ECEN 5823-001
Internet of Things Embedded Firmware

Lecture #25

27 November 2018

Be Boulder.

University of Colorado Boulder

Agenda

- Class Announcements
- Course project rubric - preliminary
- Reading Assignment
- Final Exam
- Comparing different Low Power RF technologies
- Low power RF co-existence

Course Project questions/discussions

Class Announcements

- Course project update 2 is due Tuesday, November 27th at 11:59pm
- Final Exam is on Monday, December 17th
  - On-campus students will take it at 4:30pm in ECCS 1B14
  - Distant students the exam will be open at 4:30pm and must be completed by 11:59pm on the 17th

- Course demo signup has started!
  - https://docs.google.com/spreadsheets/d/16ptNNX_VnZ24nZUCIAx9v0wLgThQoEv4PflUBVypAbM/edit#gid=0
  - You must use your @Colorado.edu email address for access

ECEN 5823
Final Project Report Assignment
Fall 2018

Course Project Report

Objective: To update the status and state the project functionality as well as summarize what you have learned and accomplished.

Note: You can use your course project update #2 as a base for this final project report

Project Proposal Due Date: End of Day on December 13th via Canvas drop box

Team proposals: (Include and Provide update to the below items)

1. Describe what problem this project addresses
2. How does this project alleviate or solve the problem?
3. Functional block diagram of the team project
4. Summary of each individual project and how it plays a role in solving the problem
5. Project team members

Course Project Report Rubric

ECEN 5823-001
Internet of Things Embedded Firmware
Final Report Rubric worksheet
Fall 2018

Team Members: _____

Date: _____

	Points
Overview of project (1pts)	_____
What problem does the project solve? (1pts)	_____
Hardware block diagram (1pt)	_____
Key components (1pt)	_____
Functional Description (2pt)	_____

Reading Assignment

ECEN5023-001 – Reading List
Internet of Things Embedded Firmware
Week 13

There is no quiz on this reading, but material from these readings will be on the final exam!

1. "Selecting the Appropriate Wireless Mesh Network Technology"
    a. https://www.silabs.com/whitepapers/selecting-the-appropriate-wireless-mesh-network-technology

2. "Driving Wi-Fi, zigbee, and Thread coexistence in the 2.4 GHz band, part 1: Unmanaged coexistence"
    a. http://www.embedded-computing.com/embedded-computing-design/driving-wi-fi-zigbee-and-thread-coexistence-in-the-2-4-ghz-band-part-1-unmanaged-coexistence#

3. "Driving Wi-Fi, zigbee, and Thread coexistence in the 2.4 GHz band, part 2: Managed coexistence"
    a. http://www.embedded-computing.com/embedded-computing-design/driving-wi-fi-zigbee-and-thread-coexistence-in-the-2-4-ghz-band-part-2-managed-coexistence#

Final Exam

- This Final Exam comprises of 80 questions in total
  - You will have 90 minutes to complete
- Forty questions will be from past quizzes
  - These questions will be from quizzes 6 thru 10.
- Forty questions will be new questions based from lectures
  - These questions will be from lecture 13 onward
  - All questions related to assignment or the course project are also valid to be asked on the exam.
- All students are allowed notes comprising of both sides of a single sheet of 8x11 paper which must be turned in at the end of the final.
  - This page of notes must be of your original work.

Final Exam

- On-campus students must take the final exam in the assigned final exam room, ECCS 1B14, on Monday the 17th.
- Distant students will have until end of day, 11:59pm, on Monday, December 17th, to complete the final.
- CU Honor Code will be in forced for this exam.
- I will enable you to see your question responses after everyone has completed the final exam and I have completed grading the final exam.

Comparing ZigBee, Thread, and Bluetooth Mesh

- Which protocol dominates the smart home and building automation products?
- What are some of the important traits that these radio protocols must meet?
- If we wanted to measure robustness, how would we quantify it?

http://www.embedded-computing.com/networking/how-zigbee-thread-and-bluetooth-mesh-stack-ip-in-performance-benchmarking

Comparing ZigBee, Thread, and Bluetooth Mesh

- It is your job to pick and deploy an industrial automation mesh based system. What are the key considerations that you must analyze to make a decision?
  - Power consumption
  - Throughput
  - Latency
  - Scalability
  - Security
  - Internet Protocol (IP) connectivity

tp://www.embedded-computing.com/networking/how-zigbee-thread-and-bluetooth-mesh-stack-ip-in-performance-benchmarking

Comparing ZigBee, Thread, and Bluetooth Mesh

- What are the two basic low power RF wireless topologies?
- What are the two biggest reasons that mesh is chosen over star topology for industrial automation?
- What is a third reason that mesh is chosen for industrial automation?

