ENSC 427 Project

Evaluation of ZigBee Protocol Network Topologies in Medical Monitoring Environments

Team 3

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Roadmap

- Introduction
  - Comparison of Technology Standards, Chosen Technology
- Overview Chosen Technology
- Related Works
- Simulations and Results
  - Basic
  - Stationary
  - Self-healing
  - Mobile
- Conclusion
- Future Work

Introduction

- Motivation
  - Determining most suitable communication protocol and respective topology for medical monitoring environments
- Reliable monitoring of patient vital signs include:
  - Heart rate
  - Blood saturation
  - Body temperature

Comparison of Standards

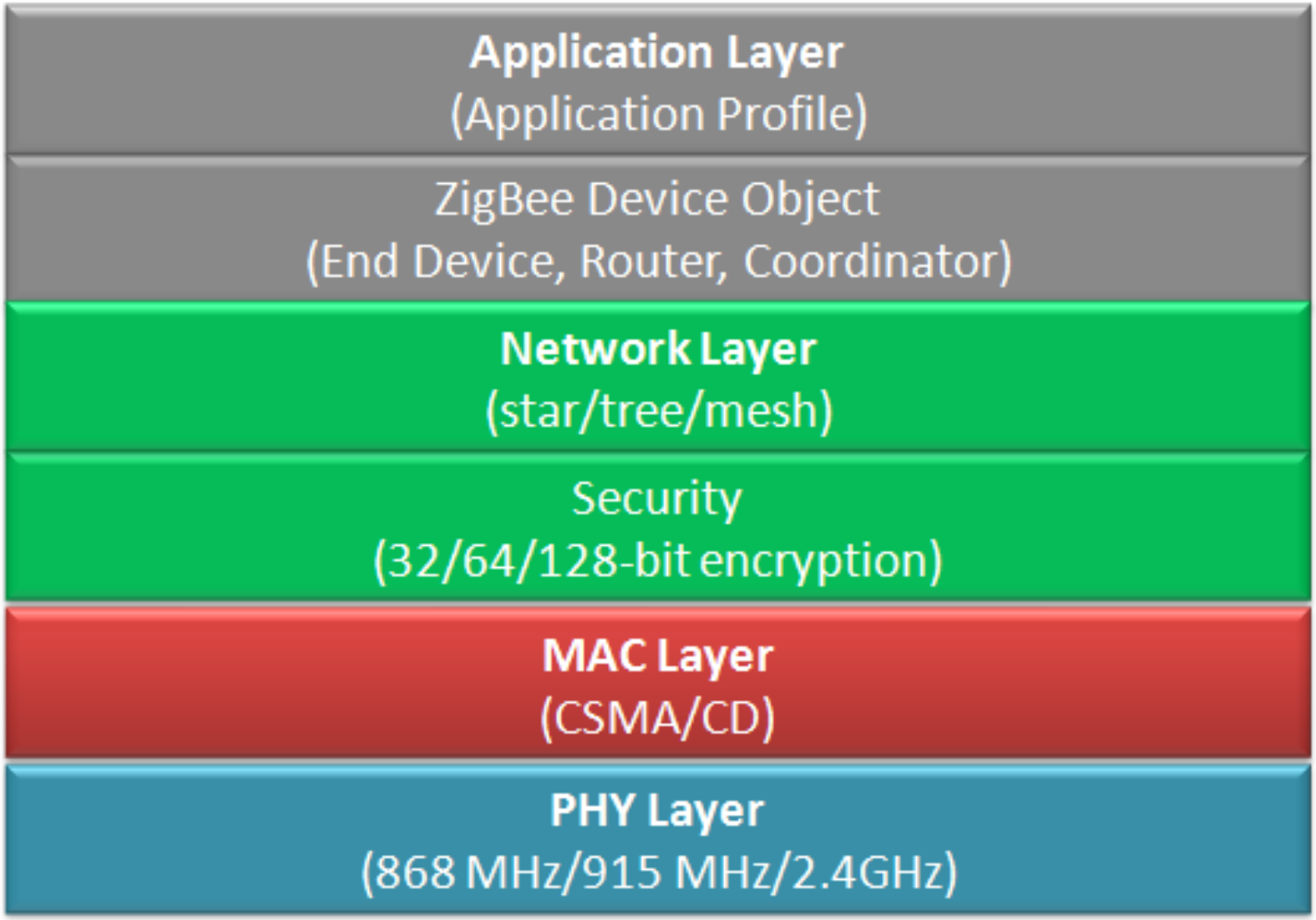
STANDARD	IMPORTANT PARAMETERS							
	COVERAGE	DATA RATES	FREQUENCY	BANDWIDTH REQUIREMENTS	POWER REQUIREMENTS	NETWORKING TOPOLOGY	SECURITY	COMPLEXITY (DEVICE/ APPLICATION)
Wi-Fi	100 m	11 and 54 Mbps	2.4 GHz and 5 GHz	20 MHz	High	Infrastructure (point-hub)	AES block cipher and 32 bit CRC	High
Bluetooth	10 m	1 Mbps	2.4 GHz	1 MHz	Medium	*Ad hoc*, very small network	64 and 128 bit encryption and 16 bit CRC	High
UWB	10 m	100–500 Mbps	3.1–10.6 GHz	≥ 500 MHz	Low	Point-to-point	AES block cipher and 16 bit CRC	Medium
ZigBee	70–100 m	250 Kbps	2.4 GHz	2 MHz	Very low	*Ad hoc*, peer-to-peer, star or mesh	128 AES with application layer security	Low
WiMax	50 m	75 Mbps	2–11 GHz	10 MHz	Low	Infrastructure	AES triple data encryption standard	Low
WiBro	<2 miles	1–75 Mbps	2.3–2.4 GHz	8.75 MHz	Low	Infrastructure mesh	AES with extensible authentication protocol	Low
Wireless USB	10 m	480 Mbps	3.1–10.6 GHz	528 MHz	Low	Point-to-point	AES 128	Low
IR wireless	<10 m with LOS	4 Mbps	16 KHz	2.54 MHz	Low	Point-to-point	Very secure	Low

AES, advanced encryption standard; CRC, cyclic redundancy check; IR, infrared; Kbps, kilobits per second; LOS, line of sight; UWB, ultra-wideband; WiBro, wireless broadband.

Zigbee Overview - Advantages

- Range is ideal for medical environment (70 m – 100 m)
- Sufficient data rate for sensors
- Low power
- Secure network
- Low complexity

ZigBee Overview - Architecture



Chosen Technology: ZigBee

- IEEE 802.15.4 physical radio standard
- Operates at three different frequencies

Frequency Range (MHz)	Transfer Rate (kbit/s)	Region
868-868.6	20	Europe
902-928	40	North America
2400-2483.5	250	Worldwide

ZigBee Overview - Nodes

- Coordinator 

- Router 

- End Device 

Related Work

- Group 6 in 2009 analyzed ZigBee transmission in the tree topology
  - Concluded that the end to end delay is different for different routes
- Group 4 in 2009 simulated a ZigBee mesh network and studied routing selection
  - Concluded that the ZigBee model had several limitations

Related Work

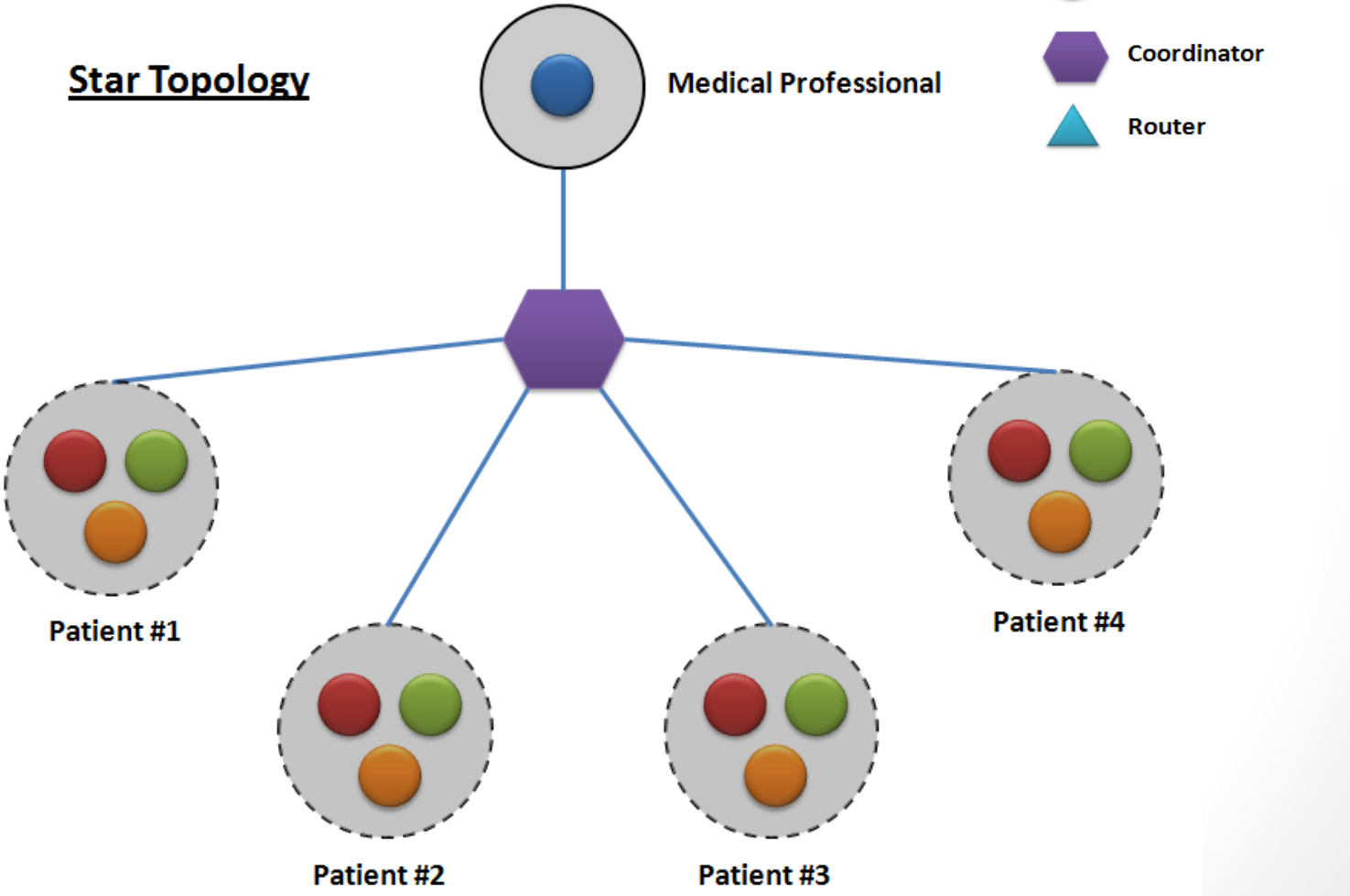
- Research team from Europe studied the OPNET modeler for ZigBee
  - Ran simulations for star, tree, and mesh topologies
  - Investigated end to end delays
  - Found higher delays in mesh topology compared to tree topology
- Research team from Romania
  - Suggested that ZigBee could be used in the medical environment
  - Simulated and “L” shaped hallway with 24 rooms – each with 2 end devices in each room
    - Measured bit error rate
  - Concluded that they needed routers to cover larger areas
  - No mention of network topology

