University of Colorado Boulder

ECEN 5823 IoT Embedded Firmware

Final Course Project

Home Automation using Bluetooth Mesh

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Home Automation using Bluetooth Mesh

Summary

We are taking the commonly implemented Door unlocking mechanism using a smart phone app and extended it further to make smart room lighting decisions. Whenever we enter the house, the first thing we do is switch on the lights. We are planning to build a system which takes the daylight measure, and decide the course of actions. Whenever we enter the house i.e. the door unlocked event occurs, depending on the time of the day – either the lights turn on or the window blinds roll up. We generally turn on the lights as it is an easy task vs reaching the window and manually opening up the blinds. The system does it automatically using Bluetooth Mesh, which in turn proves to be an energy/effort saving technique.

But what if we want to roll down the window blinds during the day. We can roll down the blinds with the smartphone app too.

The lights can be controlled individually using the smartphone app as well.

The Door module indicates the window module, and the window module in turn indicated the Room light module depending on the daylight sensor value. This communication is possible due to mesh network. Above that, all the nodes can be controlled using the smartphone which in turn communicates only to the proxy node i.e. Door module. The pub-sub feature of the mesh enables us to have control over each module and perform actions as and when required. So above are the advantages of using Bluetooth Mesh.

Modules used

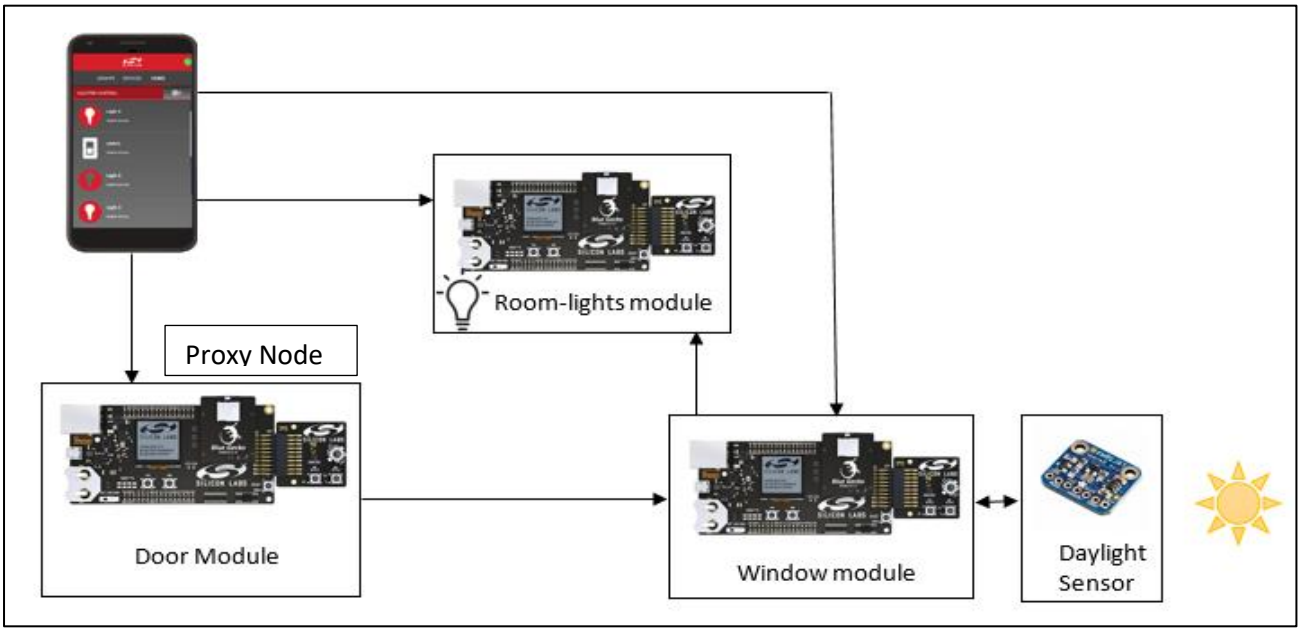
1. Door lock/unlock module (Blue Gecko board)
    - This will be Proxy node[1] with a control model
        i. Server model which listens to the Smartphone and changes the state. Generic OnOff Serve model.
        ii. Client model which is responsible to send the messages to other server model nodes such as the Window module and the Room Light module. Generic OnOff Client model.
    - The lock/unlock state will be indicated using LED.
    - The door unlocks only if a certain set pattern is entered using the Joystick.
2. Room Lights module (Blue Gecko board)
    - This will be Proxy node[1] with a server model
        i. Generic OnOff Server model
    - LEDs will be used
3. Window module (Blue Gecko board) with Daylight sensor (Adafruit TSL2561)
    - This will be Proxy node[1] with the control model
        i. Server model which changes its state from sleep state to active state.
        ii. Client model which sends the message to the Room light module server model depending on the daylight sensor value
    - The rolled up/down state will be indicated using LED.
    - The Daylight sensor used will be the Adafruit TSL2561 Digital Luminosity/Lux/Light Sensor Breakout (PRODUCT ID: 439), having an **I2C interface**. The module requires a supply current of

