ENSC 427: COMMUNICATION NETWORKS

SPRING 2012

FINAL PROJECT PRESENTATION

SIMULATION OF ZIGBEE SENSOR NETWORKS

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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

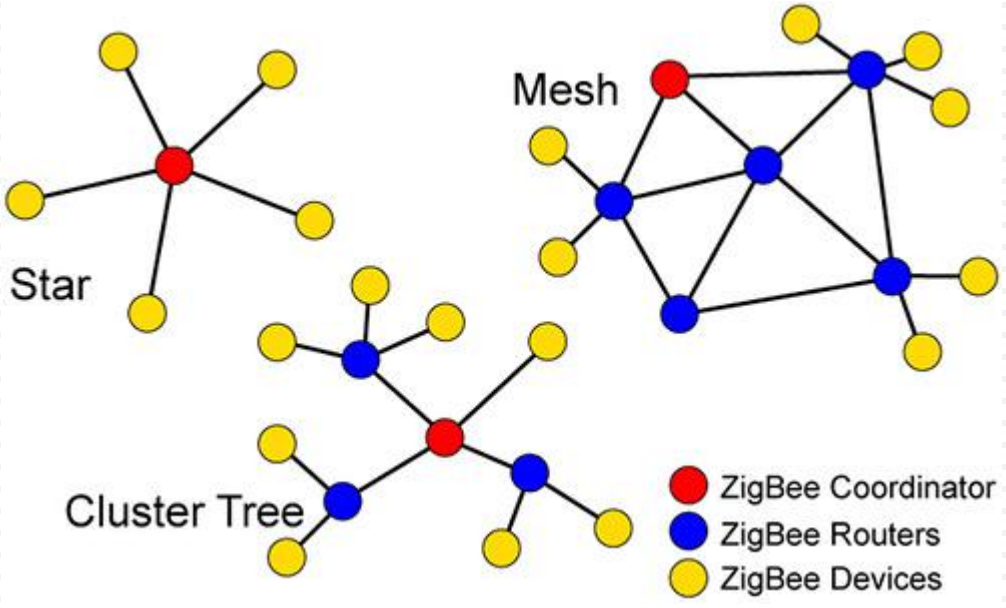
*Can operate at different frequencies in certain jurisdictions

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 – initilization/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

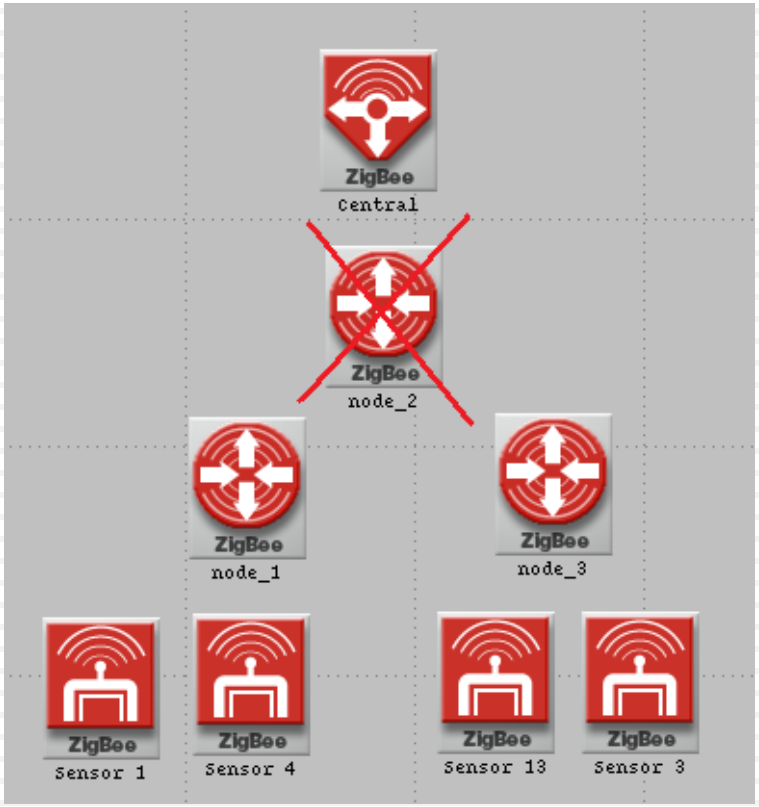
Packet Reception-Power Thre...	-90
Network Parameters	(...)
PAN ID	Auto Assigned
Application Traffic	
Destination	No Traffic