Project Scope

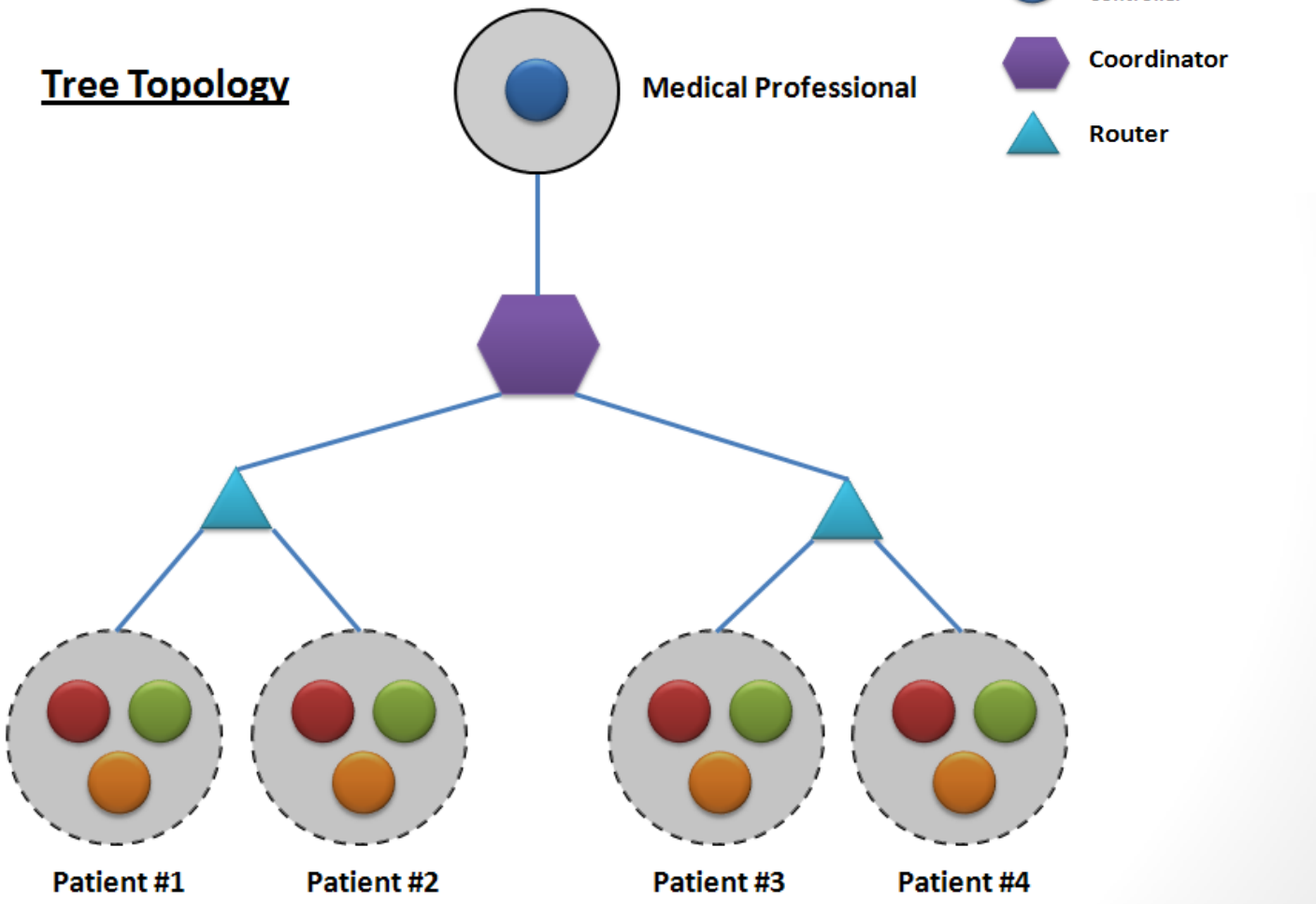
- Investigate which ZigBee Network Topology is best suited for the medical environment with a stationary and mobile medical professional
  - Star topology
  - Tree topology
  - Mesh Topology
- Medical Environment
  - Emulate a hospital ward
  - 1 medical professional responsible for 4 patients
  - 3 sensors per patient