0.6 mA(MAX) as per the Datasheet. This enables us to use a **GPIO for Load power management** of the module.

The above modules will expose:

- Mesh Provisioning services
- Mesh Proxy Services

Functional Block diagram



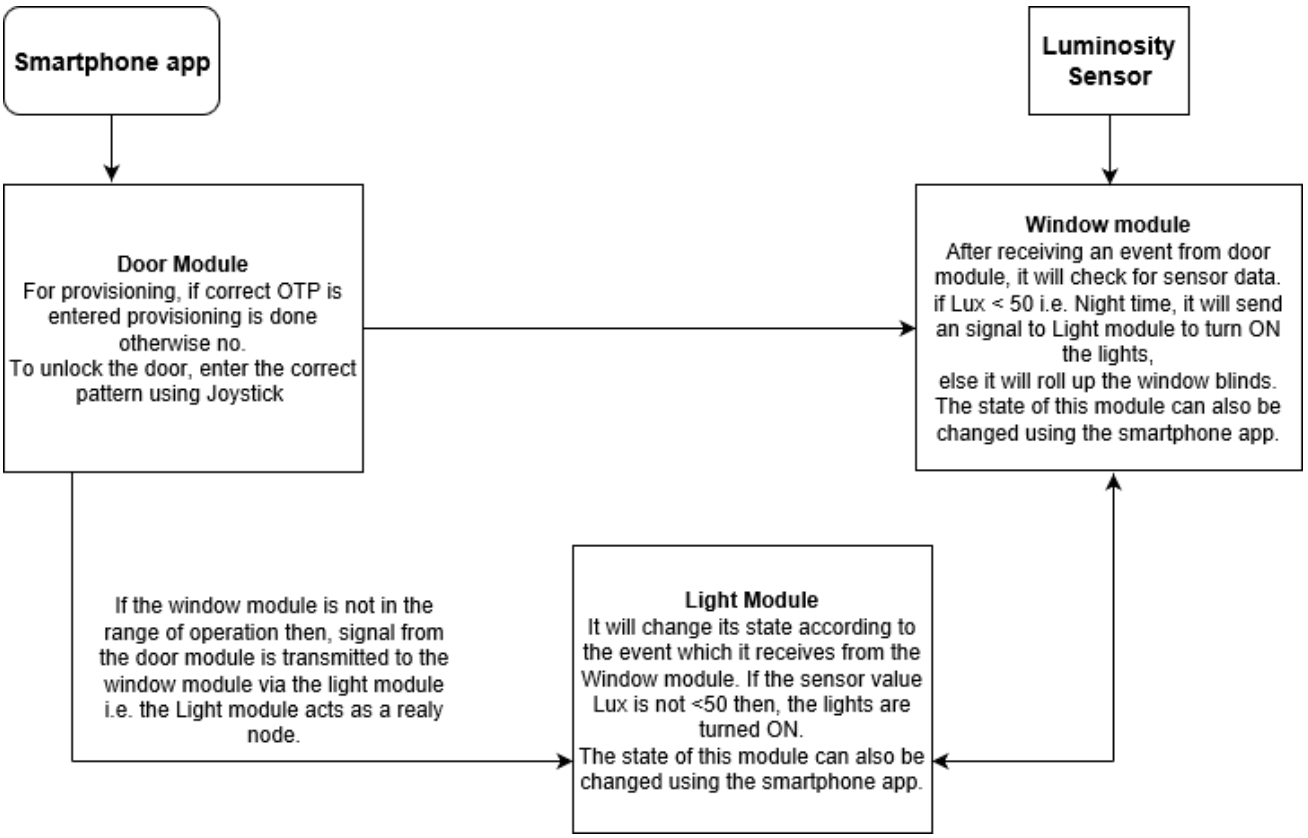
Project Development Schedule

Tasks	Expected Deadline
OTA firmware update	11/9/2017
Understanding SiLabs Bluetooth Mesh SDK	11/11/2017
Interfacing code for Light sensor with Window Module	11/14/2017
Persistent Data storage code module	11/18/2017
Interfacing code to LCD	11/18/2017
Developing Bluetooth Mesh code for Room light module	11/20/2017
Developing Bluetooth Mesh code for Door module	11/23/2017
Developing Bluetooth Mesh code for Window Module	12/05/2017
Integrating Light sensor to Window Module	12/06/2017
Integrating all the modules and testing of system	12/08/2017
Final demo of Project	12/14/2017

Functionality

The smartphone app has 1-many connections. Smartphone app can control the Door, Light, and Window module.
While provisioning the Nodes, we have added OOB authentication. A random 6 digit numeric OTP is generated and displayed on the LCD, from which we have to input the values onto the Smartphone App to successfully provision the node. The door and window module supports this OOB functionality whereas the Light node does not require any OOB authentication.
The door module (Proxy node) is responsible to listen to the smartphone and change its state from lock to unlock. This change of state triggers the signal to the Window module. The door module can only be unlocked if we give a certain pattern using joystick. In the joystick as we press North, south, east and west, in our code, values 1,2,3 and 4 are stored in the array respectively. The required pattern is hardcoded in our code, if the input pattern and the required pattern is same the door unlocks.
The window module will be in sleep mode, as soon as it receives the signal from the Door module, it powers on the sensor using a GPIO, takes the value of the sensor and depending on the sensor value, it decided either to roll up the window blinds or send ON signal to the LED module.