Comparing ZigBee, Thread, and Bluetooth Mesh

- There are commonly three types of devices in an industrial automation network in terms of the perspective of power, what are they?
- Why would energy harvesting be found in an industrial automation system?
- Why would AC-powered devices be concerned with low power?

Comparing ZigBee, Thread, and Bluetooth Mesh

- Roughly, how much energy in the US is spent of “Vampire Devices?”
  - Americans spend $19 Billion dollars on “Vampire Energy” annually per Treehugger magazine

- How has the energy lost to “vampire devices” changed over the last 15-20 years?

https://www.treehugger.com/energy-efficiency/vampire-power-costs-americans-19-billion-electricity-every-year.html

Comparing ZigBee, Thread, and Bluetooth Mesh

- What are the use cases of meshed building automation devices?
- What are the routing methodologies for each of these mesh protocols?
- With routing, what does this infer about these devices?

Comparing ZigBee, Thread, and Bluetooth Mesh

- Going back to routing mesh networks, what benefits does it profit over flooding networks?

- What advantages does a “managed flooding” network have over a routing based mesh network?

ttp://www.embedded-computing.com/networking/how-zigbee-thread-and-bluetooth-mesh-stack-ip-in-performance-benchmarking

Comparing ZigBee, Thread, and Bluetooth Mesh

- Let's look at the differences in these mesh protocol max transmission payload packets?
  - ZigBee: 127-byte
  - Thread: 68-bytes
  - Bluetooth 16-bytes
  - All three protocols have methods for segmentation and reassembly for larger payloads

- What can you infer from these max packet sizes in terms of energy?

Comparing ZigBee, Thread, and Bluetooth Mesh

- What can you infer from these packet sizes regarding quantifiable measures of robustness?
  - Latency
  - Throughput
  - Reliability

ttp://www.embedded-computing.com/networking/how-zigbee-thread-and-bluetooth-mesh-stack-ip-in-performance-benchmarking

Comparing ZigBee, Thread, and Bluetooth Mesh

- ZigBee routes traffic through several techniques
  - Flooding of the mesh for route discovery or group messages
  - Next-hop routing for controlled messages
  - Many-to-one routing to a gateway

ttp://www.embedded-computing.com/networking/how-zigbee-thread-and-bluetooth-mesh-stack-ip-in-performance-benchmarking

Comparing ZigBee, Thread, and Bluetooth Mesh

- Thread routes traffic through several techniques
  - Next-hop routes to all routers as part of normal network maintenance instead of a device performing route discovery
  - Manages the number of active routers to address scalability to large networks as well as spacing
  - What advantages does limiting the number and spacing of active routers provide to the network?

ttp://www.embedded-computing.com/networking/how-zigbee-thread-and-bluetooth-mesh-stack-ip-in-performance-benchmarking

Comparing ZigBee, Thread, and Bluetooth Mesh

- Bluetooth supports “managed flooding”
  - The user can designate which powered devices participate in message flooding to reduce the impact to the network capacity
    - Requires the user to determine the appropriate density and topology for routers in the network
  - How does Bluetooth mesh managed active routers compare to Thread?

tp://www.embedded-computing.com/networking/how-zigbee-thread-and-bluetooth-mesh-stack-
ip-in-performance-benchmarking

Comparing ZigBee, Thread, and Bluetooth Mesh

- As a mesh network grows from 10-nodes to 100-nodes, what typically occurs in the network?
  - Grows in size
  - Increased density of devices
  - Increased number of hops
- What does all the above mean to the network?
  - Increased message latency
  - Decrease reliability

tp://www.embedded-computing.com/networking/how-zigbee-thread-and-bluetooth-mesh-stack-ip-in-performance-benchmarking

Comparing ZigBee, Thread, and Bluetooth Mesh

- Figures of merit
  - Throughput defines the scalability of the network as well as how well it can deliver higher data operations such as pushing out a firmware update
  - Latency describes how long an action to happen
    - People can detect operations that take longer than 100mS
    - Processes can require less than 100mS for synchronization
  - Reliability is just a must
    - For data transmission
    - Component/device operation

Comparing ZigBee, Thread, and Bluetooth Mesh

What does this chart tell us about latency?

Which would be more appropriate for time critical industrial automation?