Application
ECG
Blood Saturation
Temperature

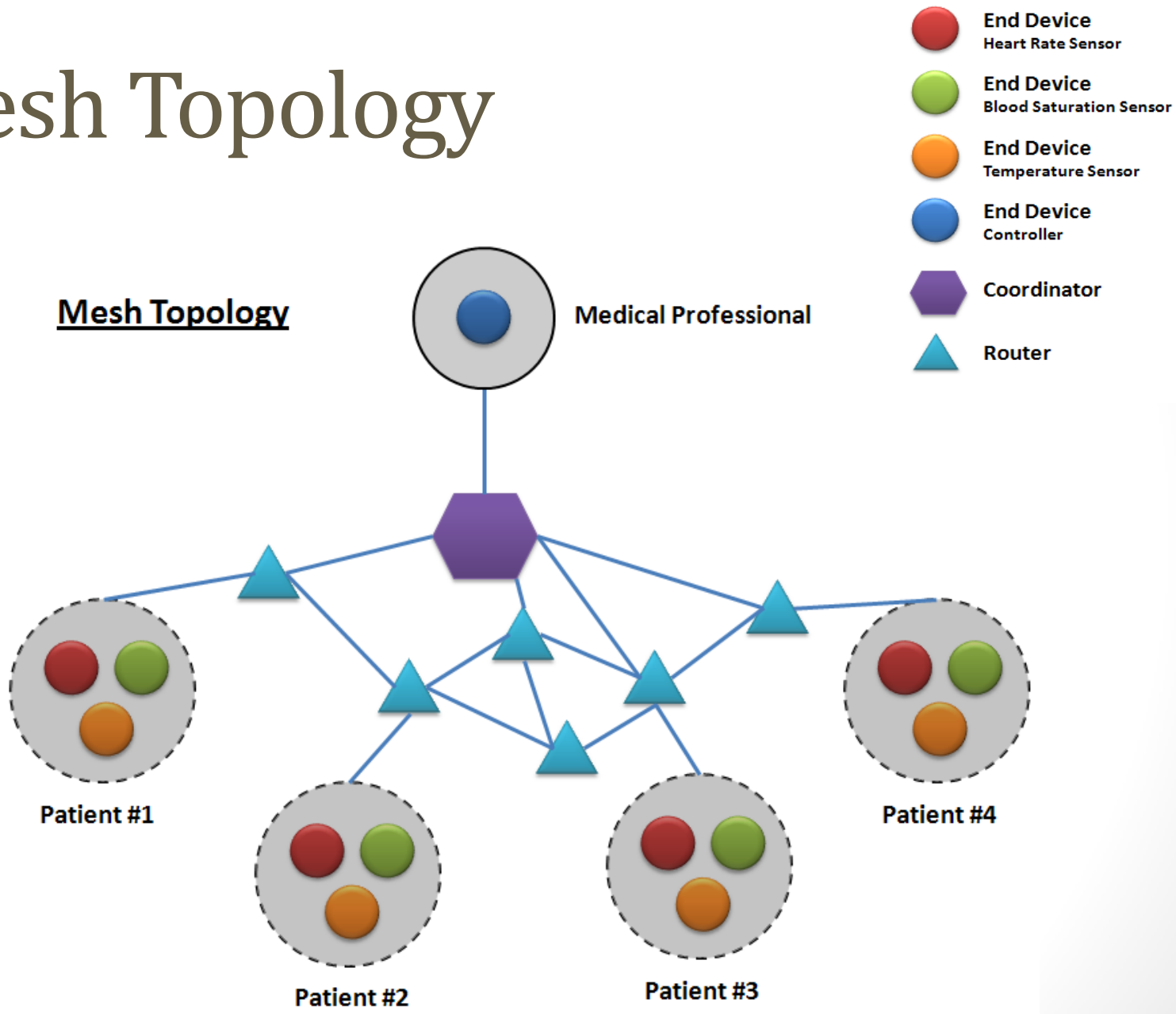
Star Topology



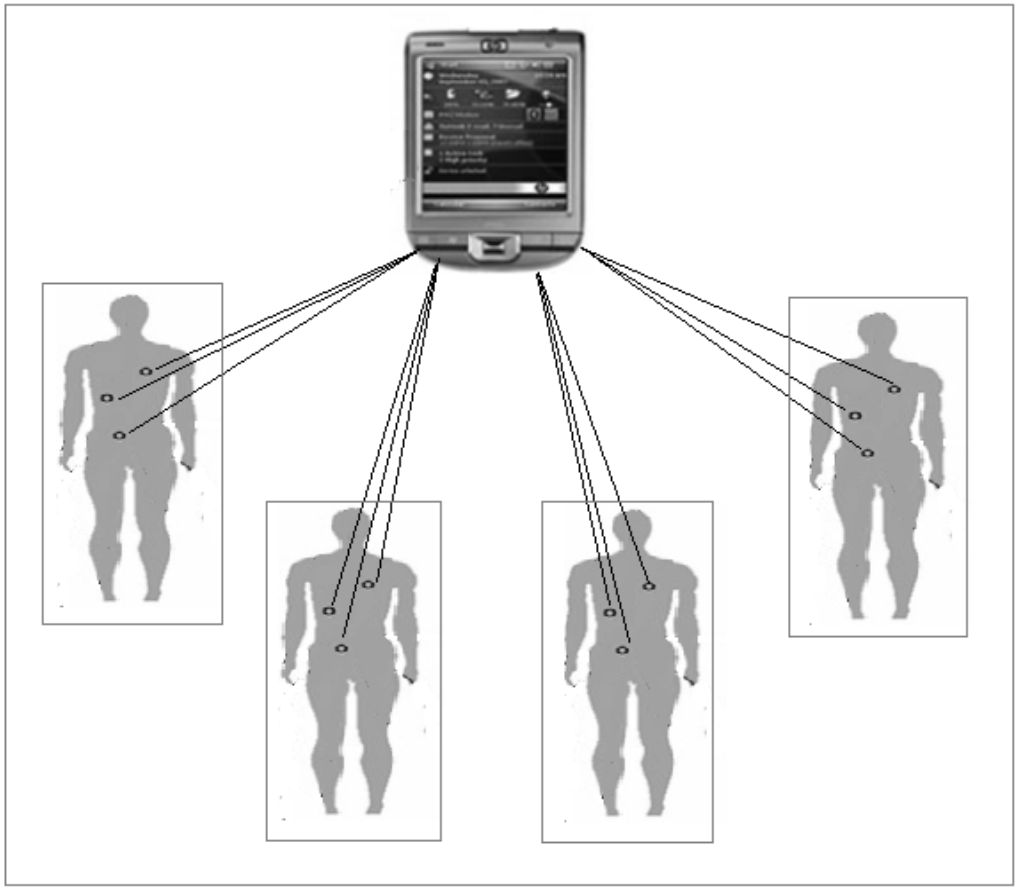
Tree Topology



Mesh Topology



Project Scope: Medical Environment



Evaluation Criteria

- Transmission Efficiency (how many bits/s are received)
  - Rationalized that data loss can be fatal
- Network Delay
  - Delays should be minimized for timely response in emergencies

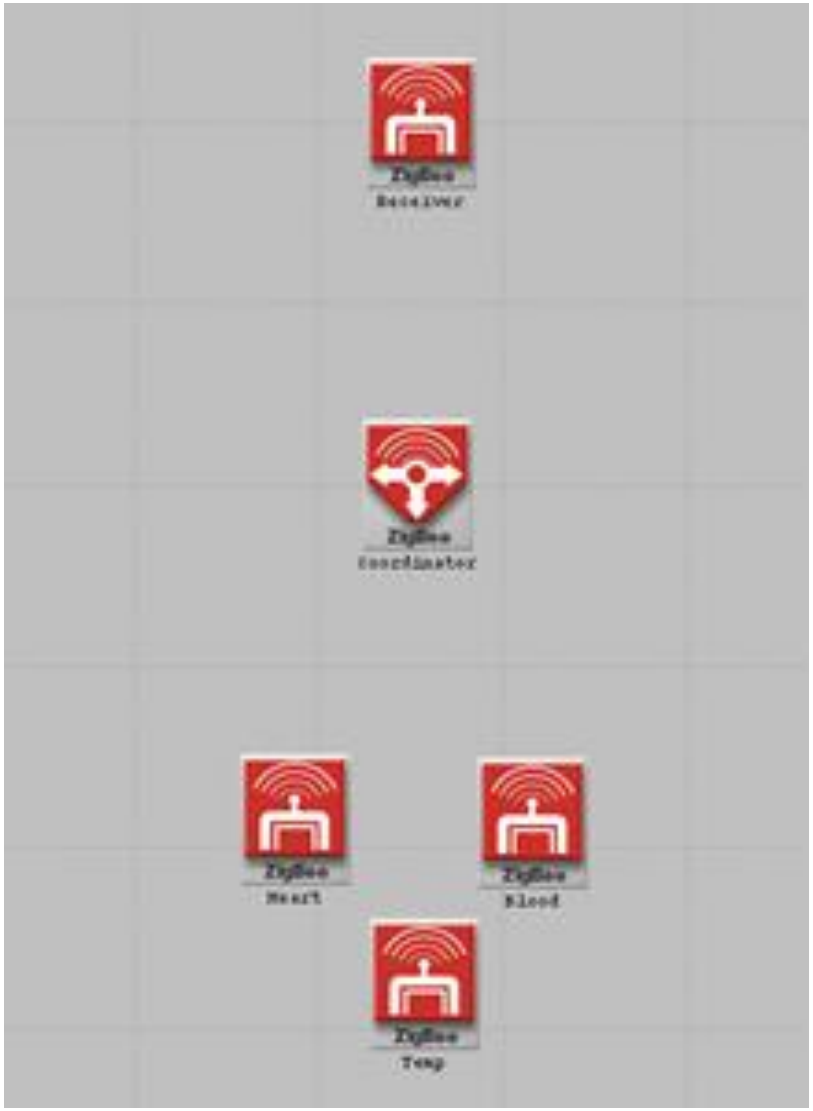
Application	Data Rate
ECG	12 Kbps
Blood Saturation	16 bps
Temperature	120 bps

Simulation Overview

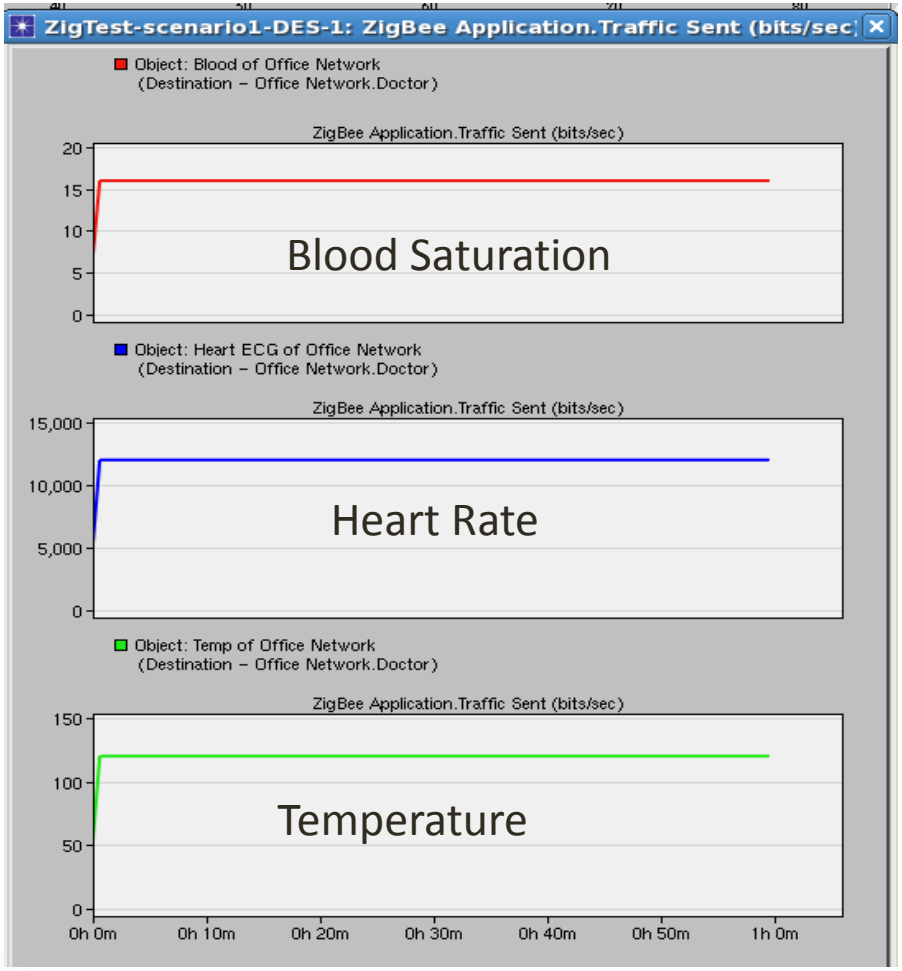
- 4 Scenarios
  - Basic Simulation
  - Stationary Doctor
  - Self-healing test (tree and mesh)
  - Mobile Doctor

