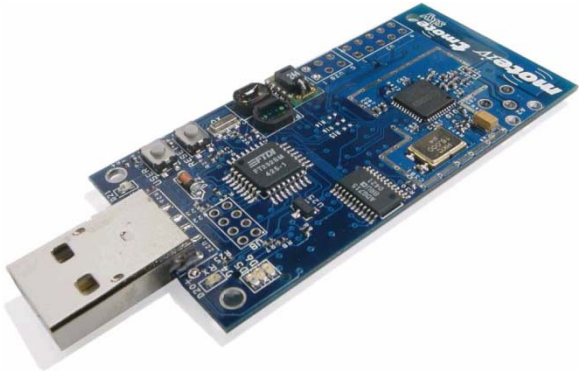
# **SPINE:** Framework for Wireless Body Sensor Networks

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

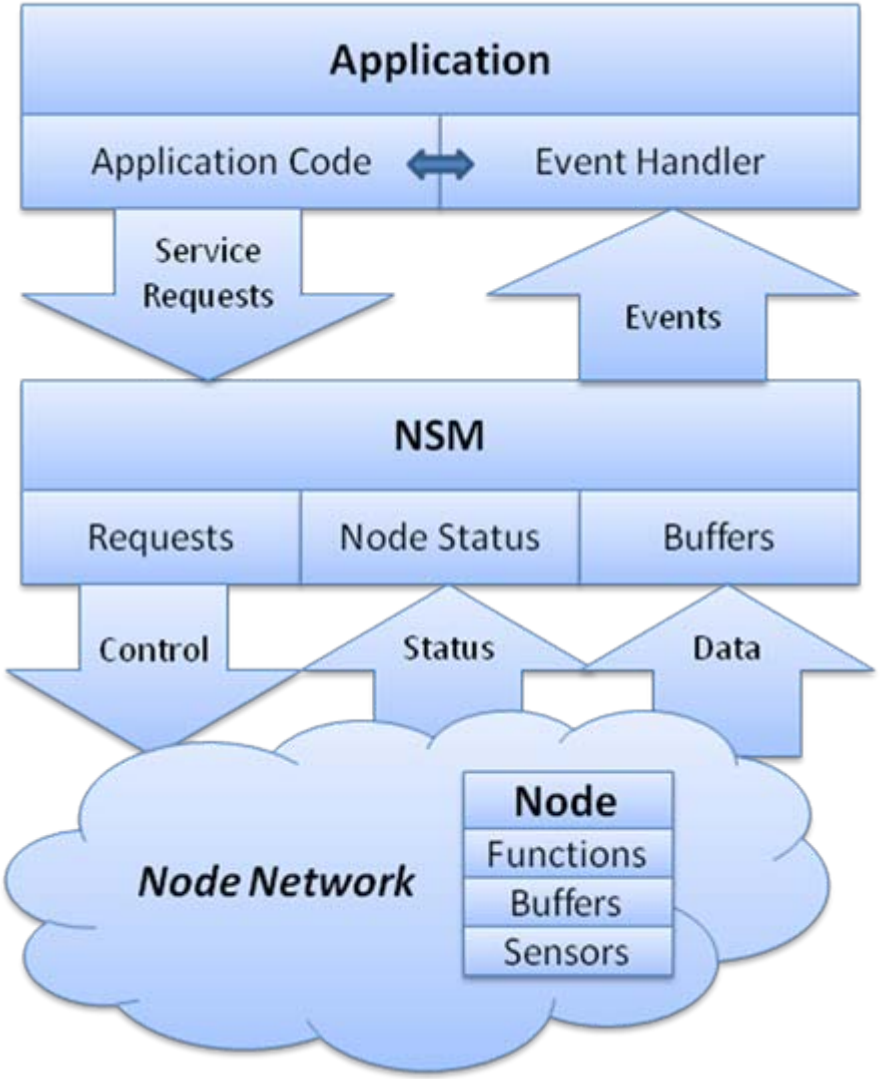
- **Extensible**
- **Developer Focused**

