Ad Hoc and Sensor Networks

Fall 2007

Ad Hoc and Sensor Networks – Roger Wattenhofer – 1/1
Introduction
Chapter 1
Today, we look much cuter!

And we’re usually carefully deployed

Power
Radio
Processor
Memory
Sensors
A Typical Sensor Node: TinyNode 584

- TI MSP430F1611 microcontroller @ 8 MHz
- 10k SRAM, 48k flash (code), 512k serial storage
- 868 MHz Xemics XE1205 multi channel radio
- Up to 115 kbps data rate, 200m outdoor range

<table>
<thead>
<tr>
<th>Current Draw</th>
<th>Power Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>uC sleep with timer on</td>
<td>6.5 uA</td>
</tr>
<tr>
<td>uC active, radio off</td>
<td>2.1 mA</td>
</tr>
<tr>
<td>uC active, radio idle listening</td>
<td>16 mA</td>
</tr>
<tr>
<td>uC active, radio TX/RX at +12dBm</td>
<td>62 mA</td>
</tr>
<tr>
<td>Max. Power (uC active, radio TX/RX at +12dBm + flash write)</td>
<td>76.9 mA</td>
</tr>
</tbody>
</table>
After Deployment

multi-hop communication
Even more visuals?!? No problem…
<table>
<thead>
<tr>
<th>Ad Hoc Networks</th>
<th>vs. Sensor Networks</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Laptops, PDA’s, cars, soldiers</td>
<td>• Tiny nodes: 4 MHz, 32 kB, …</td>
</tr>
<tr>
<td>• All-to-all routing</td>
<td>• Broadcast/Echo from/to sink</td>
</tr>
<tr>
<td>• Often with mobility (MANET’s)</td>
<td>• Usually no mobility</td>
</tr>
<tr>
<td>• Trust/Security an issue</td>
<td>• but link failures</td>
</tr>
<tr>
<td>– No central coordinator</td>
<td>• One administrative control</td>
</tr>
<tr>
<td>• Maybe high bandwidth</td>
<td>• Long lifetime → Energy</td>
</tr>
</tbody>
</table>

There is no strict separation; more variants such as mesh or sensor/actor networks exist.
Overview

- Introduction
- Applications

- Course Overview
- Literature
Animal Monitoring (Great Duck Island)

1. Biologists put sensors in underground nests of storm petrel
2. And on 10cm stilts
3. Devices record data about birds
4. Transmit to research station
5. And from there via satellite to lab
Environmental Monitoring (Redwood Tree)

- Microclimate in a tree
- “10km less cables on a tree; easier to set up”
Environmental Monitoring (SensorScope)

- Comfortable access with web interface
- Swiss made (EPFL)
- Various deployments (campus, glacier, etc.)
Environmental Monitoring (Volcanic monitoring)

- Old hardware vs. new hardware
- Sensors: infrasonic mic (for pressure trace) and seismometer (for seismic velocity)
- Equivalent: Earthquake, Tsunami, etc.
Environmental Monitoring (PermaSense)

- Understand global warming in alpine environment
- Harsh environmental conditions
- Swiss made (Basel, Zurich)
Underwater Sensor Networks

• Static sensor nodes plus mobile robots
• Dually networked
  - optical point-to-point transmission at 300kb/s
  - acoustical broadcast communication at 300b/s, over hundreds of meters range.

• Project AMOUR [MIT, CSIRO]

• Experiments
  - ocean
  - rivers
  - lakes
Vehicle Tracking

- Sensor nodes (equipped with magnetometers) are packaged, and dropped from fully autonomous GPS controlled “toy” airplane

- Nodes know dropping order, and use that for initial position guess

- Nodes then track vehicles (trucks mostly)
Smart Spaces (Car Parking)

- The good: Guide cars towards empty spots
- The bad: Check which cars do not have any time remaining
- The ugly: Meter running out: take picture and send fine

[Matthias Grossglauser, EPFL & Nokia Research]
Traffic Monitoring and Routing Planning (CarTel)

- GPS equipped cars for optimal route predictions, not necessarily “shortest” or “fastest” but also “most likely to get me to target by 9am”

- Various other applications e.g. Pothole Patrol
More Car Network Ideas

- CAR2CAR Consortium: Audi, BMW, Daimler, Fiat, GM, Honda, Renault, VW
Animal networks (e.g. DeerNet)

- Cars are not the only mobile objects…
- Objective: next-generation wildlife monitoring technology for behavior analysis, interaction modeling, disease tracking and control
- Two-tier system
- Including video data
- Other animals are available: ZebraNet, etc.
Acoustic Detection (Shooter Detection)

- Sound travels much slower than radio signal (331 m/s)
- This allows for quite accurate distance estimation (cm)
- Main challenge is to deal with reflections and multiple events
Structural Health Monitoring (Bridge)

Detect structural defects, measuring temperature, humidity, vibration, etc.

Swiss Made [EMPA]
Home Automation

- Light
- Temperature
- Sun-Blinds
- Fans

- Energy Monitoring
- Audio/Video
- Security
  - Intrusion Detection
  - Fire Alarm
Standby Energy [digitalSTROM.org]

- 10 billion electrical devices in Europe
- 9.5 billion are not networked
- 6 billion euro per year energy lost

- Make electricity smart
  - cheap networking (over power)
  - true standby
  - remote control
  - electricity rates
  - universal serial number
  - ...
Inventory Tracking (Cargo Tracking)

- Current tracking systems require line-of-sight to satellite.
- Count and locate containers
- Search containers for specific item
- Monitor accelerometer for sudden motion
- Monitor light sensor for unauthorized entry into container
Agriculture (COMMONSense)

- Idea: Farming decision support system based on recent local environmental data.

