Robust Data Dissemination in Sensor Networks

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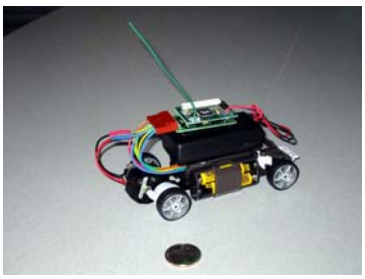
September, 2003

Sensor Networks: The Next Big Thing?

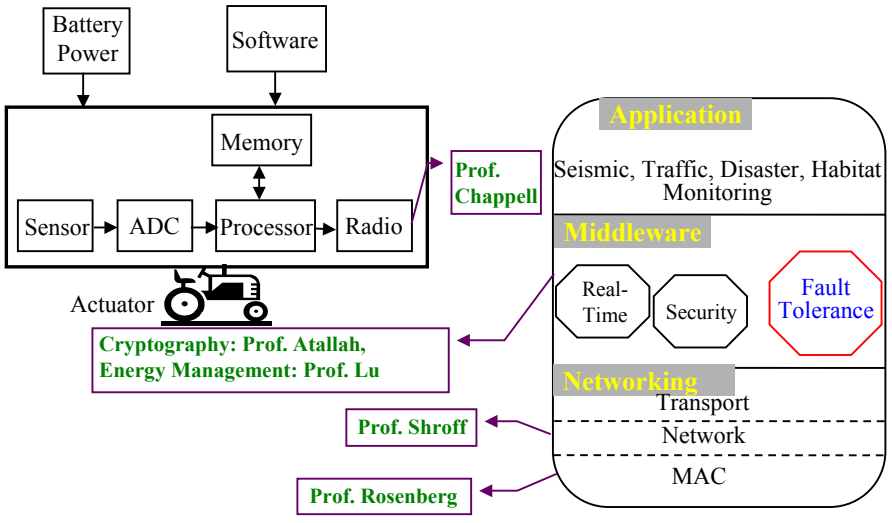
- Large scale networks built of sensor nodes
- Miniature nodes with capacity for computation, sensing and communication
- Short range wireless RF communication (≈ 100 feet)
- Limited computation power (Atmel Atmega processor of 4 MHz)
- Sensor board with variety of sensors: temperature, light, magnetometer
- Characteristics
  - Energy constrained
  - Memory constrained
  - Computational power constrained
  - Unreliable

Radio-Processor Board

Sensor Board



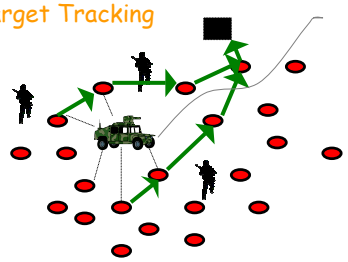
Sensor Node Architecture



Why Dependability in Sensor Networks?

Forest Fire Detection

Battlefield Target Tracking



Reliability

- Critical applications
- Nodes inherently unreliable
- Links inherently unreliable
- Long paths with the possibility of multiple failures

Security

- Deployed in hostile environments
- Broadcast nature of communication medium
- Nodes can be compromised
- Possibility of denial of service attacks

Data Dissemination in Sensor Networks

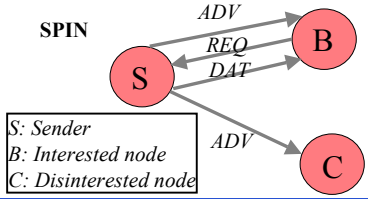
- Large part of a sensor network's role is sensor data gathering and dissemination
- The data is often critical and has soft real-time requirements
- The paths on which the data traverses are often unreliable – nodes and links may fail transiently or permanently
- Motivation of robust data dissemination

- Goals of data dissemination protocols
  - Minimize energy drain
  - Distribute data among the nodes quickly
  - Reduce redundant data transmissions
  - Tolerate node and link failures

Existing Approaches to Data Dissemination

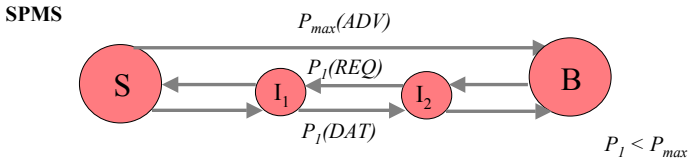
- TTDD – Sources are the sensor nodes and sinks are mobile nodes interested in sensor data
  - o Sets up a grid structure and proactively determines routing from data source to sink
  - o At runtime, when sink needs data it locates a near "dissemination point" which uses pre-computed route from source to sink
  - o Drawbacks: Cost of setting up entire routing grid.
- LEACH - Clustering of nodes for data forwarding to base station
  - o Clusters formed and cluster heads chosen
  - o Data forwarded to cluster head in TDMA manner, which is responsible for sending data to sink
  - o Drawbacks: Data exchange on pre-determined schedule, all nodes need to be able to communicate directly with base station