- Why focus on body sensor networks?
  - Common requirements
    - Latency, Frequency, Reliability, Signal Processing
  - Exploit topology
    - Small networks instead of large meshes

# Target Applications

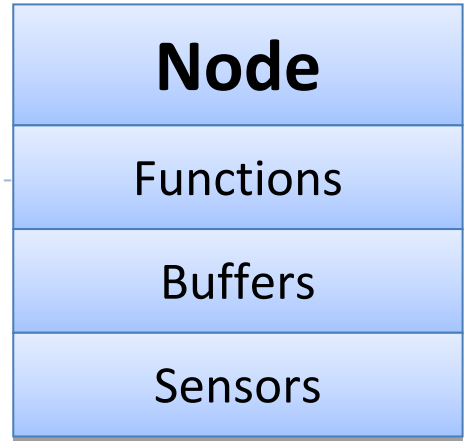
- **Assisted Living**
  - Fall Detection and Prevention
  - Parkinson's Disease
- **Motion Analysis**
  - Gait Analysis
  - Balance
- **Remote Patient Monitoring**
  - Rehabilitation
  - Physical Therapy
  - In-Hospital Surgery Recovery
  - Metabolism

# System Overview



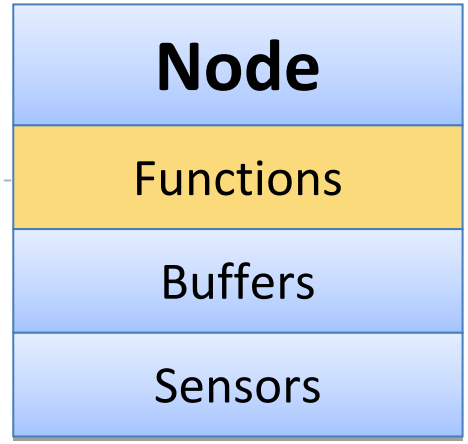

- The **application** makes **service requests**
- The **NSM (Network Service Manager)** coordinates the nodes and responds via **events**
- The **nodes** perform local sensing and processing

# 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

# Functions




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

**Raw sensor data**

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

**Logic**

**Return sensor$_1$ value if greater than sensor$_2$**

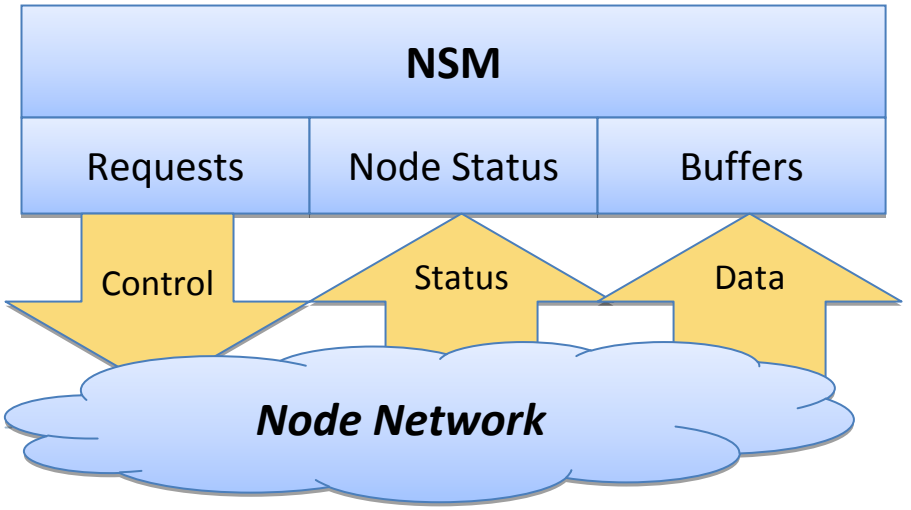
```
compare (id1, id2)
  if (getSensorValue(id1) >
                getSensorValue(id2))
    return getSensorValue(id1)
```