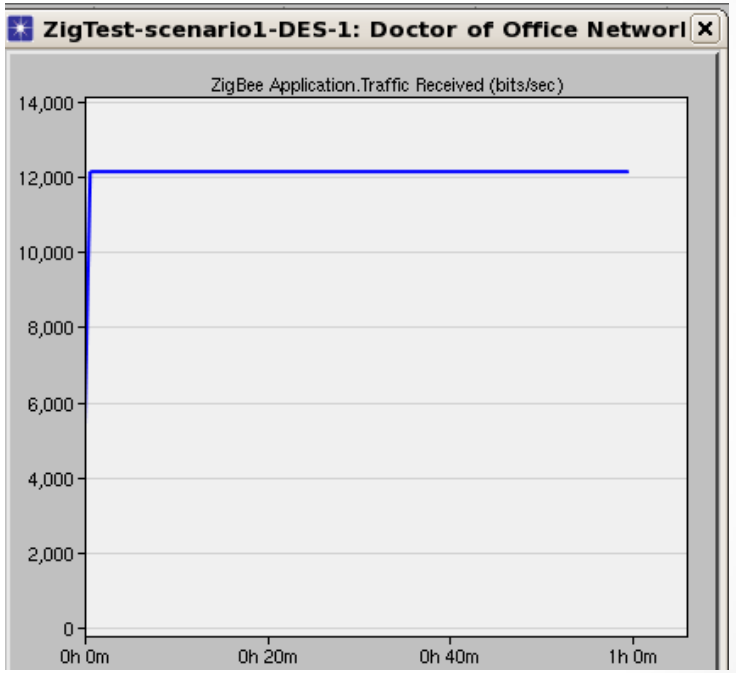
- Simulation Conditions
  - Time: 1 complete day

