Overview of Sensor Networks

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Agenda

- Introduction
- Sensor Networks Architecture
- Physical Layer
- Data Link Layer
- Network Layer
- Transport Layer
- Application Layer
- Presentation Schedule
References*

- Scalable Routing Protocols for Mobile Ad Hoc Networks; X. Hong, K. Xu, M. Gerla; IEEE Network, July/August 2002.

* The lectures will make liberal use of drawings from the references
Introduction

- Enabling technologies for deployment of low-power and low-cost sensor nodes
  - Advances in wireless communications
  - Advances in Electronics

- Applications
  - Health
  - Military
  - Home
  - Commercial
  - ...

- Poised for tremendous impact
  - Brings together challenges of many fields like electronics, communication, software, business opportunities
Introduction – Main Tasks

- Key tasks performed by Sensor Nodes:
  - Sensing
  - Data Processing
  - Communication

- Networking is a distinguishing feature
Introduction – Distinguishing Features

- Differences between Sensor Networks and traditional Mobile Ad Hoc Networks (MANETs)
  - Much larger number of nodes
  - Dense deployment
  - Limited in power
  - Mainly use broadcast paradigm
  - Higher failure rate
  - No global identifiers
Sensor Network architecture
Introduction – Design Issues

- Key design issues
  - Fault tolerance
  - Scalability
  - Production cost
  - Hardware constraints
  - Network topology
  - Environment
  - Power consumption
Introduction: Protocol Stack

- Protocol stack for Sink and Sensor Nodes
  - Power management impact
  - Location impact
Physical Layer

- 915 MHz ISM is widely used
- Long distance wireless is expensive
  - Power needed behaves like $d^n$, where $d$ is distance and $2 \leq n < 4$ and $n$ is closer to 4 for near-ground channels
- Multihop networks can overcome shadowing and path loss effects
- Binary modulation is more power efficient
Data Link Layer

- Existing MAC protocols (why they can’t be used)
  - Central controlling agent
  - QoS and BW efficiency very important
  - Power efficiency of secondary importance
- Bluetooth and MANET closest cousins, still key differences
  - Dense deployment
  - Power conservation critical
  - Node failures
Data Link Layer: MAC

- MAC for Sensor Networks
  - Self-Organizing Medium Access Control for Sensor Networks (SMACS) and Eavesdrop-and-Register (EAR) Algorithm
  - CSMA-based Medium Access
  - Hybrid TDMA/FDMA-based

<table>
<thead>
<tr>
<th>MAC protocol</th>
<th>Channel access mode</th>
<th>Sensor network specifics</th>
<th>Power conservation</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMACS and EAR [13]</td>
<td>Fixed allocation of duplex time slots at fixed frequency</td>
<td>Exploitation of large available bandwidth compared to sensor data rate</td>
<td>Random wake up during setup and turning radio off while idle</td>
</tr>
<tr>
<td>Hybrid TDMA/FDMA [8]</td>
<td>Centralized frequency and time division</td>
<td>Optimum number of channels calculated for minimum system energy</td>
<td>Hardware-based approach for system energy minimization</td>
</tr>
<tr>
<td>CSMA-based [9]</td>
<td>Contention-based random access</td>
<td>Application phase shift and pretransmit delay</td>
<td>Constant listening time for energy efficiency</td>
</tr>
</tbody>
</table>
Data Link Layer: MAC Considerations

- Key design consideration for MAC
  - Power saving modes of operation
    - Avoid turning on and off based on component characteristics
  - Error control
    - FEC is preferred over ARQ
Network Layer

Driving factors for design of Network Layer

- Power efficiency
- Data aggregation
- Attribute-based addressing and location awareness
Network Layer: Energy Efficient Routing

- Energy efficient routing
  - Maximum PA route: Sink-E-F-T
  - Minimum energy route: Sink-A-B-T
  - Minimum hop route: Sink-D-T
  - Maximum minimum PA node route: Sink-D-T
Network Layer: Proposed Schemes

- **Routing schemes**
  - Small Minimum Energy Communication Network (SMECN)
    - Create energy-efficient subgraph
  - Flooding
    - Deficiencies include implosion, overlap, resources blindness
  - Gossiping
    - Broadcast to randomly selected neighbor
    - Long propagation time
Network Layer: Proposed Schemes - 2

- Routing schemes
  - Sensor Protocol for Information via Negotiation (SPIN)
  - Low-energy Adaptive Clustering Hierarchy
    - Setup phase: Periodically select new clusterhead
    - Steady state phase
Network Layer: Proposed Schemes - 3

- Routing schemes
  - Directed Diffusion
    - Sink sends interest
    - Nodes store interest entry
    - Source setup gradient from source to sink
  - Rumor routing optimizes the interest indication phase

- Diagram:
  - Step 1: propagate interest
  - Step 2: set up gradient
  - Step 3: send data
# Network Layer:
## Proposed Schemes - 4

<table>
<thead>
<tr>
<th>Network layer scheme</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMECN [18]</td>
<td>Creates a subgraph of the sensor network that contains the minimum energy path</td>
</tr>
<tr>
<td>Flooding</td>
<td>Broadcasts data to all neighbor nodes regardless if they receive it before or not</td>
</tr>
<tr>
<td>Gossiping [19]</td>
<td>Sends data to one randomly selected neighbor</td>
</tr>
<tr>
<td>SPIN [15]</td>
<td>Sends data to sensor nodes only if they are interested; has three types of messages (i.e., ADV, REQ, and DATA)</td>
</tr>
<tr>
<td>SAR [13]</td>
<td>Creates multiple trees where the root of each tree is one hop neighbor from the sink; selects a tree for data to be routed back to the sink according to the energy resources and additive QoS metric</td>
</tr>
<tr>
<td>LEACH [16]</td>
<td>Forms clusters to minimize energy dissipation</td>
</tr>
<tr>
<td>Directed diffusion [5]</td>
<td>Sets up gradients for data to flow from source to sink during interest dissemination</td>
</tr>
</tbody>
</table>
Transport and Application Layers

- Not much work on these layers
- UDP/TCP splitting along sensor node – sink – user is proposed
- Limited power and memory consideration for transport layer design
- Application layer ideas:
  - Sensor Management Protocol
  - Task Assignment and Data Advertisement Protocol
  - Sensor Query and Data Dissemination Protocol
## Ongoing Research Projects

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Research Area</th>
<th>HTTP Location</th>
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<tr>
<td></td>
<td>and task management planes.</td>
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<td></td>
<td>Submicrowatt electronics.</td>
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<td></td>
<td>Power sources.</td>
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<td></td>
<td>Macro Motes (COTS Dust).</td>
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<tr>
<td>PACMAN</td>
<td>Mathematical framework that incorporates key features of computing nodes and</td>
<td><a href="http://pacman.usc.edu">http://pacman.usc.edu</a></td>
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<tr>
<td></td>
<td>networking elements.</td>
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</tr>
<tr>
<td>Dynamic Sensor Networks</td>
<td>Routing and power aware sensor management. Network services API.</td>
<td><a href="http://www.east.isi.edu/DIV10/dsn/">http://www.east.isi.edu/DIV10/dsn/</a></td>
</tr>
<tr>
<td>Aware Home</td>
<td>Requisite technologies to create a home environment that can both perceive and</td>
<td><a href="http://www.cc.gatech.edu/ice/ahri">http://www.cc.gatech.edu/ice/ahri</a></td>
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<td></td>
<td>assist its occupants.</td>
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