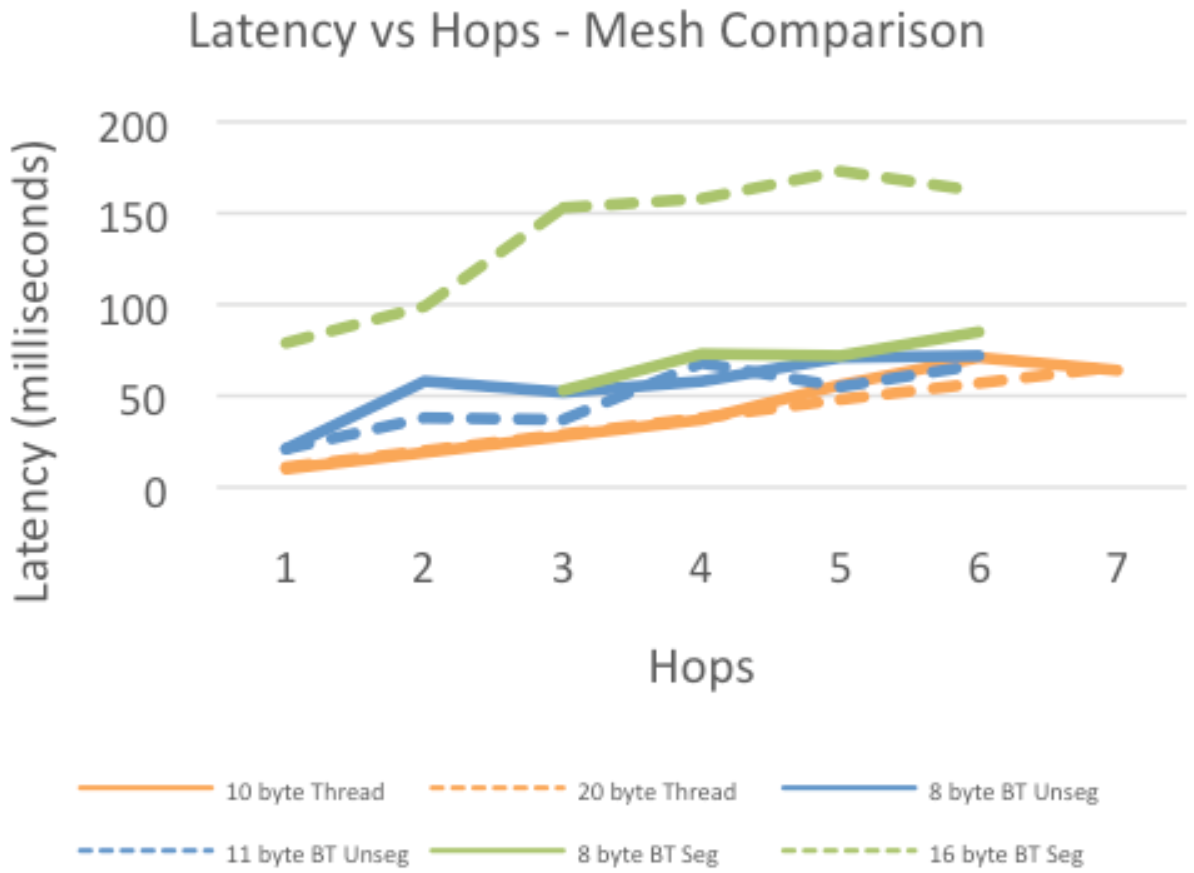

Figure 6. Latency versus hops

http://www.embedded-computing.com/networking/how-zigbee-thread-and-bluetooth-mesh-stack-ip-in-performance-benchmarking

Comparing ZigBee, Thread, and Bluetooth Mesh

What does this chart tell us about throughput?

What does this tell us about the type of applications for Bluetooth and Thread?

