Low Power Medium Access Control Protocols for Wireless Sensor Networks

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Outline

Introduction
Analytical power consumption

Radio model
- Steady states
  - Sleep
  - Transmission
  - Reception
- Transient states
  - Setup Rx
  - Setup Tx
  - Switch RxTx
  - Switch TxRx

Analytical power consumption(I)

Introduction

MAC protocols must meet
- Low power requirements
- Be robust to node failures
- Deal with low data rate traffic
- Accomodate to sporadic bursts

MAC protocols influenced by radio => analytical model
- Bit rate
- Power consumption
  - Steady state
  - Transition state
- Byte-level or packet level

MAC protocol Implementation
Analytical power consumption(II)

**Traffic scenario**
- Network of $N$ devices, fully connected
- Traffic generation according to exponential distribution ($\lambda = 1/L$)
- $L$ is mean interval between two packets
- Packets of duration $T_M$

**Mathematical modeling of power consumption**
- Ideal protocol
- SCP-MAC
- CrankShaft
- WiseMAC and optimal LPL

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### Protocols Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_M$</td>
<td>500 ms</td>
</tr>
<tr>
<td>$T_M$ (bytes)</td>
<td>6.9 ms</td>
</tr>
<tr>
<td>$T_{ack}$</td>
<td>1.02 ms</td>
</tr>
<tr>
<td>$T_{poll}$ (bytes)</td>
<td>0.0615 ms</td>
</tr>
</tbody>
</table>

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Analytical power consumption(III)

**Ideal protocol**
- Channel info acquired instantaneously
- Receiver and transmitter meet without wasting energy

\[
F_{Ideal}^A = \frac{1}{T} [T_M (P_{tr} + P_{tx}) + E_{SetupTx} + E_{SetupRx} + (L - 2T_M - T_{SetupRx} - T_{SetupTx}) P_L]
\]

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Analytical power consumption(IV)

**SCP-MAC**
- Optimal polling time ($T_{poll} = L/N$)
- Neglecting cost of synchronization and failed channel access

\[
F_{SCP}^A = \frac{1}{T_{poll}} [F_{Poll} + F_{Rec} + F_{Trans} + F_{Sync}]
\]

\[
F_{Poll} = \frac{1}{T_{poll}} [E_{setup} + E_{tx} + E_{rec} + E_{sync}]
\]

\[
F_{Rec} = \frac{1}{T_{poll}} [E_{tx} + E_{rec} + E_{sync}]
\]

\[
F_{Trans} = \frac{1}{T_{poll}} [E_{tx} + E_{rec} + E_{sync}]
\]

\[
F_{Sync} = \frac{1}{T_{poll}} [E_{setup} + E_{tx} + E_{sync}]
\]

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Analytical power consumption(V)

**CrankShaft**
- Neglecting cost of broadcast traffic

\[
F_{CrankShaft} = \frac{1}{T_{poll}} [E_{tx} + E_{rec} + E_{sync} + E_{setup} + E_{tx} + E_{rec} + E_{sync}]
\]

\[
E_{tx} = T_{M} P_{tx} + E_{SetupTx} + E_{SetupRx} + E_{tx} + E_{rec} + E_{sync} + E_{setup}
\]

\[
E_{rec} = T_{M} P_{rx} + E_{SetupRx} + E_{SetupTx} + E_{tx} + E_{rec} + E_{sync} + E_{setup}
\]

\[
E_{sync} = T_{M} P_{rx} + E_{SetupRx} + E_{SetupTx} + E_{tx} + E_{rec} + E_{sync} + E_{setup}
\]

\[
E_{setup} = T_{M} P_{setup} + E_{SetupRx} + E_{SetupTx} + E_{tx} + E_{rec} + E_{sync} + E_{setup}
\]
Analytical power consumption (V)

WiseMAC and optimal preamble sampling
- WiseMAC, SyncWUF, CSMA-MPS, X-MAC
- Zero-length wake-up preamble

$$P_{MAC} = P_{CCA} + P_{Frame} + P_{Transmit} + P_{Receive}$$

$$P_{CCA} = T_{CCA} P_{MAC} + E_{Frame}$$

$$P_{Transmit} = T_{Transmit} P_{Transmit} + E_{Frame}$$

$$P_{Receive} = T_{Receive} P_{Receive} + E_{Receive}$$

Results

- Matlab implementation
- Two scenarios
  - Traffic adaptation
  - To evaluate influence of data rate on power consumption
  - Network density

Summary

- A mathematical modeling of power consumption of MAC protocols has been proposed.
- Preamble sampling is best choice for low power MAC protocols.
- Performance comparison with ideal protocol shows there is a little room for future improvement.
- Future development on better scalability with high data rate or better latency.