- PEGASIS - Single node responsible for sending entire data to the sink
  - o Aggregate data from all cluster heads at single node
  - o Drawbacks: Uneven drain of energy, higher delay
- SPIN - Exchange of meta data prior to actual data exchange, mix of push-pull
  - o Advertisement and request with meta-data before data sent only to interested nodes
  - o Drawbacks: Single hop communication leading to high energy expenditure and contention delay



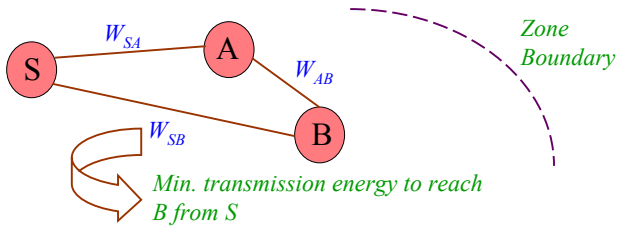
Our Approach: SPMS

- Single hop communication is inefficient in energy consumption and delay
- Forming efficient clusters and reconfiguring them in the face of motion are difficult
- Our protocol: Shortest Path Minded SPIN (SPMS)
  - Use meta data to avoid redundant data transmissions
  - Incorporate multi-hop communication to use the available multiple transmit power levels
  - Reduce energy and latency (due to MAC contention) by using smaller power.



SPMS Details

- Zone routing
  - Each node maintains routes for nodes in its zone
  - Uses Distributed Bellman Ford. Convergence time: O(n.e), where n: number of nodes in zone (~ 5-50), e: number of edges



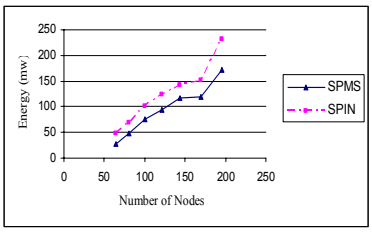
- Timers
  - ADV Timer (τ_{ADV}): To optimize transmission energy. Backoff before sending REQ
  - DAT Timer (τ_{DAT}): To tolerate failures. Wait this long after sending REQ

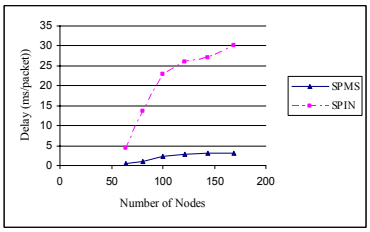
SPMS Details

- Mobility
  - Simple scheme currently: Recalculate Zone Routing Tables on node movement
  - More intelligent scheme: Recalculate on an as needed basis
- Failures
  - Caching of data at intermediate nodes
  - Can tolerate multiple failures (including sender) on data propagation path

Results: Energy Dissipation & Delay

Failure Free Case



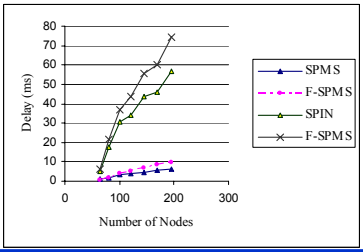


Static Case

$$\frac{Delay_{SPIN}}{Delay_{SPMS}} \sim 10$$

$$\frac{Energy_{SPIN}}{Energy_{SPMS}} \sim 3.3$$

Failure Case



Mobile Case

$$\frac{Energy_{SPIN}}{Energy_{SPMS}} \sim 1.05 - 1.25$$

Open Questions? (aka Research Opportunities)

- Can actuation help data dissemination protocols?
  - What kinds of intelligent mobility models?
  - What is the energy implication?
- What effect does low energy modes of sensor node operation have on robustness of system?
  - For example, routing functionality being turned off on some nodes
- How does enhanced hardware help the cause of data dissemination?
  - RF hardware, such as directional antennas
  - On-chip memory on the sensor processors
- A hybrid of clustering and push-pull in homogeneous networks may be applicable in some application domains

Contact Information

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