- Irrigation, fertilization, pest control, etc. are output of function of sunlight, temperature, humidity, soil moisture, etc.

- (Actual sensors are mostly underground)
Virtual Fence (CSIRO Australia)

- Download the fence to the cows. Today stay here, tomorrow go somewhere else.
- When a cow strays towards the co-ordinates, software running on the collar triggers a stimulus chosen to scare the cow away, a sound followed by an electric shock; this is the "virtual" fence. The software also "herds" the cows when the position of the virtual fence is moved.
- If you just want to make sure that cows stay together, GPS is not really needed…

Cows learn and need not to be shocked later… Moo!
Mesh Networking (Roofnet)

- Sharing Internet access
- Cheaper for everybody
- Several gateways → fault-tolerance
- Possible data backup
- Community add-ons
  - I borrow your hammer, you copy my homework
  - Get to know your neighbors
Games / Art

• Uncountable possibilities, below, e.g. a beer coaster that can interact with other coasters…
Economic Forecast

- **Industrial Monitoring (35% – 45%)**
  - Monitor and control production chain
  - Storage management
  - Monitor and control distribution

- **Building Monitoring and Control (20 – 30%)**
  - Alarms (fire, intrusion etc.)
  - Access control

- **Home Automation (15 – 25%)**
  - Energy management (light, heating, AC etc.)
  - Remote control of appliances

- **Automated Meter Reading (10-20%)**
  - Water meter, electricity meter, etc.

- **Environmental Monitoring (5%)**
  - Agriculture
  - Wildlife monitoring

![Graph showing millions of wireless sensors sold from 2002 to 2010](image)
Related Areas

RFID

Wearable

Wireless

Mobile

Ad Hoc & Sensor Networks

...
RFID Systems

- Fundamental difference between ad hoc/sensor networks and RFID: In RFID there is always the distinction between the passive tags/transponders (tiny/flat), and the reader (bulky/big).

- There is another form of tag, the so-called active tag, which has its own internal power source that is used to power the integrated circuits and to broadcast the signal to the reader. An active tag is similar to a sensor node.

- More types are available, e.g. the semi-passive tag, where the battery is not used for transmission (but only for computing)
Wearable Computing / Ubiquitous Computing

- Tiny embedded “computers”
- UbiComp: Microsoft’s Doll

I refer to my colleague Gerhard Troester and his lectures & seminars

[Schiele, Troester]
Wireless and/or Mobile

- Aspects of mobility
  - User mobility: users communicate “anytime, anywhere, with anyone” (example: read/write email on web browser)
  - Device portability: devices can be connected anytime, anywhere to the network

- Wireless vs. mobile Examples
  - ✗ ✗ Stationary computer
  - ✗ ✓ Notebook in a hotel
  - ✓ ✗ Historic buildings; last mile
  - ✓ ✓ Personal Digital Assistant (PDA)

- The demand for mobile communication creates the need for integration of wireless networks and existing fixed networks
  - Local area networks: standardization of IEEE 802.11 or HIPERLAN
  - Wide area networks: GSM and ISDN
  - Internet: Mobile IP extension of the Internet protocol IP
Wireless & Mobile Examples

- Up-to-date localized information
  - Map
  - Pull/Push
- Ticketing
- Etc.

[Asus PDA, iPhone, Blackberry, Cybiko]
General Trend: A computer in 10 years?

• Advances in technology
  – More computing power in smaller devices
  – Flat, lightweight displays with low power consumption
  – New user interfaces due to small dimensions
  – More bandwidth (per second? per space?)
  – Multiple wireless techniques

• Technology in the background
  – Device location awareness: computers adapt to their environment
  – User location awareness: computers recognize the location of the user and react appropriately (call forwarding)

• “Computers” evolve
  – Small, cheap, portable, replaceable
  – Integration or disintegration?
Course Overview

Application
1 Applications
7 Positioning
8 Time Synchronization

Transport
12 Transport

Network
5 Mobility
3 Geo-Routing
11 Routing
6 Data Gathering

Link
10 MAC
4 Topology Control
7 Clustering

Physical
2 Basics
2 Models
13 Capacity

Practice Theory

\((a + b)^2 = a^2 + 2ab + b^2\)
Course Overview: Lecture and Exercises

- Maximum possible spectrum of systems and theory
- New area, more open than closed questions
- General ideas, concepts, algorithms, impossibility results, etc.
- In other words, almost no protocols

- Lecture and exercises are not really synchronized
- Three types of exercises: theory, practice/lab, creative
- Assistants: Nicolas Burri, Pascal von Rickenbach

- dcg.ethz.ch → courses
Literature
More Literature

- Bhaskar Krishnamachari – *Networking Wireless Sensors*
- Paolo Santi – *Topology Control in Wireless Ad Hoc and Sensor Networks*
- Ivan Stojmenovic – *Handbook of Wireless Networks and Mobile Computing*
- C. Siva Murthy and B. S. Manoj – *Ad Hoc Wireless Networks*
- Jochen Schiller – *Mobile Communications*
- Charles E. Perkins – *Ad-hoc Networking*
- Andrew Tanenbaum – *Computer Networks*

- *Plus tons of other books/articles*
- *Papers, papers, papers, …*
Rating (of Applications)

• Area maturity
  - First steps
  - Text book

• Practical importance
  - No apps
  - Mission critical

• Theoretical importance
  - Not really
  - Must have
Open Problem

- Well, the open problem for this chapter is obvious:

- Find the killer application! Get rich and famous!!