The WiseNET™ Project


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Introduction

Wireless Sensor Network – WiseNET™

- WiseNET™ is a wireless network of distributed sensors that combine sensing, local signal processing and short-range wireless communication capabilities, in a compact, low-power system.

Main Challenges

- Energy dissipation
  - Reduce radiated power
  - More power efficient radio
  - Energy efficient protocols and routing algorithms
  - Better trade-off between communication and local computing
- Size
  - Higher integration (System-on-Chip or SoC)
- Cost
  - Standard Digital CMOS Technology
The Energy Dissipation Challenge

Energy Constraint – Single AA Alkaline Battery

- Model of a single alkaline battery with 2.6 Ah and 27 µW power leakage
- 2 to 7 years autonomy \(\Rightarrow\) Average power budget of 10 – 100 µW
- Radios still in the 1 to 10 mW range \(\Rightarrow\) Average duty cycle 0.1 – 1%

The WiseNET Approach

- Reduction of power consumption \(\Rightarrow\) optimization across all the layers
- PHY and MAC layers play a fundamental role particularly for low duty cycled radios with small traffic
- WiseNET project focuses on PHY and MAC layer
- Analysis of the WiseMAC protocol to identify the most critical radio parameters
  - Power in receive mode
  - Wake-up and turn around (Rx-to-Tx and Tx-to-Rx) times
  - Power in transmit mode
- Design of a dedicated radio optimized for WiseMAC
Energy efficient protocols

Sources of MAC Layer Energy Waste

1. **Idle listening**
   - Channel expected to be idle during long periods in WSN

2. **Overhearing**
   - Can become important in case of dense ad-hoc networks
   - Limits scalability in infrastructure sensor networks

3. **Collisions**
   - To be avoided as retransmissions cost energy

4. **Protocol Overhead**
   - Required frame header and signaling to implement the MAC

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Energy efficient protocols

WiseMAC – An Ultra-Low Power MAC for WiseNET

CSMA with preamble sampling

Synch. CSMA with preamble sampling

Sampling schedule information

Courtesy: A. El-Hoiydi, CSEM
Energy efficient protocols

Wake-up Preamble Length Reduction

1st transmission: no sampling schedule info, using long preamble

2nd transmission: sampling schedule info gained through previous communication, using short preamble = less overhearers!

Sequence takes 1 second in real time (40 times faster)

Energy efficient protocols

Performances

- Lattice Network
  - Traffic inserted in the left-side nodes
  - Forwarded towards the right
  - Statistics collected on central node
  - Models an infinitely large sensor network

- WiseMAC is adaptive to the traffic:
  - Ultra-low power consumption in low traffic conditions and high energy efficiency in high traffic condition
The Energy Dissipation Challenge

Reduce the Radio Power Consumption

- The radio remains the **bottle-neck** for the realization of WSN
- Technology downscaling can be exploited to realize **low-power transceivers** by trading high speed capabilities of ultra deep-submicron (UDSM) CMOS technology with power consumption
- Take advantage of **low-voltage** operation (typically < 1V) and high integration capabilities (SoC)
- Explore innovative solutions at circuit, architecture and system levels compatible with integration in UDSM **standard digital CMOS** technologies
- New **high-Q component** can help reduce the power consumption further
  - RF Micro Electro-Mechanical Systems (**RF-MEMS**) and Bulk Acoustic Wave (**BAW**) resonators are two examples
  - They open the door to new RF multi-standard front-ends

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**Low-Power RF CMOS Transceiver – Receiver**

<table>
<thead>
<tr>
<th>Technology</th>
<th>0.18 µm <strong>standard</strong> digital CMOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dual band operation</td>
<td>434 MHz (ISM) / 868 MHz (SRD)</td>
</tr>
<tr>
<td>Channel spacing</td>
<td>400 kHz (primary) / 200 kHz (secondary)</td>
</tr>
<tr>
<td>Propagation range</td>
<td>2 km outdoor (~ 20 m indoor)</td>
</tr>
<tr>
<td>Data rate</td>
<td>12.5 / 25 / 50 kb/s</td>
</tr>
<tr>
<td>Modulation</td>
<td>FSK (Δf=12.5 / 25 / 50 kHz) / OOK (2kb/s)</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>-105 dBm (@ 25 kb/s, BER=10^-3)</td>
</tr>
<tr>
<td>NF (incl.SAW)</td>
<td>13 dB (AGC max gain)</td>
</tr>
<tr>
<td>DR</td>
<td>82 dB (@ BER=10^-3)</td>
</tr>
<tr>
<td>Wake-up time</td>
<td>&lt; 0.8 ms</td>
</tr>
<tr>
<td>Supply voltage</td>
<td>0.9 V - 1.5 V</td>
</tr>
<tr>
<td>Supply current</td>
<td>&lt; 1.8 mA (1 mA for VCO+PLL) / 16.2 µA for 0.1% duty cycle</td>
</tr>
<tr>
<td>External components</td>
<td>12.8 MHz quartz reference / SMD inductors for VCO / On-chip varactor</td>
</tr>
</tbody>
</table>

Reduce the Radio Power Consumption

**Low-Power RF CMOS Transceiver – Transmitter**

<table>
<thead>
<tr>
<th>Technology</th>
<th>0.18 µm standard digital CMOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. output power</td>
<td>10 dBm</td>
</tr>
<tr>
<td>Efficiency</td>
<td>40% @ 10dBm</td>
</tr>
<tr>
<td>Dual band operation</td>
<td>434 MHz (ISM) 868 MHz (SRD)</td>
</tr>
<tr>
<td>Channel spacing</td>
<td>600 kHz (primary) 200 kHz (secondary)</td>
</tr>
<tr>
<td>Propagation range</td>
<td>2 km outdoor (~ 20 m indoor)</td>
</tr>
<tr>
<td>FSK Data rate</td>
<td>12.5 / 25 / 50 kb/s (∆f=12.5 / 25 / 50 kHz)</td>
</tr>
<tr>
<td>OOK Data rate</td>
<td>2kb/s (Manchester) 40 dB on/off power ratio</td>
</tr>
<tr>
<td>Spurious</td>
<td>-36 dBm @ ± 100 kHz, BW=1 kHz</td>
</tr>
<tr>
<td>Supply voltage</td>
<td>0.9 V - 1.5 V</td>
</tr>
<tr>
<td>Supply current</td>
<td>35 mA (VCO + PLL + Tx) 5 mA (VCO + PLL)</td>
</tr>
<tr>
<td>External components</td>
<td>12.8 MHz quartz reference SMD inductors for VCO</td>
</tr>
<tr>
<td></td>
<td>On-chip varactor</td>
</tr>
</tbody>
</table>

Higher Integration

**The WiseNET™ SoC Architecture**

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The WiseNET™ Chip – A True SoC

- TSMC 0.18µm
- 3.6 x 3.3 mm²
- 1.7M transistors
- 1906 resistors
- 341 capacitors
- 8 inductors

Conclusion

- Optimization of the PHY and MAC layers by co-design approach
- New MAC layer (WiseMAC) based on CSMA minimized preamble sampling and optimized for low duty cycled radio
- WiseMAC is adaptive to the traffic: ultra-low power consumption in low traffic conditions and high energy efficiency in high traffic condition
- WiseNET radio optimized for WiseMAC by minimizing the critical radio parameters such as power in Rx mode, wake-up and turnaround times and power in Tx mode
- Complete SoC including optimized radio, μC, embedded memory, sensor interface and power management unit
- WiseNET™ can offer a complete highly integrated and ultra-low power solution for the PHY and the MAC layers of WSN
Thank you for your attention.