Physical Layer Parameters	
Data Rate	250000
Packet Reception-Power Thre...	-90
Transmission Bands	(...)
2450 MHz Band	Enabled
915 MHz Band	Disabled
868 MHz Band	Disabled
Transmit Power	0.003

- 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

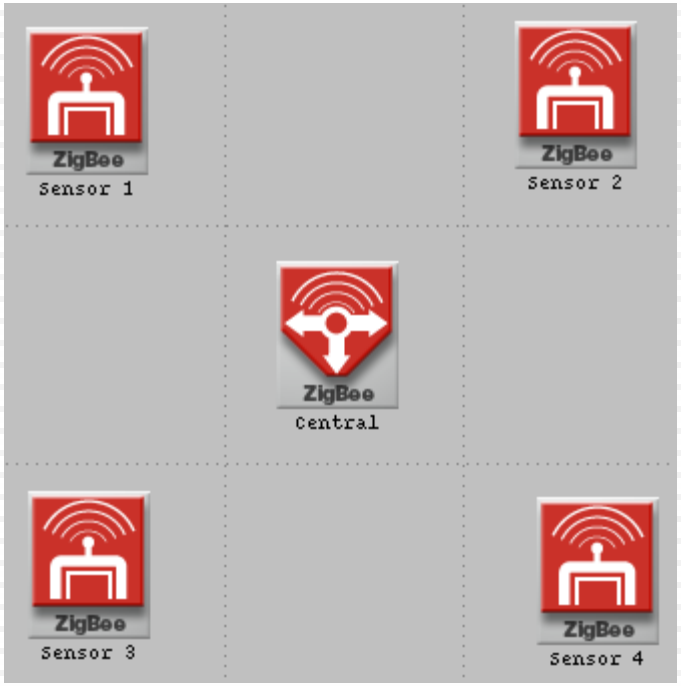
OPNET Implementation-cont'd

- 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

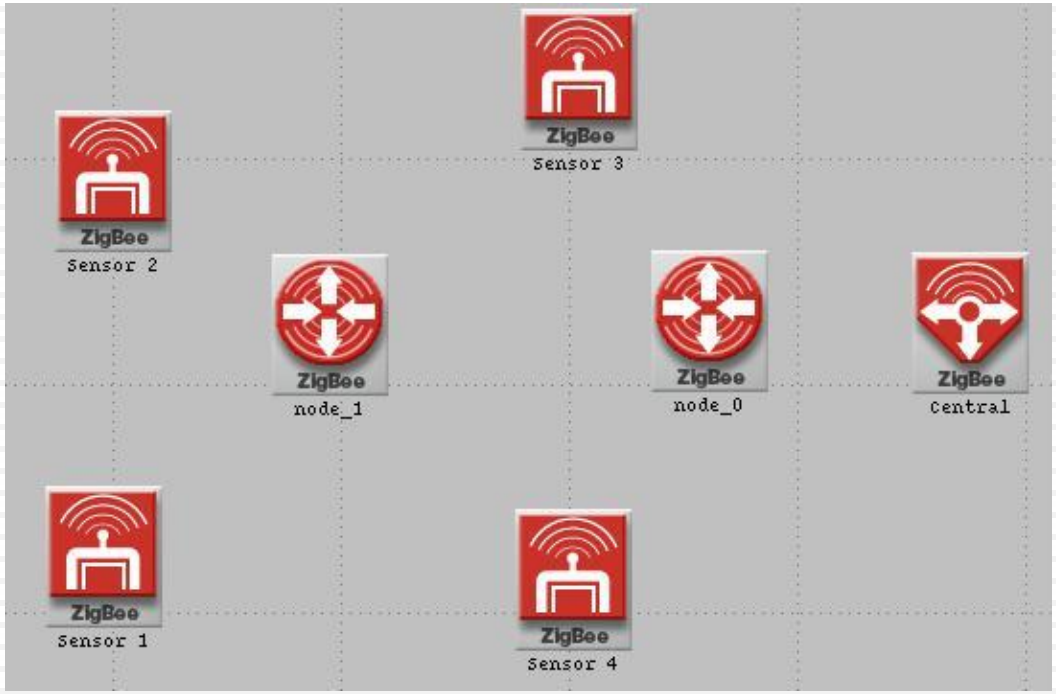
OPNET Implementation-cont'd



- Star topology
  - Sensor nodes transmit data
  - Coordinator receives all data
