Embedded Systems: An Application-Centered Approach

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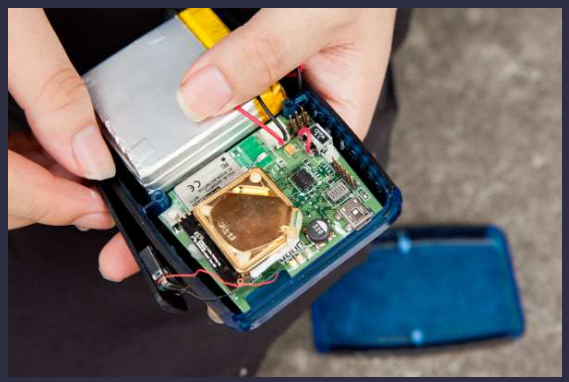
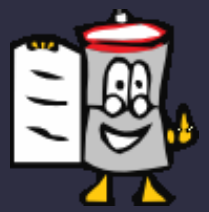




Outline

Definitions

Wireless Sensor Network

Distributed wireless network of sensing and computation nodes.

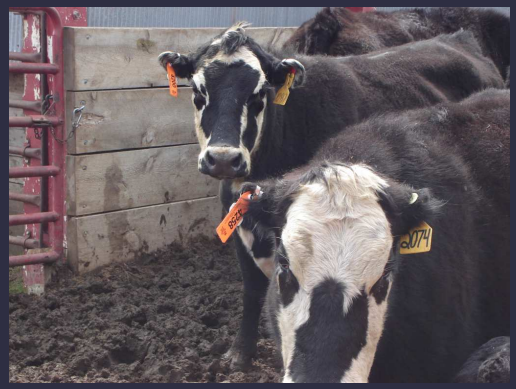
Radio Frequency Identification (RFID)

Generally-passive device from which data may be read via radio frequency communication.

Wireless sensor network and RFID examples

Medical devices

Structural integrity monitor



Cattle (credit North Dakota State University)

Saltwater intrusion detector (Stephen Brosnan, CSIRO ICT Center)

Sensor network goals and conditions

- Distributed information gathering
- Frequently no infrastructure
- Battery-powered, wireless common
- Battery lifespan of central concern
- Scavenging also possible
- Communication and data aggregation important

What they sense

- Temperature
- Pressure
- Light
- Acceleration
- Sound
- Humidity
- Images
- Etc.

Wireless sensor network status

Lots of hype

One of the top 21 technologies for 21st century (Business Week)

Numerous companies

E.g. Crossbow, Dust networks, Ember, Sensoria Intel, IBM, TI, Oracle, HP

Active research

SenSys, IPSN, ES Week, journals

Wireless sensor network challenges

- Wireless: Effects of the communication medium important
- Price constrained: Must deploy many nodes
- Reliability: Cheap components, harsh environments
- Low power: Battery life, scavenging
- Self organization: Unattended and fault-tolerant operation
- Data management, compression, aggregation, and analysis
- Wireless network management

Sensor network hardware power consumption

Power consumption central concern in design

Processor?

RISC μ-controllers common

Wireless protocol?

Low data-rate, simple: Proprietary, Zigbee

OS design?

Static, eliminate context switches, compile-time analysis

Sensor network software power consumption

Power consumption central concern in design

Runtime environment?

Avoid unnecessary dynamism

Language?

- Some propose compile-time analysis of everything practical
- Others offer low-overhead run-time solutions

Prototype networks

Biology: monitor seabirds

- Senses: temperature, humidity, infrared
- Developers: Intel, Berkeley
- Size: 150 nodes

Monitor activity of elderly

- Senses: motion, pressure, infrared
- Developer: Intel
- Size: 130 nodes

Prototype networks

Detect source of gunshot

- Senses: sound, shock wave, location
- Developer: DARPA, Vanderbilt
- Size: 45 nodes

Structural integrity monitoring

- Senses: vibration, precise displacement
- Developer: Northwestern University
- Size: Deployed in six buildings, constantly growing
  - Approximately 30 nodes

Habitat monitoring

Joseph Polastre, Robert Szewczyk, Alan Mainwaring, David Culler, and John Anderson. Analysis of wireless sensor networks for habitat monitoring.
In Krishna M.S̃ivalingam C. S.R̃aghavendra and Taieb Znati, editors, *Wireless Sensor Networks*, chapter 18, pages 399–423. Springer US, 2004

- Application: Monitor petrels on Great Duck Island
- Mica motes used
- High failure rate
- 50% packet loss, with spatial and temporal variation

Virtual machines for sensor networks

P. Levis and D. Culler. Mate: A tiny virtual machine for sensor networks.
In *Proceedings of Internation Conference on Architectural Support for Programming Languages and Operating Systems*, October 2002

- How to support rapid in-network programming?
- Virtual machine
- Great idea if reprogramming frequent compared to normal duty cycle
- Generally not the case

Wireless demand paging

Yuvraj Agarwal, Curt Schurgers, and Rajesh Gupta. Dynamic power management using on demand paging for networked embedded systems.
In *Proc. Asia & South Pacific Design Automation Conf.*, pages 755–759, January 2005

- Use two wireless interfaces
- One fast but high-power, one slow but low-power
- Awaken node using low-power interface
- Report 20–50% power savings
- Cannot beat 50% because processor consumes half of power
- Are there better alternatives?

Routing and media access

Too many routing and media access articles to count. Key problems:

- Reliability on unreliable components with varying network structure
- Tight power constraints
- Limited communication rates
- Self-organization

Other active areas

- Blind calibration
- Localization
- Operating system design: TinyOS, MANTIS OS, etc.
- Simulation environments
- Efficient implementation of media encoding algorithms
- Security: encryption power implications
- Applications: structure monitoring, security, biology, geology
- Small-scale robotics
- Biomotion capture

Outline

Homework

- 20 February: Prepare report for project checkpoint 1 following template on website.
- 23 February: Teams 1-3 give 15-minute presentation on project status.
- 25 February: Teams 4-5 give 15-minute presentation on project status.
- Starting 25 February, we will have assigned reading of papers on embedded systems research and practice.