Basic Simulation



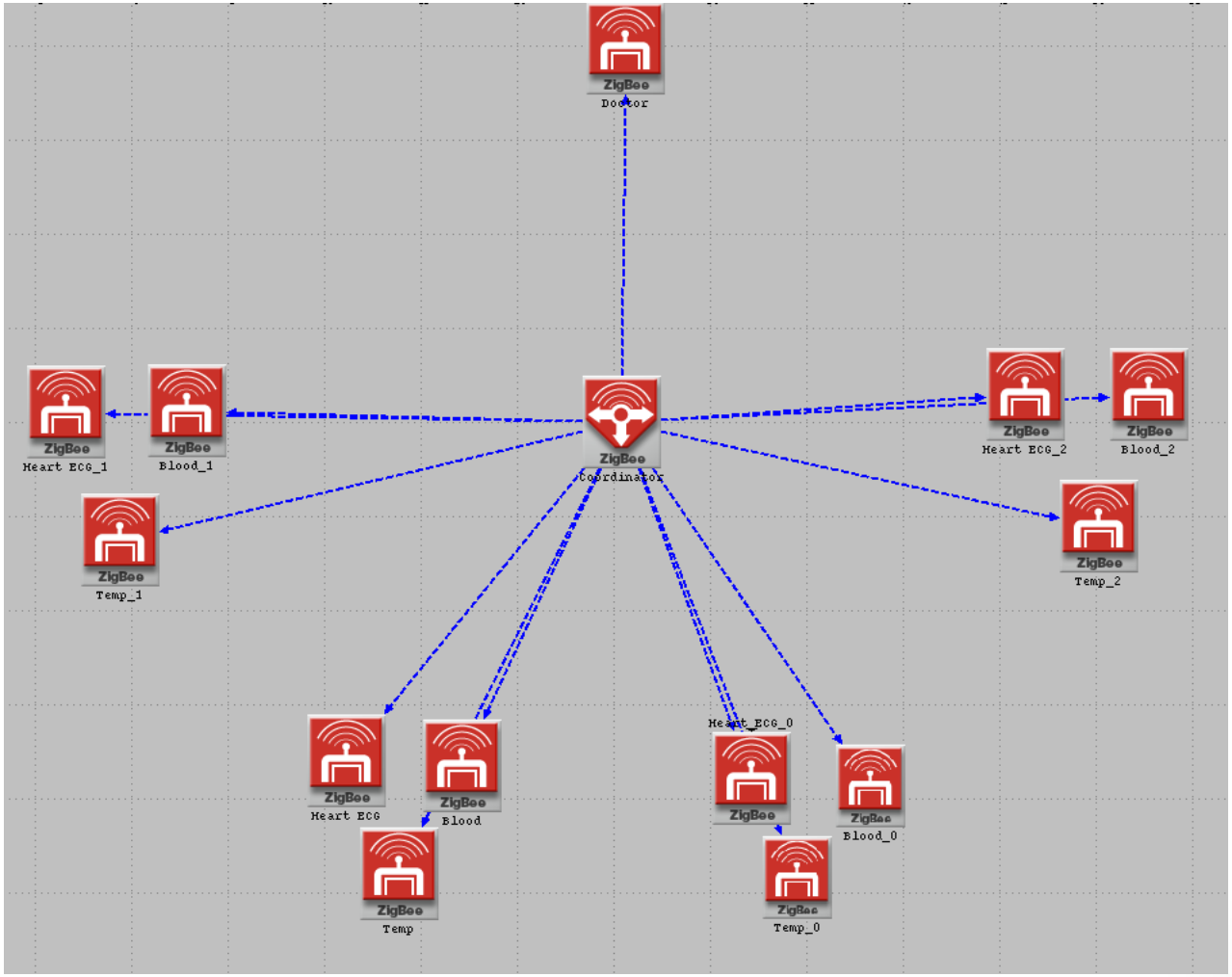
Basic Simulation Results



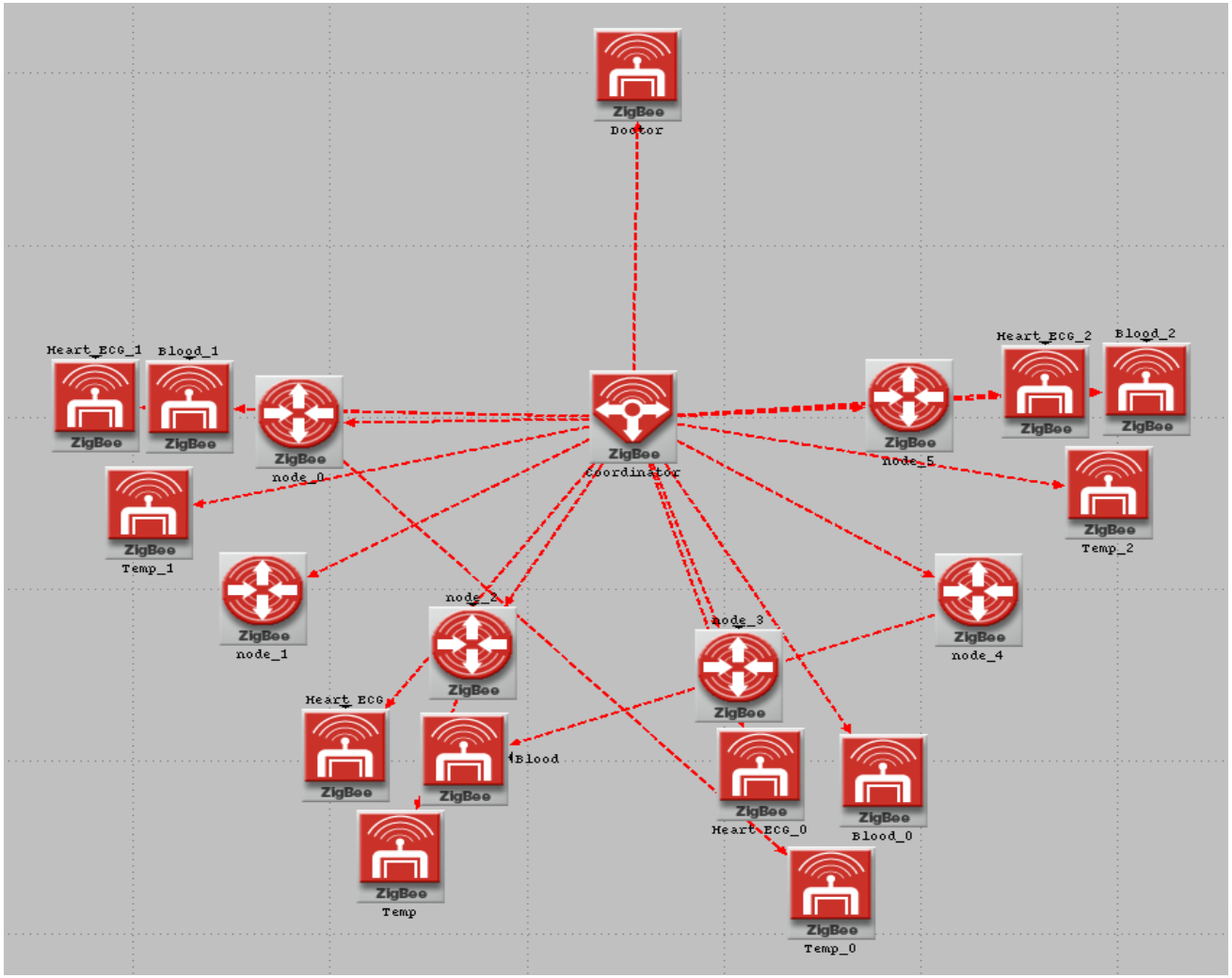


Ideal results for 1 patient:
12000+120+16 = 12136 bits/s

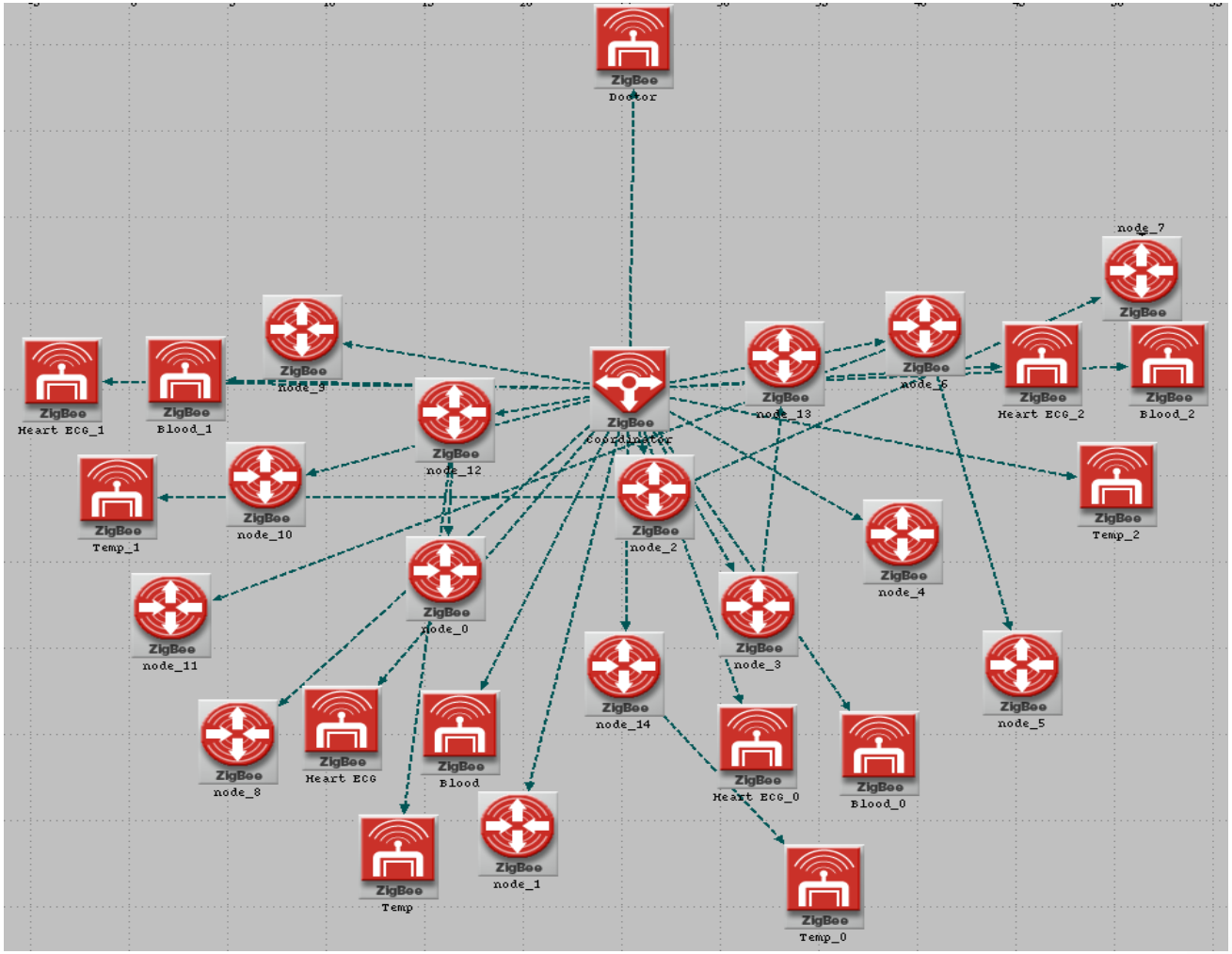
Star Topology



Tree Topology

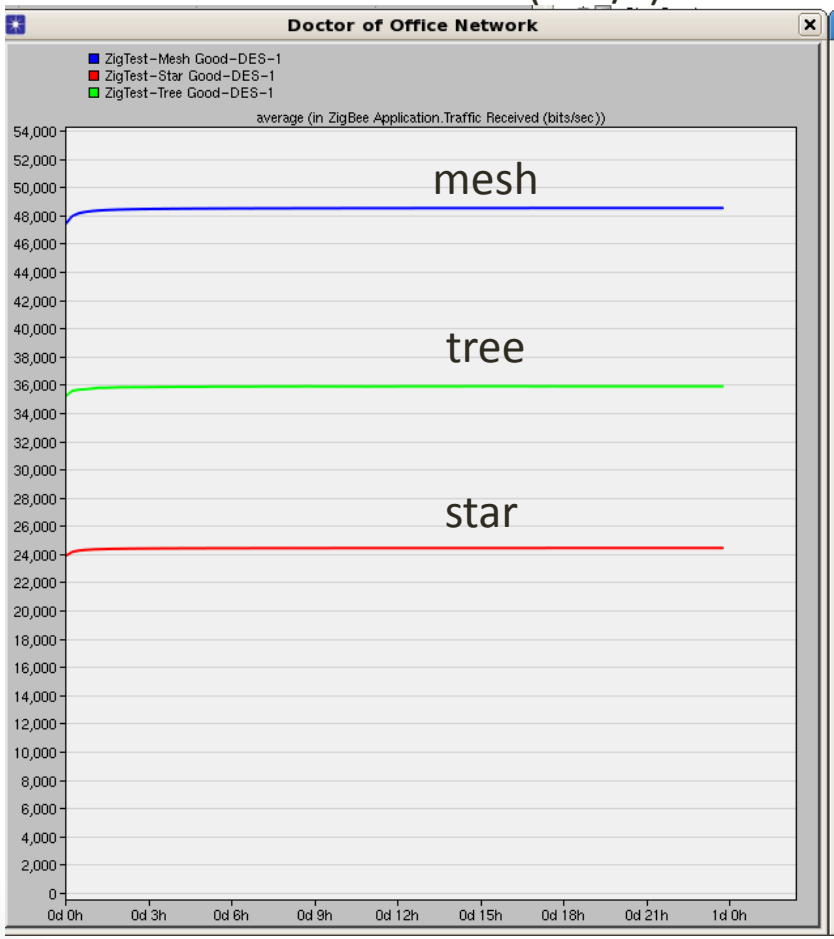


Mesh Topology

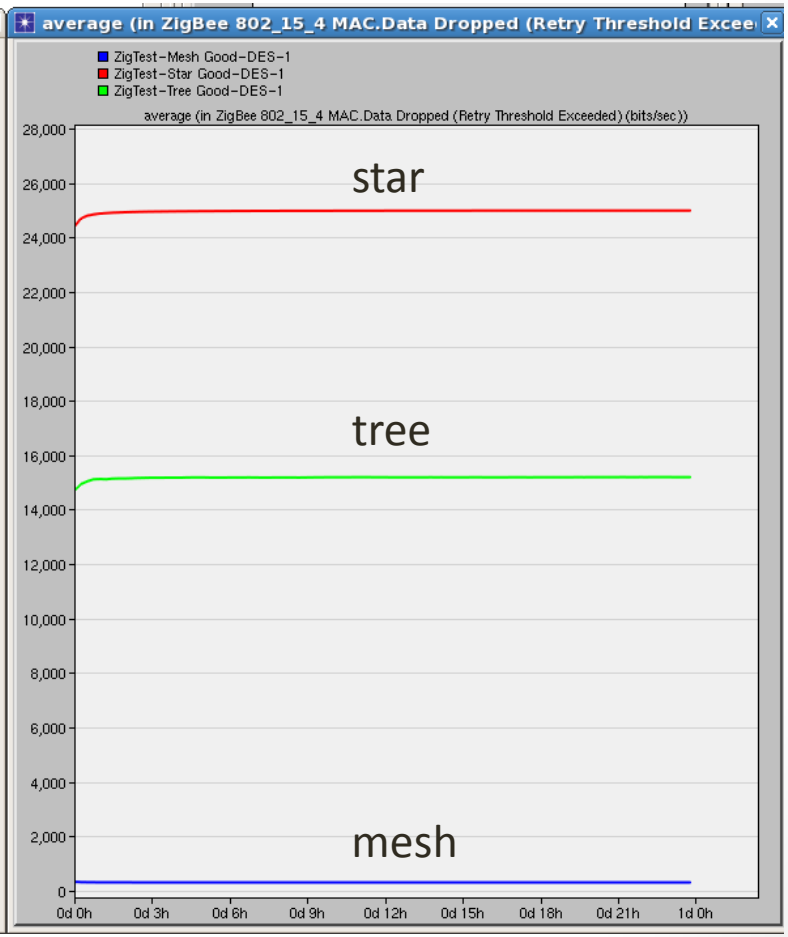


Results: Transmission Efficiency

Data Received (bits/s)