  - Direct link
- Advantages
  - Simplicity
  - Sensor isolation
  - Network centralization
- Disadvantages
  - Limited range
  - Only one route

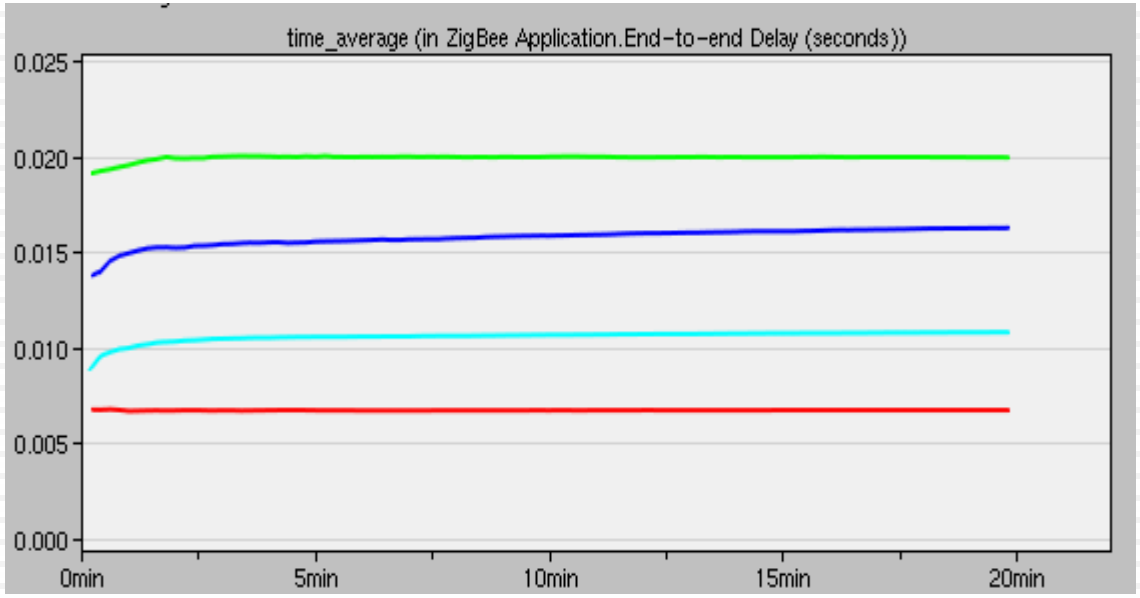
OPNET Implementation-cont'd

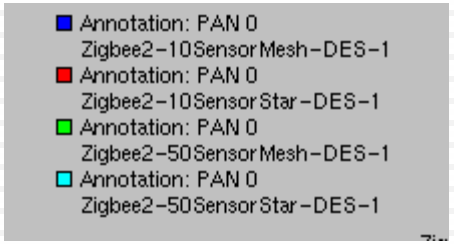
- Mesh topology
  - Sensor nodes transmit data
  - Coordinator receives all data
  - Routers are relays and sensors



- Advantages
  - Increased range
  - Multiple paths
  - Interference flexibility
- Disadvantages
  - Increased hops
  - Increased delay
  - More complex

