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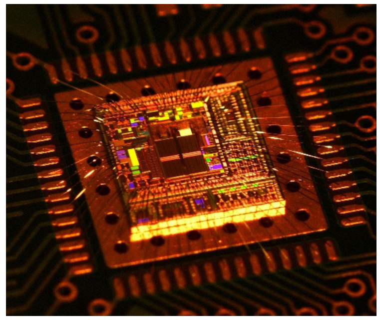

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The WiseNET™ Project

An Ultra-low Power Solution for Wireless Sensor Network

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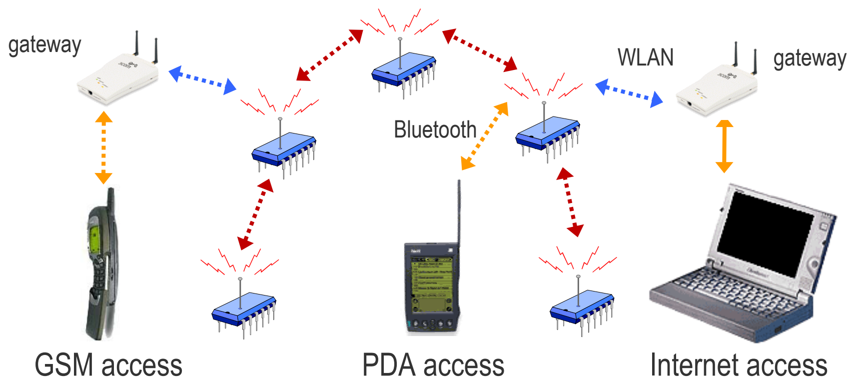
Introduction

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**



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Introduction

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

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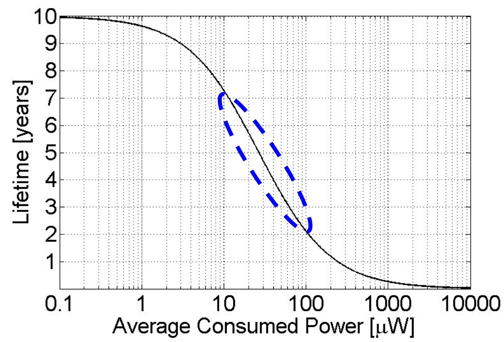
The Energy Dissipation Challenge

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 → **Average power budget of 10 – 100 μW**
- Radios still in the 1 to 10 mW range → **Average duty cycle 0.1 – 1 %**



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The Energy Dissipation Challenge

The WiseNET Approach

- Reduction of power consumption → 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

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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

Courtesy: A. El-Hoiydi, CSEM

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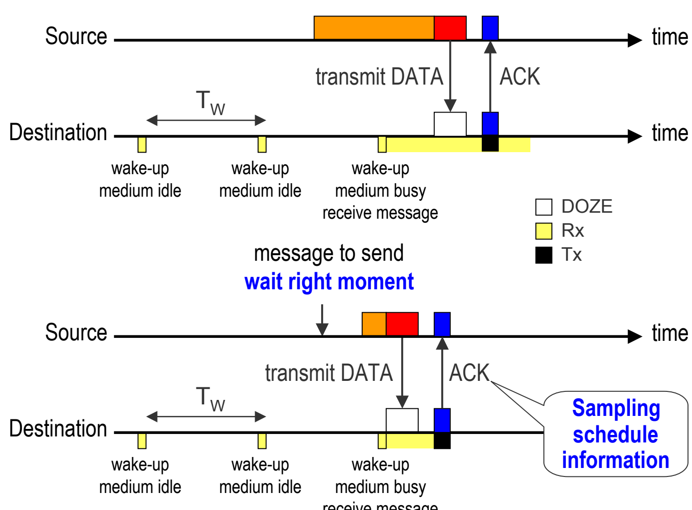
Energy efficient protocols

