SPINE: Framework for Wireless Body Sensor Networks

Sameer Iyengar, Filippo Tempia Bonda, Raffaele Gravina, Antonio Guerreri, Giancarlo Fortino and Alberto Sangiovanni-Vincentelli

University of California at Berkeley, Telecom Italia Research
Body Sensor Networks

- **Potential to revolutionize healthcare**
  - Reduce cost
  - Reduce physical barriers
  - Improve quality of care

- **Enabling**
  - Prevention
  - Detailed monitoring
  - Continuous, real-time reporting
A Pipe Dream?

Application development is difficult.

- Designers re-invent the wheel
- Need abstractions to see widespread adoption

“2.5PhDs are needed to deploy a SensorNet”

– Professor Joe Hellerstein, UC Berkeley
What is SPINE?

- A software framework that **automates** and **simplifies** development tasks for BSN applications

- **Extensible**

- **Developer Focused**

Why focus on body sensor networks?

- Common requirements
  - Latency, Frequency, Reliability, Signal Processing

- Exploit topology
  - Small networks instead of large meshes

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Target Applications

- **Assisted Living**
  - Fall Detection and Prevention
  - Parkinson’s Disease

- **Motion Analysis**
  - Gait Analysis
  - Balance

- **Remote Patient Monitoring**
  - Rehabilitation
  - Physical Therapy
  - In-Hospital Surgery Recovery
  - Metabolism

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System Overview

- The **application** makes service requests.
- The **NSM (Network Service Manager)** coordinates the nodes and responds via **events**.
- The **nodes** perform local sensing and processing.
Nodes

- **Communication:** Queue of requests
  - Sensors
  - Time constraint
  - Computation

- **Data:** Nodes poll sensors and buffer data

- **Processing:** Computation is abstracted via **functions**
  - Modular
  - Reusable
  - Extensible

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Functions

- Abstraction for requested tasks
  - Processing algorithms
  - Logic to control communication
  - Local storage and retrieval

Raw sensor data

```python
sensorValue(id)
return getSensorValue(id)
```

Logic

```python
compare(id1, id2)
if (getSensorValue(id1) >
    getSensorValue(id2))
    return getSensorValue(id1)
```

Mean value of a data buffer

```python
meanValue(id, start, end, interval)
counter = 0, total = 0
for (t = start; t < end; t += interval)
    total += getSensorValue(id, t)
    counter++
return total/counter
```
Node Coordination

- **NSM manages TDMA schedule**
  - Maintain node status
  - Responsible for clock synchronization

- **Nodes know when to transmit**
  - Combine multiple values into a single packet
  - Power off radios
NSM

- **Service Requests**
  - Just ask
    - Make requests without monitoring the network
    - Can specify fallback options
  - Each request assigned a unique identifier

- **Events**
  - Response to a request
  - Asynchronous

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NSM: Requests

- Application can:
  - Query Data
  - Disseminate data
  - Network Status/Capabilities

A request for data follows the following generic format:

<table>
<thead>
<tr>
<th>Node Id</th>
<th>Function Id</th>
<th>Parameters (determined by function definition)</th>
</tr>
</thead>
</table>

For example, to request the mean value of sensor $s$ on node $n$ over the last 10 seconds computed every second ($t$ is the current time):

| $n$ | meanValue | $s$ | t-10 | $t$ | $l$ |
NSM: Events

- NSM buffers incoming data
  - Processed by application event handler
    - Java API makes this easy
    - No parsing hex strings
  - Graceful error handling
    - Network continues operation even if request cannot be satisfied
Implementation

- Java-compatible base station
- 802.15.4 device running TinyOS

Inertial Sensor
Bio-sensor

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Implementation

- SPINE open-source project
  - [http://spine.tilab.com](http://spine.tilab.com)

- Collaborators
  - UC Berkeley
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Questions?