Simulation Results

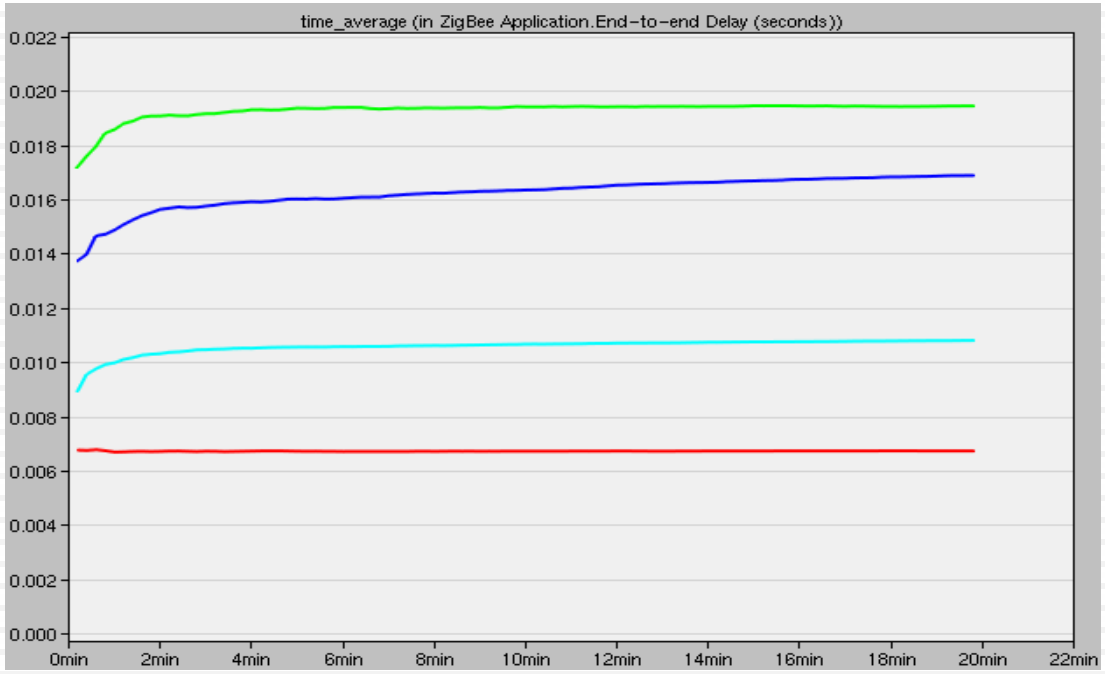


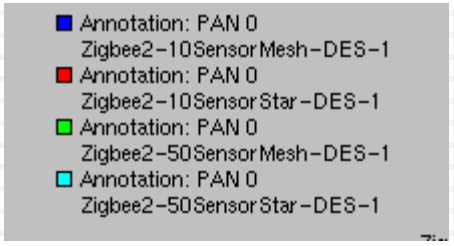


- Scale: 10 x10 metres
- Routers
  - 2 routers for 8 sensors
  - 7 routers for 43 sensors

- 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
  - Delay factor of 2 introduced by extra hop