WiseMAC – An Ultra-Low Power MAC for WiseNET

CSMA with preample sampling

Synch. CSMA with preample sampling



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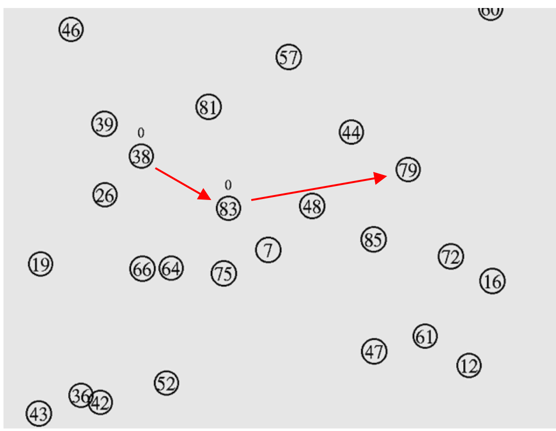
Energy efficient protocols

Wake-up Preamble Length Reduction



Node
Black: Sleeping
Green flash: Sampling
Yellow: Listening
Purple: Waiting for the right tx time
Circled: Backoff

Message
Brown: Preamble
Red: Data
Dark Blue: Ack

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

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

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

Courtesy: A. El-Hoiydi, CSEM

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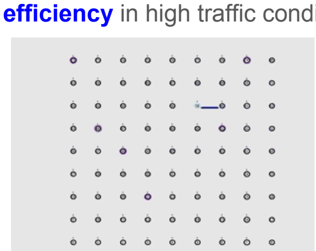
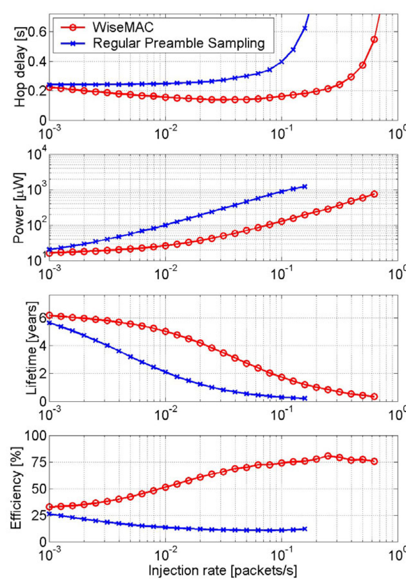
Energy efficient protocols

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





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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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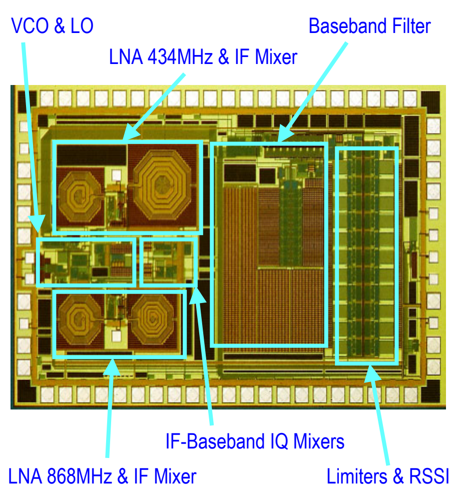
Reduce the Radio Power Consumption

Low-Power RF CMOS Transceiver – Receiver



Technology	0.18 µm **standard** digital CMOS
Dual band operation	434 MHz (ISM) 868 MHz (SRD)
Channel spacing	600 kHz (primary) 200 kHz (secondary)
Propagation range	2 km outdoor (~ 20 m indoor)
Data rate	12.5 / 25 / 50 kb/s
Modulation	FSK (Δf=12.5 / 25 / 50 kHz) OOK (2kb/s)
Sensitivity	**-105 dBm** (@ 25 kb/s, BER=10^{-3})
NF (incl.SAW)	13 dB (AGC max gain)
DR	82 dB (@ BER=10^{-3})
Wake-up time	< 0.8 ms
Supply voltage	**0.9 V** - 1.5 V
Supply current	**< 1.8 mA** (1 mA for VCO+PLL) **16.2 µA for 0.1% duty cycle**
External components	12.8 MHz quartz reference SMD inductors for VCO
	On-chip varactor