**Mean value of a data buffer**

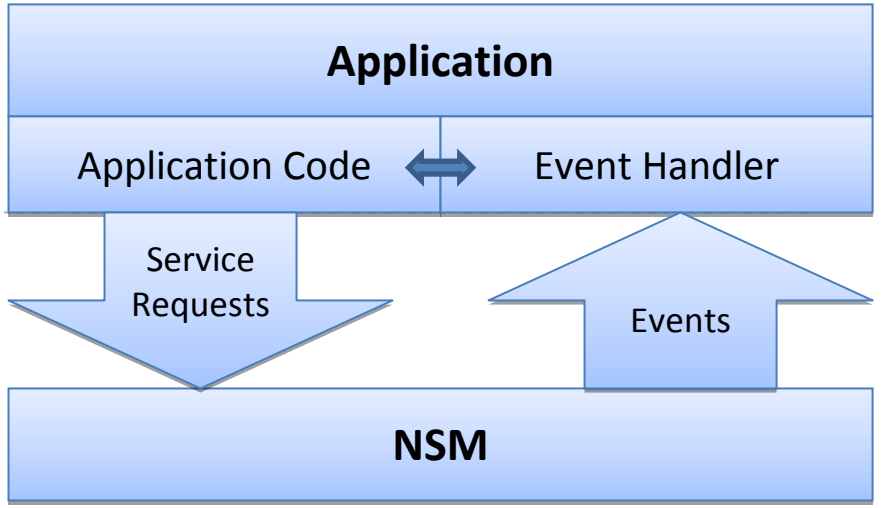
```
meanValue (id, start, end, interval)
  counter = 0, total = 0
  for (t = start; t < end; t += interval)
    total += getSensorValue(id, t)
    counter++
  return total/counter
```