The LED module is a pure server module as it just decides its state specified by the window module.

Flow of the project



Verification plan

Sr No	To be verified	Definition of passing	Date test performed	Tested by	Measured Result	Passed
1	Developing persistent memory routine	State of the LEDs should be retained even after power is removed. (except the door module)	11/18/2017	Gunj & Vipraja	State of the LEDs are retained (except the door module)	Yes
2	Interfacing code to SPI LCD display	Display State of LEDs, Module name, Module address and information that tells us whether the module is provisioned or not.	12/1/2017	Gunj & Vipraja	Status messages were dynamically printed along with the changed background/foreground.	Yes
3	Interface software to new sensor	Get correct sensor data	12/13/2017	Vipraja	Got correct sensor data	Yes
4	Integrating sensor to application code (Daytime scenario)	Using the sensor data, we perform actions. If its Daytime – Roll up the window blinds and no action on Lights	12/14/2017	Vipraja	Sensor value is greater than "" then its Day time – Roll up the window blinds and take no action on Lights	Yes
5	Integrating sensor to application code (Night time scenario) (Window node Client model testing)	If it's Night time – Turn on Lights and no action on window blinds	12/14/2017	Vipraja	Sensor value is less than "" then its Night time – Turn on the Lights and no action is taken on the window blinds	Yes
6	Unlock door from mobile (Door module Server model test) -Feature added: Added security through pattern. Refer 14	The door unlocks	11/23/2017	Vipraja	The LED changes the state indicating Door unlock	Yes
7	Control Lights using App (Light room node server model testing)	Lights can be turned on/off	11/23/2017	Gunj	The LED changed states when we change it from mobile	Yes
8	Control Lights using window module	If the Lux value is <50 then, the window module will send a signal to light module to switch on the lights	11/14/2017	Gunj	The lights turn ON when the sensor value is <50	Yes

