Wireless Sensor Networks

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Course: http://www.cs.tufts.edu/comp/150CB
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Wireless Sensor Networks -- Welcome!!!

Everywhere!
- Deeply embedded, network enabled sensors (temperature, pressure, light, motion, vibration).
- The Economist article, May 2007

Diverse Applications!
- monitoring earthquake-prone regions, volcanoes, patient health, compost piles, vineyards, vehicle movement, traffic, pollution plumes, war zones ..
Applications: Vehicle Monitoring

- Sensors take magnetometer readings, localize object
- Communicate using geographic routing to base station
- Robust against node and radio link failure
Course Covers

- Wireless communication
- Focuses on Wireless Sensor Networks
  - Small, low power, wireless devices with sensors
  - Hands-on, develop a sensor net application
  - Research the state of the art
Course Outline – 3 parts

• Survey of Wireless Communication
  – radio communication, antennas, propagation
  – coding scheme, broadband, MAC
  – protocols: 802.11, Bluetooth, 802.15.4

• Research in Adhoc networks and TCP in mobile environments

• Wireless Sensor Networks
  – Applications
  – Support: operating system, security, power management, routing, localization, time synch
Class Goals

• Learn about wireless networks and sensor networks
• Read research papers
• Experiment with a real sensor network
• Do a project or write a paper (possibly survey) on an aspect of interest to you, perhaps publish.
Programming Project

• Goal learning the ropes of programming wireless sensor motes
  – Familiarize yourself with the mote kit
  – Learn to use the TinyOS operating system
  – Work in alone or in pairs
  – Code a simple multihop wireless protocol
  – Equipment from Prof. Hwa Chung, Tufts University.
  – Give yourself more ramp up time if you need to get comfortable with C programming.
Project Proposal

- Anything of interest to you related to the course
- Proposal 1-2 paragraphs due class-5 indicating what will be investigated and how to propose to go about it.
- Class 8 an update on project status
- Class 11 presentation, 20 mins + 5 mins for questions
- Paper summarizing your findings, 8-12 pages long.
Project Ideas

• Study Effects of packet loss on adhoc routing protocols
• Develop an improvement to an existing routing algorithm and test
• Develop a new energy management scheme for sensor networks
• Build a medical paging system
• Develop a security protocol for sharing information among “collaborating” nodes
Look – NO Wires!

- LAN telephone lines – expensive infrastructure, construction. Mobile telephones revolutionized telecommunications.
- Cheap wireless sensing and computing devices are like Mobile phones to LAN lines! Revolutionizing sensing and reacting. Possible to scatter sensors in dangerous and/difficult to reach terrains.
Deeply embedded-networks – why is it exciting?

• The ability to sense the environment and communicate – temperature, pressure, vibrations, acoustic, light, humidity.
• Takes computing out of the lab into the real world. Ability to respond and adapt in a timely manner by analysing the sensed information. Increase safety.
Challenges

- Battery life, solar?
- Communication bandwidth (radio transmission is energy expensive).
- On board storage capacity limited (but getting cheaper – current day flash cards pack it in)
- Commutation limitations
- Routing protocols (can't have large routing tables)
- Node failure, link failure (moving out of radio range or path loss)
Sensor Networks

- Integrates sensing, computing and communication
- Getting smaller, more capable and cheaper
  - goal smart dust, cheap enough to “scatter/coat”
Applications: Vehicle Tracking

- Sensors take magnetometer readings, localize objects
- Communicate position to base station using geographic routing
- Robust against link and node failures (many sensors, all connected)
Applications: Habitat Monitoring

- Habitat sensing, Duck Island
  - without disturbing the birds detect their presence (temperature, infrared wavelength and humidity)
  - determine breeding and migration habits
Application: Habitat Monitoring

Fig. 2. System architecture for habitat monitoring
**Application: Habitat Monitoring**

**Fig. 3.** Average daily losses in the network throughout the deployment. The gap in the second part of August corresponds to a database crash.

**Fig. 4.** Distribution of packet losses in a time slot. Statistically, the losses are not independently distributed.
Applications: Volcano Monitoring

Monitoring Volcanic Eruptions
Volcan Reventador, Ecuador, July/Aug 2005

Next node 163m away
Radio modem
GPS receiver
Konrad
Four-channel sensor node
Solar panels for charging car battery (used by FreeWave and GPS only)
Application: Volcano Sensing Architecture

- Yagi to repeater
- GPS receiver for time sync
- FreeWave radio modem for long-distance communication to base
- Sensor nodes each with mic and seismometer
Applications: Medical -- CodeBlue

- pulse, EKG (heart monitoring),
- accelerometer, gyroscope and electromyogram sensing for stroke patients
Applications: Medical

The Harvard Pluto Mote

- Designed for wearable applications
  - 3-axis accelerometer
  - Tiny rechargeable battery
Applications: Medical

Pulse oximeter

Two-lead EKG

Harvard wireless vital sign sensors

- Vital sign data encrypted over radio
- About 30mA current consumption without duty cycling optimizations
Applications: Medical

The CodeBlue Network Infrastructure

1. Medics place vital sign sensors on disaster victims

2. Medic issues queries for patient vital signs

3. Patient sensors send data using multicast routing

4. Sensors locally filter, compress, or analyze data to reduce radio congestion
Applications: Medical, Real-time patient Monitoring

Patient list

Real-time data from selected patient

Map showing location and routing path
Applications: Vineyard (1)

- Conserve water, improve quality of grape crop
Applications: Vineyard (2)

- At each Mote location:
  - 2 soil moisture sensors
  - 12” and 24” depth
  - 1 soil temp sensor to calibrate soil moisture sensors
Applications: Vineyard (3)

- Vineyard Mote prototype
Applications: Vineyard -- future

- Deer monitoring, Open Gates, Easement traffic.
- Wine storage temp
- Wine Making, Temps, CO2 level, flow
- Irrigation Control, remote valves.
- Green Home Monitoring; septic, heating
- Sensors embedded in the vines.
- Database costs, Web UI
Application: Compost Monitoring

- Removable wireless temperature and humidity sensing, easier on operators!
- Determine when to water, air (cool),
Application: Building Monitoring

- Air conditioning when school out of session
- Better thermostat control without expensive infrastructure
Application: Water Treatment

- Huge concrete tanks
- Lots of metal pipes
- Multiple floors
- Install tooks hours (instead of days)
- Repeaters easy to add.
- Mesh network