Simulation Results – Cont'd

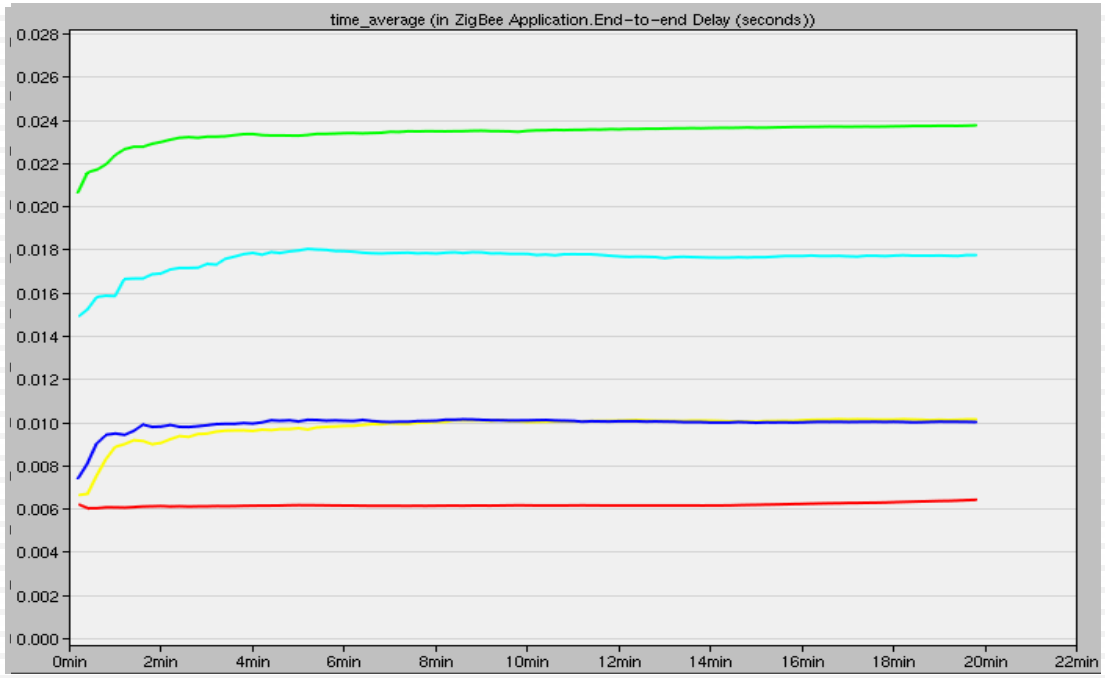




- Scale: 100 x100metres
- Routers
  - 2 routers for 8 sensors
  - 7 routers for 43 sensors

- 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

Simulation Results – Cont'd

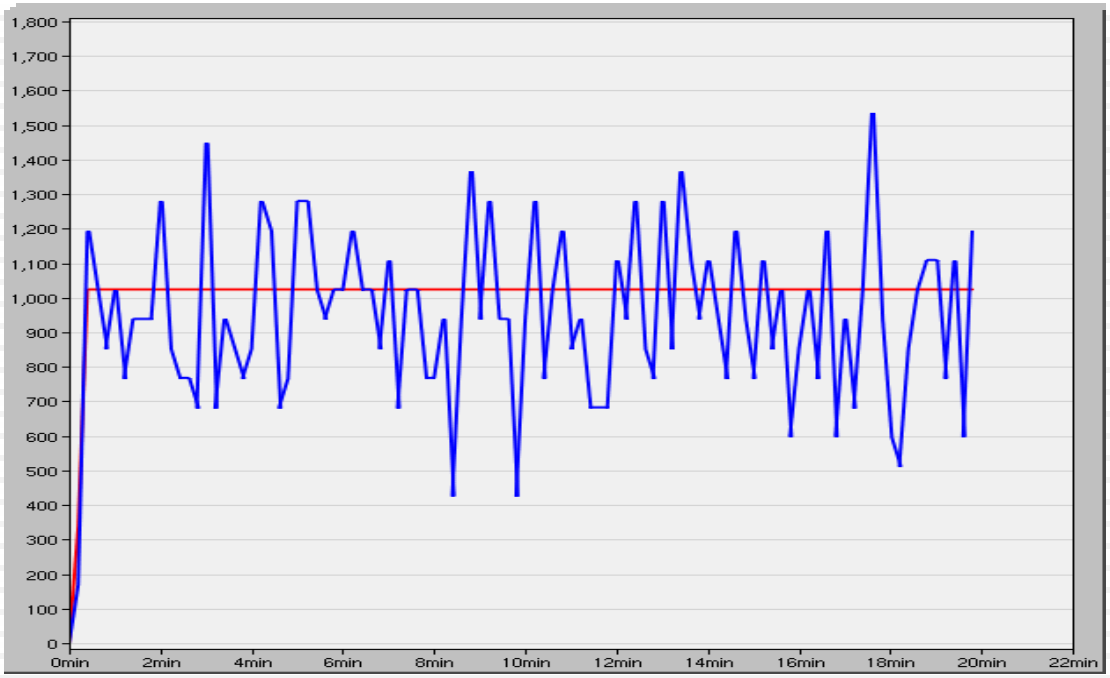


Annotation: PAN 0
Zigbee2-10SensorMeshLarge-DES-1
Annotation: PAN 0
Zigbee2-10SensorStarLarge-DES-1
Annotation: PAN 0
Zigbee2-50SensorMeshLarge-DES-1
Annotation: PAN 0
Zigbee2-250SensorMeshLarge-DES-1
Annotation: PAN 0
Zigbee2-250SensorStarLarge-DES-1

