A Wireless Sensor Network for Structural Monitoring

Ning Xu, Sumit Rangwala, Krishna Kant Chintalapudi, Deepak Ganesan, Alan Broad, Ramesh Govindan, Deborah Estrin

Presented by Fei Sun

Motivation

• Detect and localize damage in buildings, bridges, etc.
  • Collect and analyze structural response to ambient or forced excitation.
• Problem with current solutions:
  • Powerful data acquisition system: a centralized device includes sophisticated signal conditioning, processing and analysis functions
    • Expensive, not flexible, small coverage, difficult to install
  • Data logger:
    • Lacks analysis capabilities
    • Requires storage and high-bandwidth transmission capabilities

Challenges

Challenges:
• Limited bandwidth, memory, local processing capabilities
• High packet loss
• Lack of time synchronization

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Wisden Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher data rates</td>
<td>Data Compression</td>
</tr>
<tr>
<td>Loss-intolerant data transmission</td>
<td>Reliable data transport</td>
</tr>
<tr>
<td>Time synchronization</td>
<td>Data synchronization that avoids synchronizing clocks network-wide</td>
</tr>
</tbody>
</table>

Wisden – System Overview

• Abstraction of a data acquisition system
  • Current Wisden functions as a data logger as it lacks the on-line data processing capabilities present in data acquisition systems,
  • Implicit requirements:
    • Sampled data reliably delivered to BS
    • Samples are time-synchronized

Wisden – System Overview

Base Station

Tree Routing Topology

Motes with Accelerometer

Time Stamp Synchronization

Hop-by-Hop End-to-End Error Recovery

Local Data Compression

Compression

• Event detection (current implementation)
  • Advantage: only transmitting samples that exceed a certain threshold, utilizing the fact that structures will experience relatively few of these
  • Limitations:
    • Restricts the type of events that could be detected
    • Do not reduce the user-perceived latency of data acquisition
Compression

- Progressive Storage and Transmission
  - Store raw data in local cache
  - Transmit compressed cached data in near-real time
  - Limits the amount of data that can be accessed
  - Compress vibration data by a factor of 20
  - Reduce acquisition latency to < 1 min when coupled with Event Detection

Compression: Evaluation

- Integer-integer wavelet decomposition
- Quantization
- Signal shareholding
- Run-length encoding
- Bitstream

<table>
<thead>
<tr>
<th>Event Detection</th>
<th>Local Data Decomposition</th>
<th>Progressive Coding</th>
<th>Flash memory</th>
<th>Summarized data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
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</tbody>
</table>

Wisden – System Overview

- Tree Routing Topology
- Motes with Accelerometer
- Time Stamp Synchronization
- Hop-by-Hop End-to-End Error Recovery
- Local Data Compression

Reliable Data Transport

- Hop-by-hop recovery
  - Necessary for performance optimization
  - NACK-based reliability scheme
  - Track sequence number on a per source basis
  - Each node maintains a list of missing packets
- End-to-end recovery
  - Heavy packet losses may result in more lost messages than can fit in the mote’s memory
  - Topology change could cause loss of missing packet list information
  - Base station does not have constraint on storage

RDT Evaluation

- When sending rate increases, average recovery latency increases due to packet recovery as a dominant part of latency
- > 0.25 packet/sec end-to-end dominates recovery latency
**TimeStamping Data**

- Example

- **Residence time**
- **Propagation time** (ns, 100 meters)

- Sample time from local clock
- At Base Station

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**Conclusion**

- Wisden is a wireless structural data acquisition system that incorporates:
  - Data Compression
  - Reliable Transport
  - Time Synchronization

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**Critique**

- No real deployment
- Did not give a result of how well the system detects and localize damage
- No consideration of power management
- Manually configure sending rate
- Data is not sent in real-time

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**Related Work – Intel Sensys’05**

- Power management
- Location of mote deployment
- Two kinds of motes: Mica2 vs. iMote
- Hierarchical network
  - Mica2/iMote, Stargates, Server
- Real-time data streaming
  - Limits the sampling rate to 19.2 Khz (too low)
- Real deployment
  - Found that higher frequency radio (Mica2) is more reliable, due to the metal environment