# 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

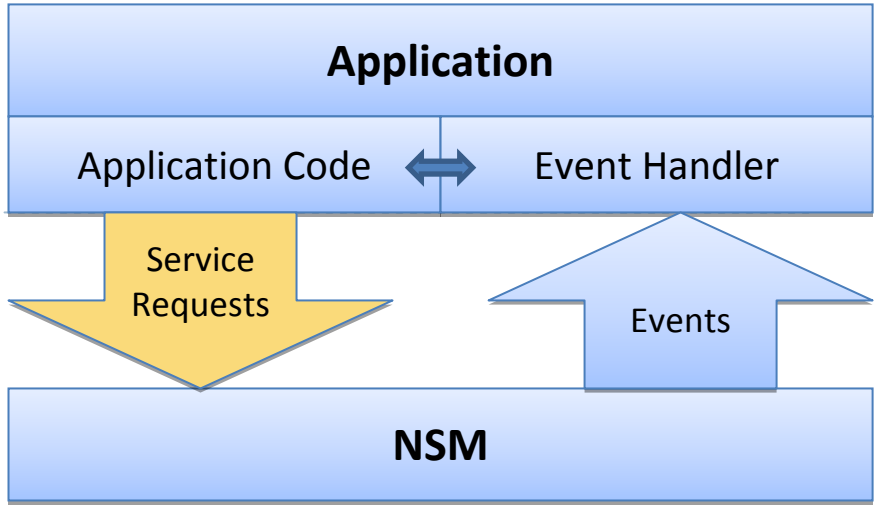


# NSM




- **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

# NSM: Requests




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

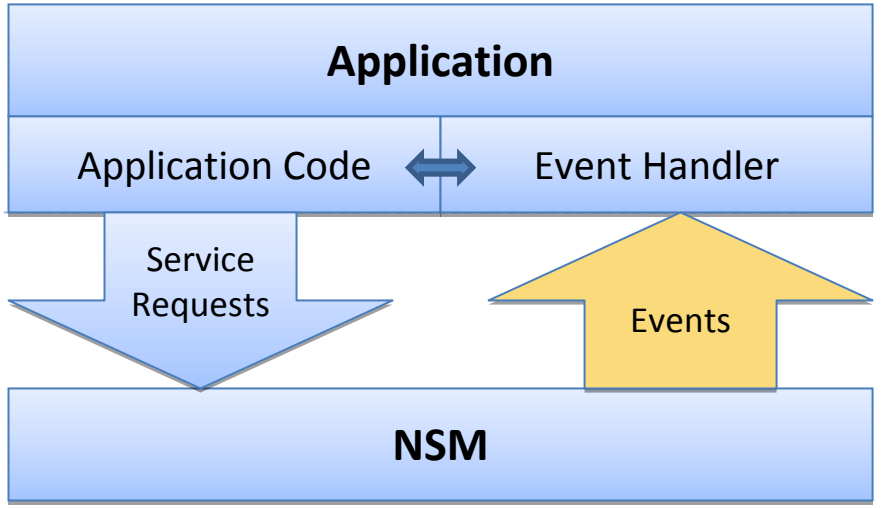
A request for data follows the following generic format:

| **Node Id** | **Function Id** | **Parameters** (determined by function definition) |
|---|---|---|

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** | **1** |
|---|---|---|---|---|---|

# NSM: Events

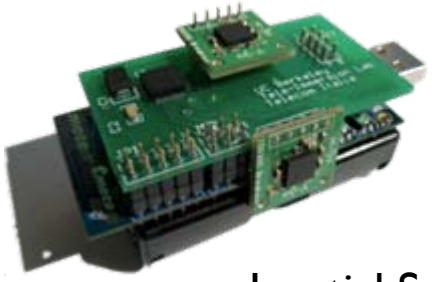



- NSM buffers incoming data
- Processed by application event handler
  - Java API makes this easy
  - No parsing hex strings
- Graceful error handling
  - Network continues operation even if request cannot be satisfied

# Implementation

- Java-compatible base station


- 802.15.4 device running TinyOS



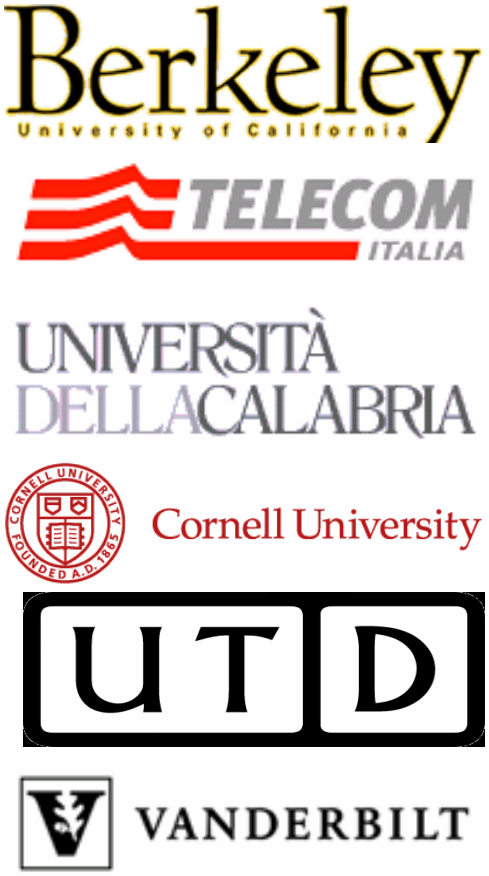
Inertial Sensor

Bio-sensor

# Implementation

- SPINE open-source project
- http://spine.tilab.com

- Collaborators
  - UC Berkeley
  - Telecom Italia
  - University of Calabria
  - Cornell
  - UT Dallas
  - Vanderbilt



# Acknowledgements


- UC Berkeley
  - Ruzena Bajcsy
  - Kris Pister
  - Victor Shia
- Telecom Italia
  - Roberta Giannantonio
  - Marco Sgroi
- Cornell University
  - Philip Kuryloski
- UT Dallas
  - Roozbeh Jafari


# Questions?