9	Control window blinds using App (Window node server model testing)	Window blinds can be rolled down/up	11/23/2017	Gunj	The LED changes the state indicating Window blinds rolled down	Yes
10	On unlock door event, the door model sends message to the Window node and it changes it state from sleep to active. (Door node Client model testing and Window	The window node takes the sensor data and perform actions depending on the sensor data.	11/23/2017	Gunj	The state of the window module changes. We can see the change in state displayed on the LCD.	Yes
11	OOB Authentication	One time password i.e. a random number should be generated and displayed on the module LCD. Which will be used to authenticate and provision that module.	12/12/2017	Gunj	One time password is generated and displayed on the module LCD, when we enter that number in our smartphone app, module provisioning is completed.	Yes
12	Flooding	Use Light Module as relay node. The light node receives and retransmits Bluetooth mesh messages using the advertising bearer.	12/14/2017	Gunj and Vipraja	The relay feature makes it possible for Bluetooth mesh messages to make multiple hops between devices and travel beyond the direct radio range of door module and window module, right across the network.	Yes
13	TX power optimization	We customize the range of operation of all the modules. We can check that separating the modules away from each other and check if they are transmitting.	12/13/2017	Gunj	The range of operation of the modules are changed.	Yes
14	Integrating all the modules and testing of system	All the modules should communicate with each other	12/13/2017	Gunj	All the modules communicate with each other	Yes
15	Use joystick for security	For security, we use joystick to give a pattern to the module. If certain pattern is obtained from the joystick then, unlock the door.	12/13/2017	Vipraja	We enter the pattern using joystick and the door unlocks.	Yes

Difficulties encountered on the project

1. We spent days on trying to integrate the Luminosity sensor to our code, the problem which we encountered was that our sensor was damaged.
2. We faced issues in Out of band authentication.
3. Our relay node i.e. Light module couldn't make multiple hops between devices and travel beyond the direct radio range of two modules, right across the network.
4. While programming our sensor, we weren't getting correct Lux values. As scaling had to be performed prior to calculating illuminance if the gain is not 16x.
5. Implementing Control model for the Door and Window model as there was no UI to do that. We had to do it manually by modifying the *_dcd file and looking up the correct values and bit masks for different configurations on the Mesh Profile/Models specifications document online.

Lessons Learnt from the project

1. Learnt how to implement Bluetooth mesh.
    a. How to implement OOB authentication while provisioning
    b. How to implement a Control Model
    c. Know where to make changes in the project to include models and elements in the node i.e. There is the DCD file which has all the configurations where we can make changes and modify as per our need.
2. We configured new sensor i.e. Luminosity sensor.
3. We should have started testing our sensor early, so we could have known the problem earlier.

Project Team Members

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Feedback Answers:

Q: In the write up, it describes the door module as a proxy node, but the block diagram has both the door module and window module as proxy nodes. Should the window node just be a mesh node?

A: Our project had the intention of controlling all the nodes/modules from the smartphone. I looked into the way Silicon labs mobile application sends when a light node is turned on/off, it sends the request directly to that node. I had an understanding that the mobile app sends request to the proxy node which in turn sends the request to the specific node changing the state.

However, we can implement such behaviour if required but the Silicon lab mobile app proves to be a limitation here.

In order to control the modules from the mobile app, we need to have the proxy service active in all the modules making them Proxy nodes.

References

1. Bluetooth LE: Mesh, https://www.bluetooth.com/what-is-bluetooth-technology/how-it-works/le-mesh?utm_campaign=mesh&utm_source=google&utm_medium=cpc&utm_term=trusted-tech&utm_content=gaw-october-general-mesh&mkwid=s&pcrid=227057148453&pkw=%2Bbluetooth%20%2Bmesh&pmt=b&pdv=c&gclid=EAIaIQobChMI1bjU29yK2AIVUZ7ACh3GDQ39EAAYASAAEgItu_D_BwE
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