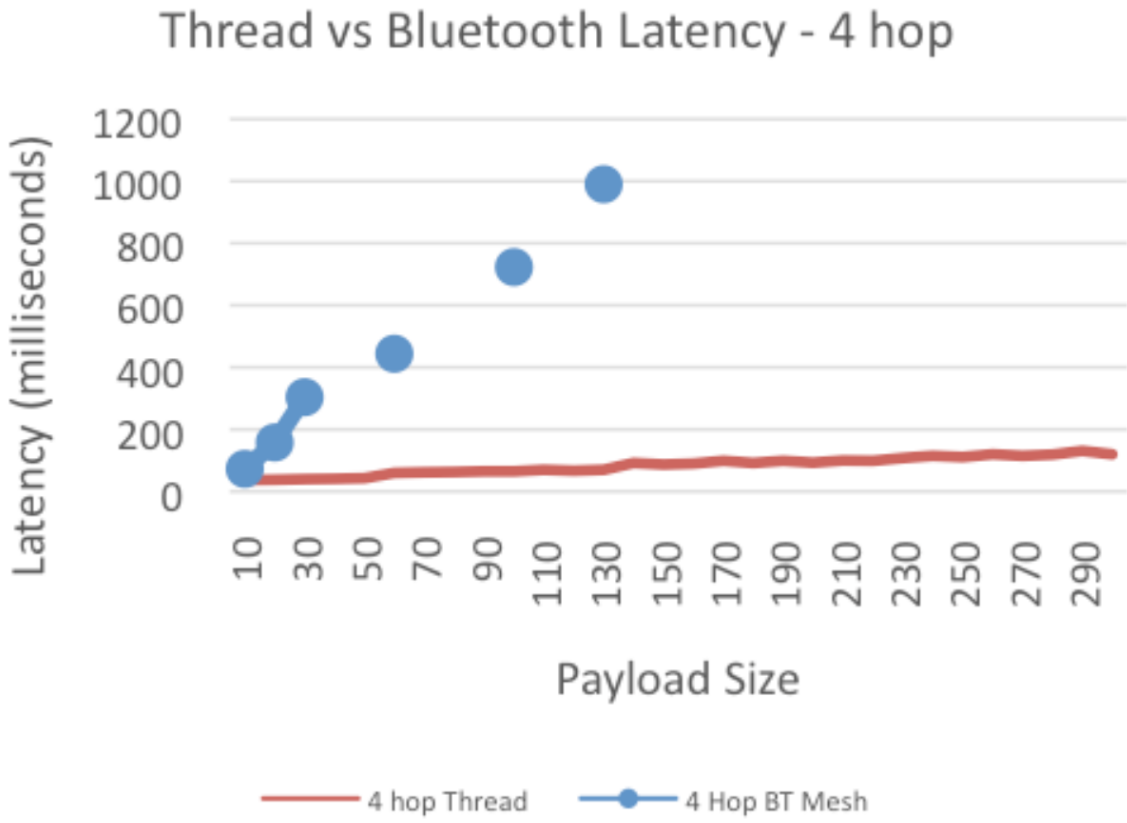

Figure 7. Thread versus Bluetooth mesh latency

http://www.embedded-computing.com/networking/how-zigbee-thread-and-bluetooth-mesh-stack-ip-in-performance-benchmarking

Comparing ZigBee, Thread, and Bluetooth Mesh

	Bluetooth Mesh	Thread	Zigbee
Market Focus	Lighting and Home Automation	Commercial/Industrial	Home Automation, Lighting, Metering
Maturity	Established 2017	Established 2015	Established 2003
Application Layer	Native Mesh Model	Flexibile support for IP-based application layers like dotdot, OCF and Nest Weave	Comprehensive Zigbee Cluster Library (ZCL)
IPv6	No	Yes	No
Cloud Connectivity	Smartphone (Temporary) Gateway	Border Router Gateway	Gateway
Ecosystems	None	Nest	Amazon, IKEA, Phillips HUE, Samsung SmartThings, Lowes Iris, Wink, Cox, Rogers, Deutsch Telekom (Qivicon) and others
Routing	Managed Flooding	Full Routing	Full Routing
Additional Notes	Beaconing, Direct Phone Connectivity	—	Most Mature

Comparing ZigBee, Thread, and Bluetooth Mesh

	Bluetooth Mesh	Thread	Zigbee
Application Layer(s)	Native - Mesh Model	IP Based e.g. dotdot, OCF, Weave	dotdot, zcl, HA, SE
Lighting	+++	+++	+++
Home Security	-	+++	+++
Home Automation	+	+++	+++
Building Automation	+	+++	+++
Metering	-	+++	+++
Beaconing	+	Full Routing	Full Routing

https://www.silabs.com/whitepapers/selecting-the-appropriate-wireless-mesh-network-technology

Comparing ZigBee, Thread, and Bluetooth Mesh

- Does one RF technology stand out from all the rest in that you can build an entire home or industrial automation with just that protocol?

- To connect to pre-existing systems in the existing ecosystem as well as to take advantage of the different protocols, multi-protocol systems will be required

tp://www.embedded-computing.com/networking/how-zigbee-thread-and-bluetooth-mesh-stack-ip-in-performance-benchmarking

Comparing ZigBee, Thread, and Bluetooth Mesh

- The addresses available to all these networks are quite large, the practical limit is in the 100s
  - Why are these systems limited in the hundreds and not in the thousands?

ttp://www.embedded-computing.com/networking/how-zigbee-thread-and-bluetooth-mesh-stack-ip-in-performance-benchmarking