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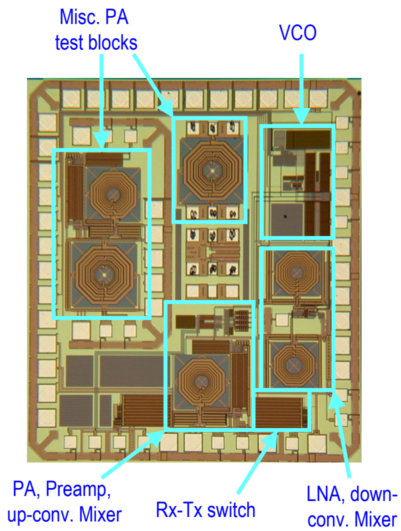
Reduce the Radio Power Consumption

Low-Power RF CMOS Transceiver – Transmitter



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

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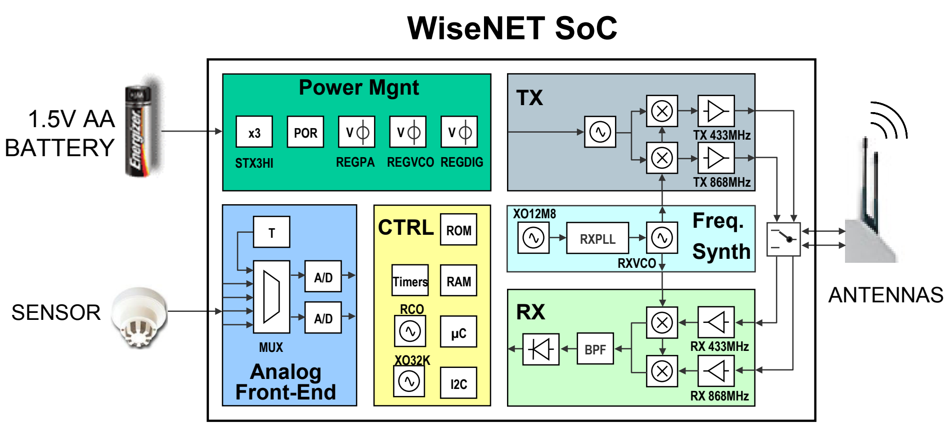
Higher Integration

The WiseNET™ SoC Architecture



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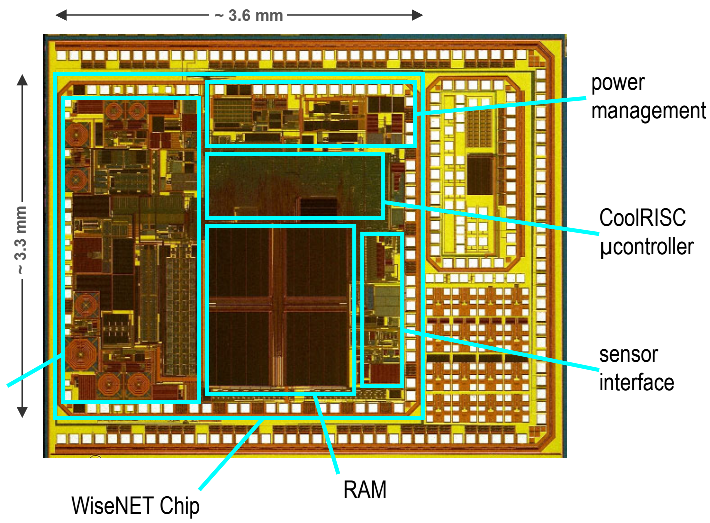
The WiseNET™ Chip – A True SoC

TSMC 0.18µm
3.6 x 3.3 mm^2
1.7M transistors
1906 resistors
341 capacitors
8 inductors



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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 managment unit
- WiseNET™ can offer a complete highly integrated and ultra-low power solution for the PHY and the MAC layers of WSN

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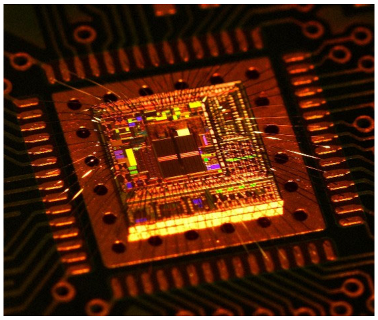
Thank you for your attention.



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