WiseNET

(Or, how to make a sensor net node that lasts as long as your battery’s shelf life)

Motivation

• Goal: sensor network hardware that can run for 2-5 years off a single 1.5V AA alkaline battery.
• This means average power less than 10-100 µW.
• Typical commercial radio transceivers require > 10mW

Outline

• WiseMAC Protocol
  – Optimized for low duty cycle operation
• Optimized Radio Transceiver
  – Low power
• System On Chip design

Communication Power Consumption

• How to communicate when nodes sleep most of the time?
• Design MAC to reduce wasted power due to:
  – Idle listening
  – Overemitting
  – Overhearing
  – Collisions

Preamble Sampling

• Carrier Sense, Multiple Access
• Preamble Sampling
  – I.e. don’t listen all the time, just sample and wait for a preamble
  – Sampling = measure received signal strength
• (This isn’t the new part…)

Fixed-Length Preamble

• All nodes sample medium with same period, independent offsets
  – If busy, listen until receive packet or not busy.
• Transmitter sends preamble longer than sampling period before each packet.
• + Low power for low traffic
• - Power overhead for long preamble
  – xmit, plus rcv for all nodes that hear preamble

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WiseMAC: Minimized Preamble

- Nodes also send time to next sample in acknowledge packets.
- Nodes maintain table of offsets for common destination nodes.
- Duration of wake-up preamble adjusted to cover maximum drift between clocks.

WiseNET Wakeup Preamble Size

- \( T_p = \min(4 \theta T_c, T_w) \)
- \( T_p \) = duration of the preamble
- \( \theta \) = frequency tolerance of time-based quartz
- \( T_c \) = interval between communications
- \( T_w \) = sampling period
- Covers potential drift between clocks

Power Comparison

- CSMA limited at low traffic
  - Receiver never turned off
- T-MAC
  - Choose duty cycle
  - Drops packets at low duty cycles, so get either low power in low traffic or high throughput
- WiseNET is ultralow-power for low traffic, efficient for high traffic

Radio Design

- Transceiver is biggest power drain in the sensor node.
- WiseMAC is designed for low duty cycle operation. Optimize the transceiver, too.
Radio Design Choices

• Chose high constant transmit power (max allowed in Europe for 434MHz ISM)
  – Nodes usually listen a lot, transmit rarely
• Dual-band, multi-channel to reject strong interference
• Reduce energy consumption and wakeup time in receive mode.

Dual-Band, Multi-Channel

• 433MHz ISS, 868 MHz SRD
• Avoid interference from other sources.
• Why not 2.4GHz? (popular, globally available) Power.
  – 50% of receiver power due to circuits operating at the carrier frequency, and power is proportional to the frequency.

Receiver Power

• Receiver power much larger for RF blocks
  – Current directly related to frequency of operation or required bandwidth.
  – These are also the blocks that wake up quickly.
• Turn-on time varies inversely with frequency.
• So save power by waking up baseband components first, then RF circuits.

WiseNET Optimizations

• Flexible wake-up sequence
  – Low frequency reference clock
  – Baseband path of channel filters, limiters, & RSSI.
  – Frequency synthesizer
  – Intermediate frequency amplifiers
  – RF frequency low-noise amplifier & mixers

WiseNET Optimizations

• Use RSSI to determine whether to power up rest of the broadband receive chain
  – I.e. if there’s no signal, don’t process it
• Minimize wakeup time for baseband and intermediate frequencies.
  – Deep submicron process, trade speed for power.
  – Circuit tricks to wake up the baseband fast.

Fast Rx/Tx Turnaround

• You’re burning power when switching from Rx to Tx or vice versa, so do it fast.
• WiseNET shares the core (intermediate frequency) circuitry for the receivers and transceivers, so there’s very little turnaround time.
WiseNET—SOC

- Custom System-On-Chip (SOC)
- Most sensor node functionality on a single chip to reduce power consumption.
  - Sensing, processing, storing, communicating

WiseNET Node Architecture

Bottom Line

- WiseNET transceiver with WiseMAC protocol consumes 25uW when forwarding 56-byte packets every 100 seconds.
- For comparison, Motes…
  - 24mW in receive mode
  - SMAC or TMAC, 10% duty cycle => 2.4mW

To Sum Up…

- SystemOnChip design
- WiseMAC protocol
  - Minimal preamble size reduces xmit and receive overhead.
  - Preamble filtering reduces overhearing.
- Cool radio transceiver
  - Low power.
  - Efficient wakeup.
  - Quick turnaround between Rx and Tx.