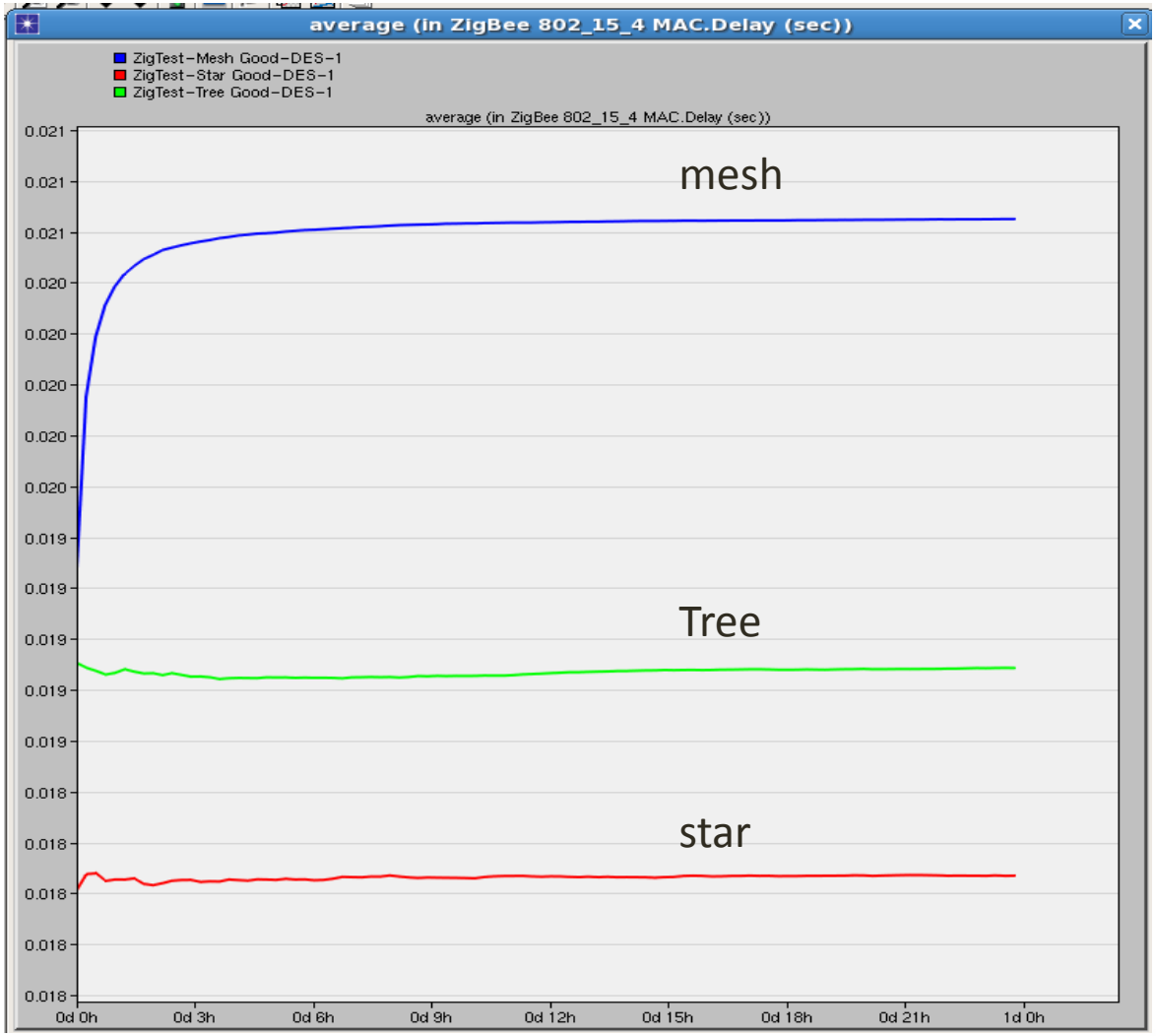


Data Dropped (bits/s)

