  – Variance between generated pkts and successfully sent pkts

X-MAC Performance (Cont.)

• Transmission success rate
  – No. of successfully received pkts

X-MAC Performance (Cont.)

• Latency

X-MAC Performance (Cont.)

• X-MAC with adaptation
  – Sleep time is adjusted between 220 to 2300 ms
  – Each experiment runs for 10 min

1 packet per ten second
0.1 packet per ten second
Summary

- X-MAC is an approach to avoid overhearing and reduce energy consumption and latency.
- Short preamble and early ACK saves energy and lower the latency.
- Strobed preambles contain target address to avoid overhearing.
- An adaptive algorithm is proposed to select optimal sleep and listen time.