- Scale: 1000 x1000 meters
- Routers
  - 2 routers for 10 sensors
  - 7 routers for 50 sensors
  - 27 routers for 250 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?

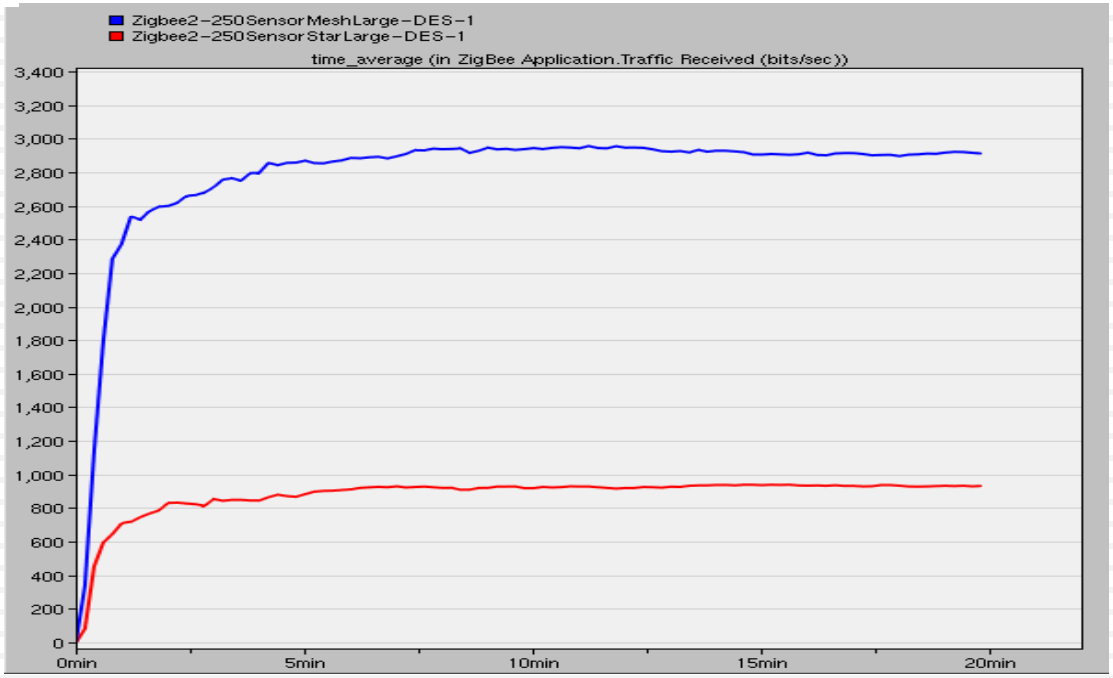
Simulation Results – Cont'd



- Coordinator receiving ~1100 bps even though each sensor sending ~1000 bps
- Most data never reaches coordinator due to increased range

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

Simulation Results – Cont'd



- 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

References

[1] I.S. Hamoodi et al (2009) “Comprehensive Performance Study of OPNET Modeler For ZigBee Wireless Sensor Network” *2009 Third International Conference on Next Generation Mobile Applications, Services and Technologies*. [On-line]. 3, pp. 357-362. Available: http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=05337413 [Mar. 26, 2012].

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[3] Sinem Coleri Ergen. "ZigBee/IEEE 802.15.4 Summary" Internet: http://pages.cs.wisc.edu/~suman/courses/838/papers/zigbee.pdf, Sept.10, 2004 [Mar.15 , 2012].

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Questions/Discussions