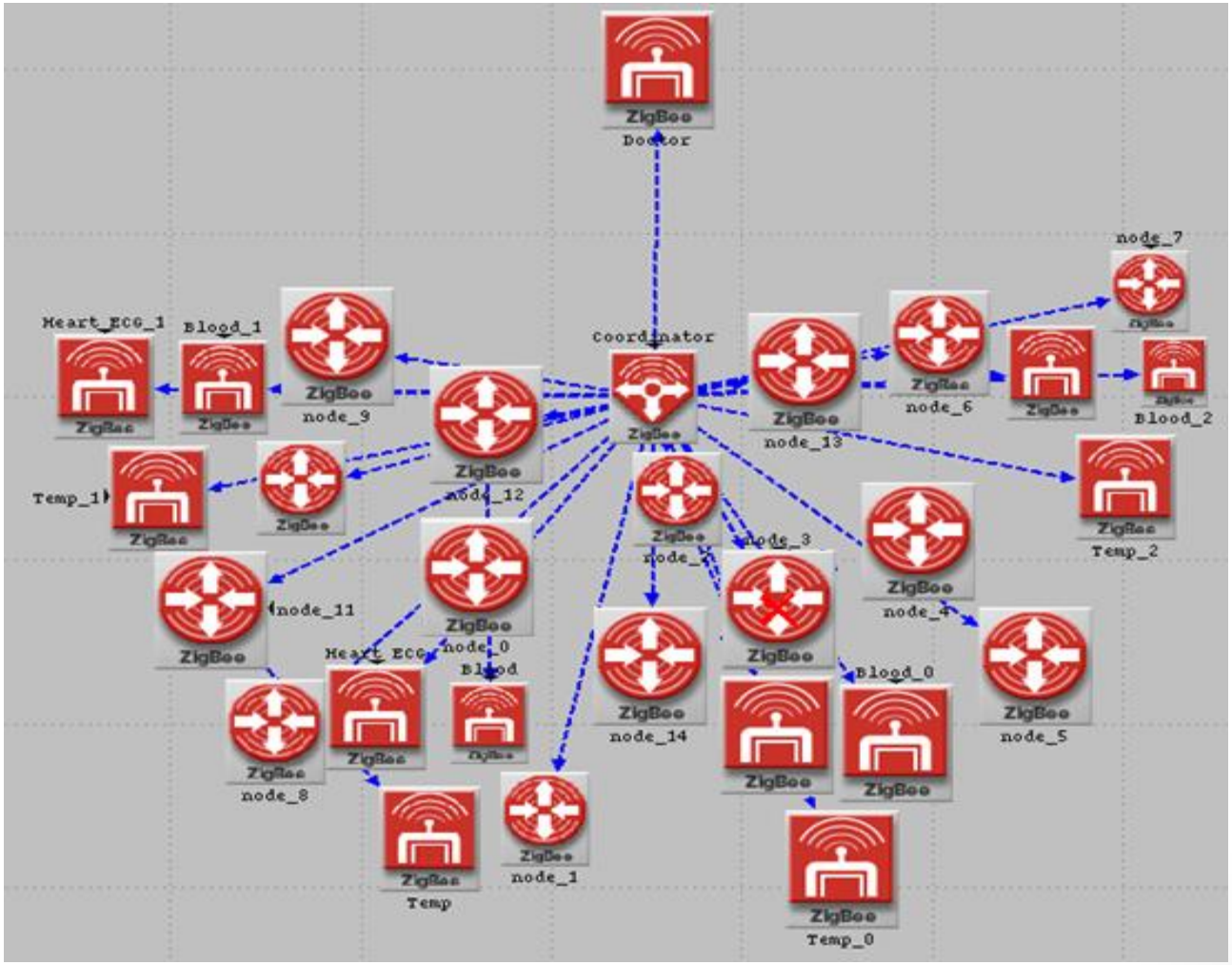


Ideal results for 4 patients - (12000+120+16)*4 = 48544 bits/s

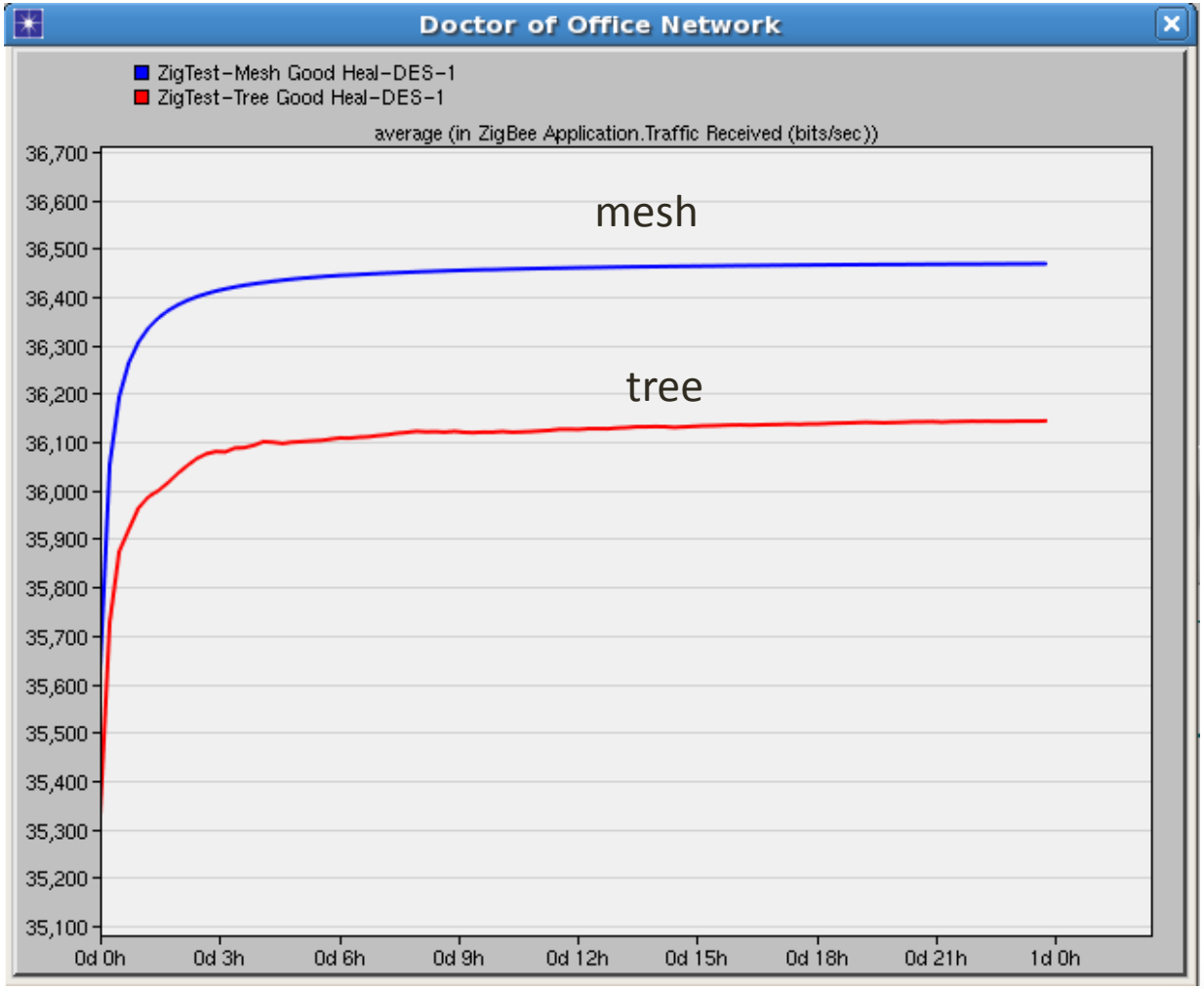
Results: Network Delay



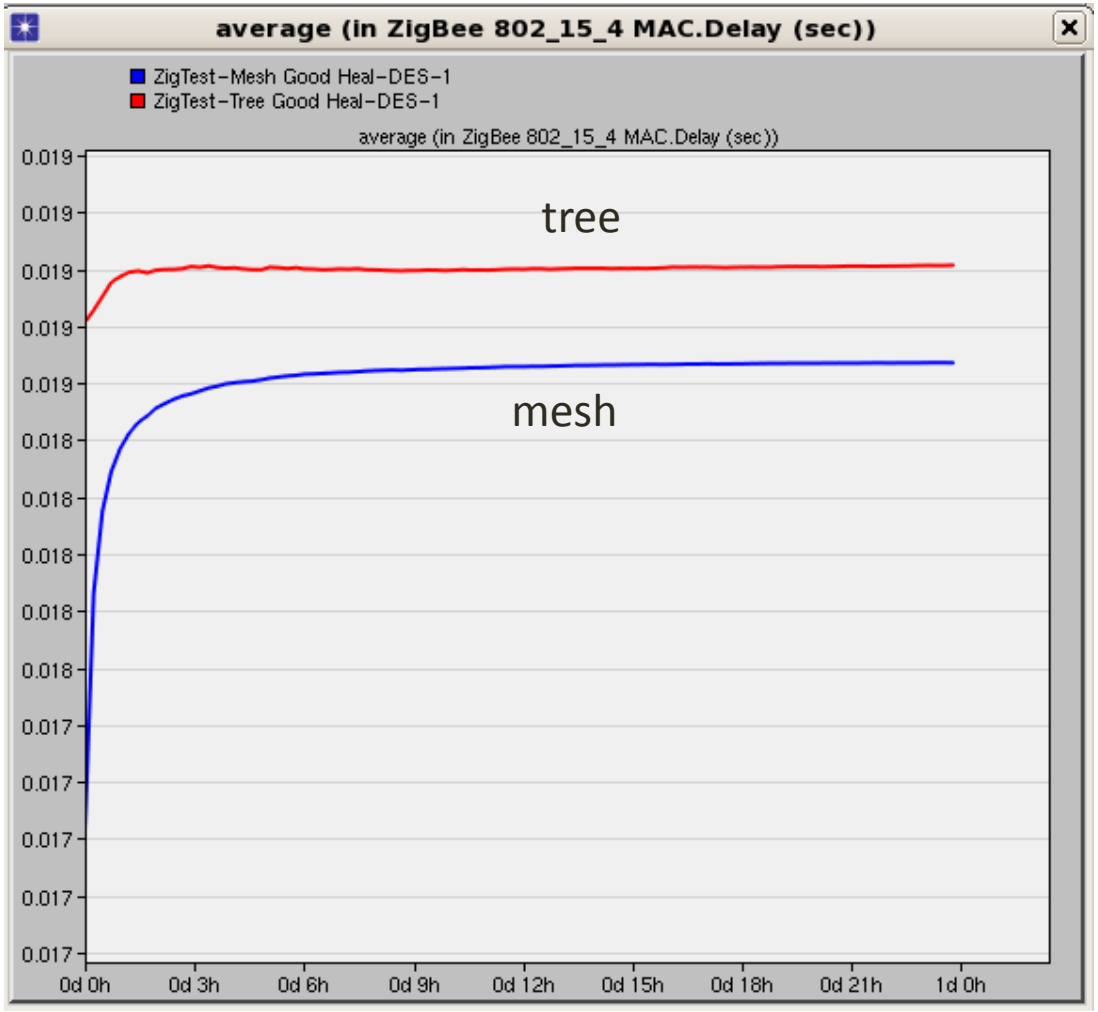
Self–healing Test



Results: Self-healing transmission efficiency



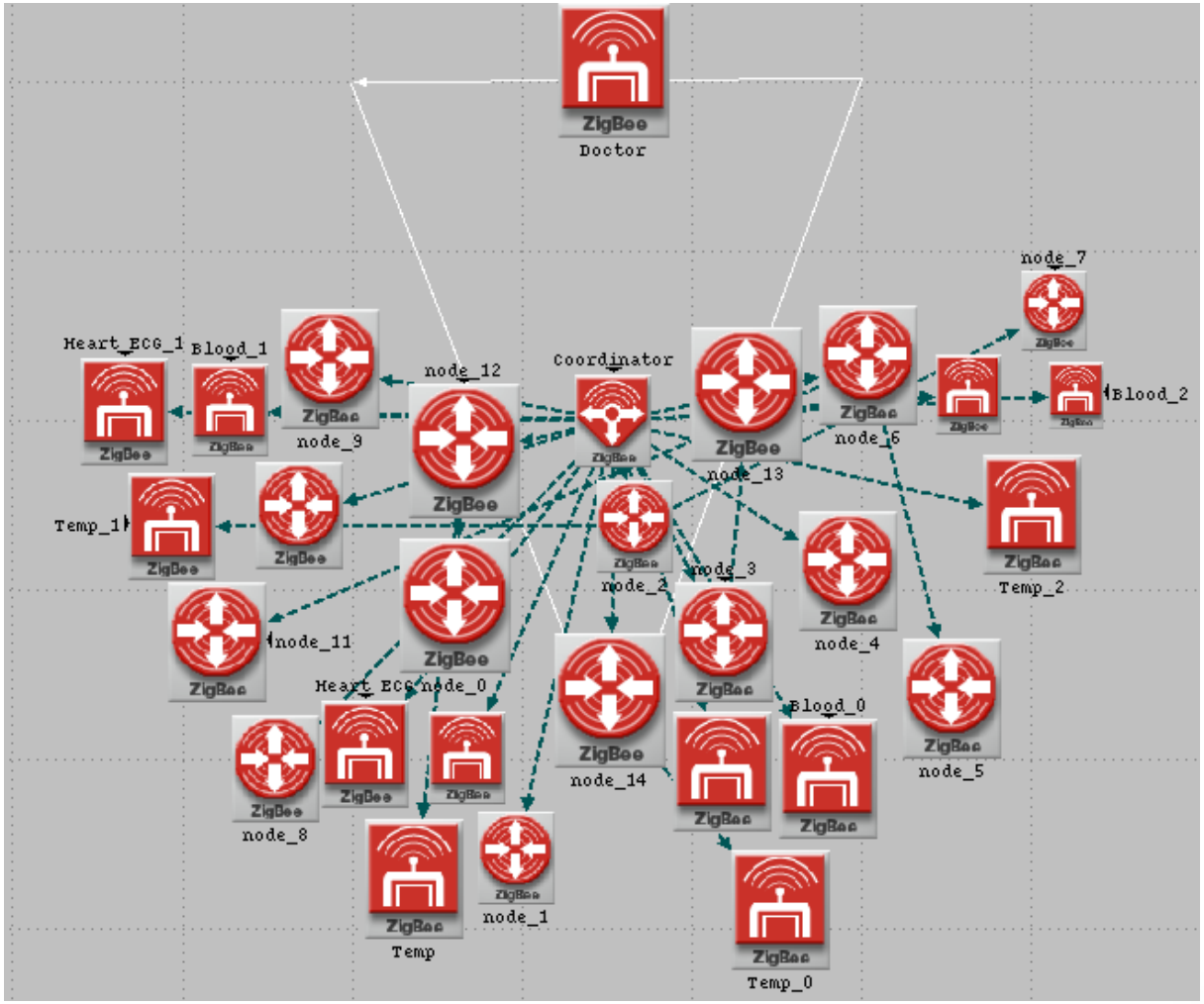
Results: Self-healing Network Delay



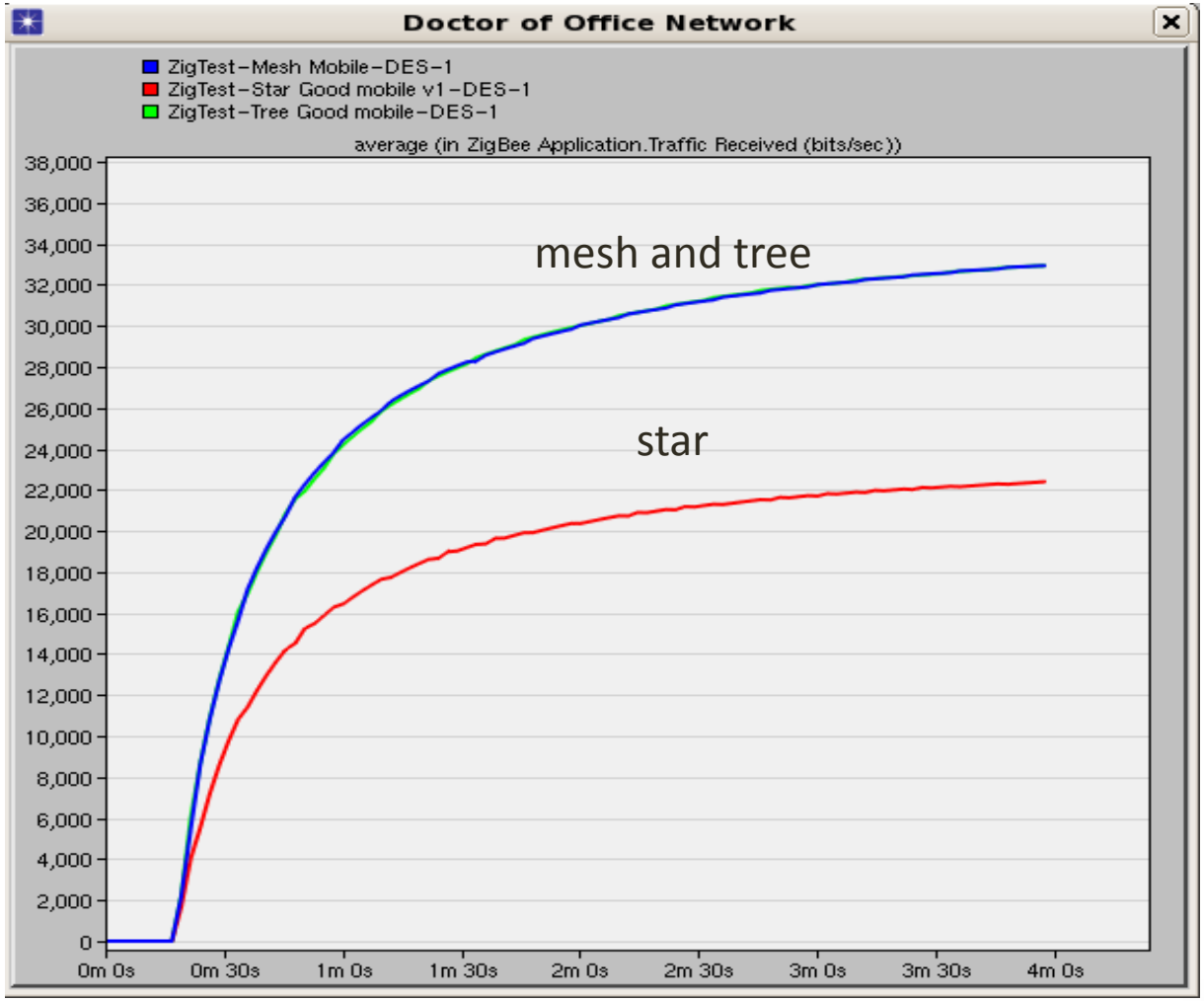
Mobile Simulations

- Medical professional is not always stationary
- Evaluation of the three topologies with a mobile medical professional
- Same trajectory used for each topology

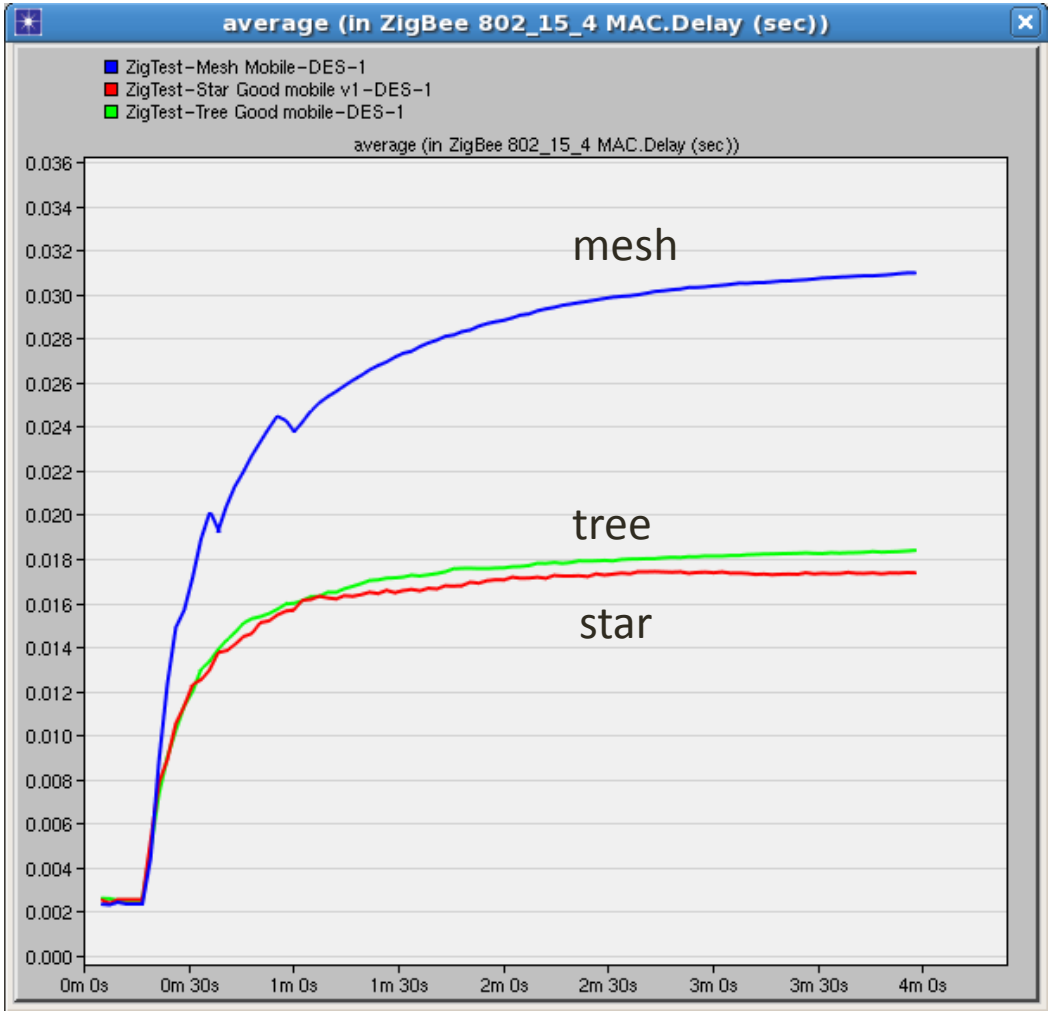
Mobile Trajectory



Results: Mobile Transmission efficiency



Results: Mobile Network Delay



Conclusions

- Mesh topology is most promising for medical monitoring environment
  - Higher transmission efficiency
  - Tolerable packet delay
  - Consistent performer in all test cases
  - Self-healing property maximized under failure cases

Future Work

- Security assessment
- More patients
- Determine what would be considered a dangerous level of network delay and data loss that could lead to patient fatality
- Compare against Wifi and Bluetooth
- Implementation of beacon mode

References

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Any Questions?