ENSC 427: COMMUNICATION NETWORKS
SPRING 2012

FINAL PROJECT PRESENTATION
SIMULATION OF ZIGBEE SENSOR NETWORKS
WWW.SFU.CA/~MFA6
Presentation Structure

- Introduction & Motivation
- Background Information
- OPNET Implementation
- Simulation Results
- Conclusion
- Future Work
- References
- Questions/Discussions
Introduction and Motivation

- What is ZigBee
  - Specification for WPAN’s operating at 2.4GHz*
  - Builds upon IEEE 802.15.4 for low-rate WPAN’s
  - Typical range of 50-100m

- Applications
  - Wireless Sensor Networks (WSN) ← Main Focus
  - Building Automation
  - Industrial Control

- Motivation
  - Embedded Applications
  - Power Consumption
  - Small footprint

*Can operate at different frequencies in certain jurisdictions
Background Information

- ZigBee Specifications
  - Data transmission up to 250 kbps
  - Supported nodes > 64,000
  - AES-128 encryption

- ZigBee Qualities
  - Acknowledgements
  - Route Discovery
  - Security
  - Scalability
Background Information

- ZigBee Devices
  - ZigBee coordinator – initialization/authentication
  - ZigBee router – relay device (can also act as sensor)
  - ZigBee end device - Talks to parent nodes

- Network topology
  - Proper Selection can:
    - Range ↑
    - Cost ↓
    - Complexity ↓
OPNET Implementation

- Coordinator
- Router
- End device

<table>
<thead>
<tr>
<th>Network Parameters</th>
<th>Coordinator</th>
<th>Router</th>
<th>End device</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAN ID</td>
<td>Auto Assigned</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Application Traffic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Destination Traffic</td>
<td>No Traffic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Packet Reception-Power Thresh.</td>
<td>-90</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Physical Layer Parameters</th>
<th>Coordinator</th>
<th>Router</th>
<th>End device</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Rate</td>
<td>250000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Packet Reception-Power Thresh.</td>
<td>-90</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transmission Bands</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 2450 MHz Band</td>
<td>Enabled</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 915 MHz Band</td>
<td>Disabled</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 868 MHz Band</td>
<td>Disabled</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transmit Power</td>
<td>0.003</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- CBR traffic at 250kbps
- Extreme case
- Transmission in 2.4Ghz band
- International interoperability
- Transmit power at 3mW (typical 1mW – 5mW)
- Emphasis on power consumption in WSN’s
- Receiver sensitivity of -90 dB
- Cost/Size emphasized
ZigBee Topology Selection

- Star and Mesh networks considered
- Tree networks not appropriate for WSN’s

Hierarchical issues

- Failure of one node destroys communication to all nodes below it
- Due to funneling of data, routers experience higher failure rates.
- Increased power consumption
Star topology
- Sensor nodes transmit data
- Coordinator receives all data
- Direct link

Advantages
- Simplicity
- Sensor isolation
- Network centralization

Disadvantages
- Limited range
- Only one route
Mesh topology
- Sensor nodes transmit data
- Coordinator receives all data
- Routers are relays and sensors

Advantages
- Increased range
- Multiple paths
- Interference flexibility

Disadvantages
- Increased hops
- Increased delay
- More complex
Simulation Results

- Time taken for application packets to be transmitted from source to destination
  - Increases as sensor nodes increase
  - Mesh topology exhibits considerable increase in end-to-end (ETE) delay

- 10 sensor star network = .007 seconds
- 10 sensor mesh network = .015
- 50 sensor star network = .010
- 50 sensor mesh network = .020

- Scale: 10 x10 metres
- Routers
  - 2 routers for 8 sensors
  - 7 routers for 43 sensors

- Delay factor of 2 introduced by extra hop
Simulation Results – Cont’d

- Increasing scale has negligible effect on ETE delay:
  - Although scale has increased it is well within transmission range
  - Mesh topology exhibits considerable increase in end-to-end (ETE) delay over star networks

- Scale: 100 x 100 metres
- Routers
  - 2 routers for 8 sensors
  - 7 routers for 43 sensors
Increasing scale has negligible effect on ETE delay:
- But ETE delay is only considering received packets.
- Other metrics required to analyze network performance on this scale:
  - Are all packets originating at sensor nodes reaching their destinations?
  - Is the Mesh topology effectively increasing sensor transmission ranges?

- Scale: 1000 x 1000 meters
- Routers:
  - 2 routers for 10 sensors
  - 7 routers for 50 sensors
  - 27 routers for 250 sensors
Simulation Results – Cont’d

- Most sensors out of reach of central coordinator
  - ETE delay alone could not provide this information
- How much more data will mesh networking recover?

- Coordinator receiving ~1100 bps even though each sensor sending ~1000 bps
- Most data never reaches coordinator due to increased range
3 fold increase when mesh networking employed with only 27 routers

Mesh networking effectively increased transmission range of outlying nodes
Great alternative to increasing TX power
Adding even more routers increased data received at coordinator
Cost considerations must be taken into account to achieve optimal balance
Conclusion

- Small WSN
  - Star topology well suited
  - Relatively low cost
  - No bottleneck of resources
- Medium WSN
  - Star or Mesh can work well
  - Dependant on specific application
- Large WSN
  - Out of average ZigBee device range
  - Transmission power can be increased
  - More favorable option is to employ a mesh network
Future Work

- Explore other ZigBee Applications
  - WSN are mainly concerned with central data collection
  - Message passing between all devices
- Incorporate energy models
  - Quantitatively describe power consumption
- Implement actual ZigBee network
  - Can verify findings


Questions/Discussions