SMART SWITCH
For Home Automation
Using BLE MESH Technology

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ABSTRACT

Home Automation in the modern world refers to the smartening of daily use devices and appliances through the means of IoT. Today, most smart home products are constrained to a single ecosystem with vendors supporting only their proprietary applications. These are also mostly confined to Wi-Fi based systems making them costly.

We try to make systems vendor independent & achieve power efficiency by designing a **SMART SWITCH** to control and monitor home appliances efficiently. Present methods of tackling this problem involve centralized control systems like DALI (Digital Addressable Lighting Interface). The Proposed Solution consists of a decentralized system using BLE Mesh Network. Decentralized systems distribute the intelligence of the system across multiple devices. A common set of rules which must be abided by are known by each device. Each respective device can process information relevant to itself and those around it, and the decision making can be made by each device within the boundaries of the rules given. A decentralized system ensures that, regardless of any singular failure anywhere in the system, the wider system remains unimpacted. BLE allows for secure commissioning of device and reliable data transmission.

<u>Novelty of Approach:</u>

Unlike the conventional existing approaches, the proposed solution also uses occupancy detection techniques utilizing RSSI based BLE sniffers. The power consumption of the proposed system is very low. This is because BLE Mesh allows for devices to enter ‘Sleep’ state (LPN & Friend Nodes) when not in use.

<u>Equipment used:</u>

nRF52832, ESP32 microcontrollers, LED’s, sensors, nRF Mesh App.

<u>Results:</u>

We were able to achieve a working prototype demonstrating lighting applications using RSSI based occupancy detection. We also implemented nodes for battery operated sensor to demonstrate power saving capabilities of the BLE Mesh Network.

CHAPTER 1

Introduction

1.1 Background

We all use several different appliances in our day-to-day life which we encounter quite frequently. These may include fans, lights, switches etc. These entities are dispersed throughout the rooms and may not be accessible easily all the time. Also, these placements are permanent and hence may not always be comfortable with our plans. While using these, we may not always be using them efficiently.

Hence to create a more robust system, so as to improve human comfort and enhance usage quality, we must develop a more ‘aware system’ to incorporate more and more appliances in a single, interconnected and smart network.

1.2 Aim of the Project

To make systems vendor independent & achieve power efficiency by designing a SMART SWITCH to control and monitor home appliances efficiently which consists of a decentralized system using BLE Mesh Network.

1.3 Objectives

Objectives:

- To control a network of interconnected appliances and devices inside a home using smart switch.
- These devices can be controlled wirelessly from anywhere inside the house by the user.
- Devices can automatically detect the presence of the user and perform automated tasks such turning lights on/off, setting mood lightings.
- Provide the option to the user to create presets such as night (turns off lights, turns off night light, closes curtains, etc.).

CHAPTER 2

System Specifications and Results

2.1 Block diagram

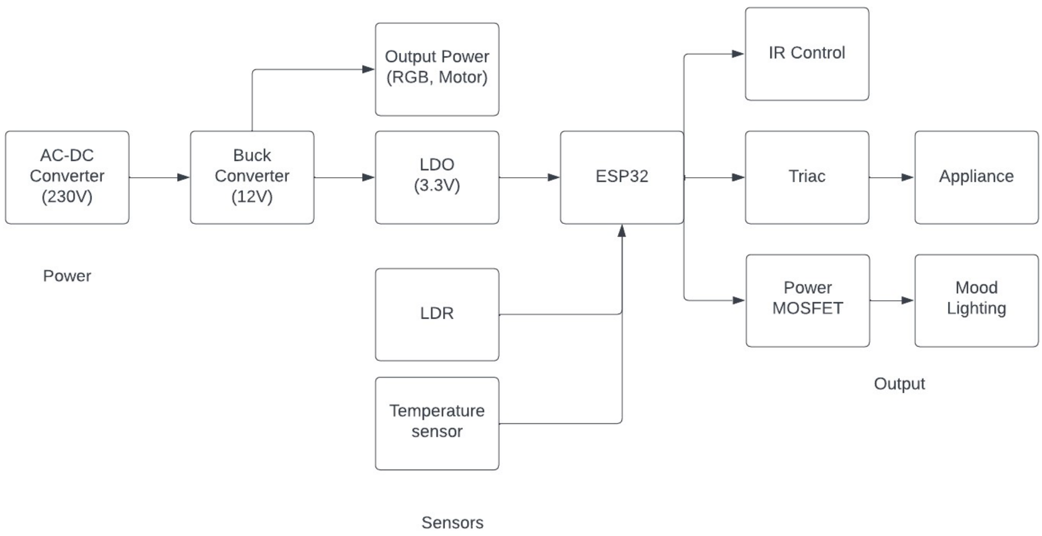

Fig: 2.1: Block Diagram of System

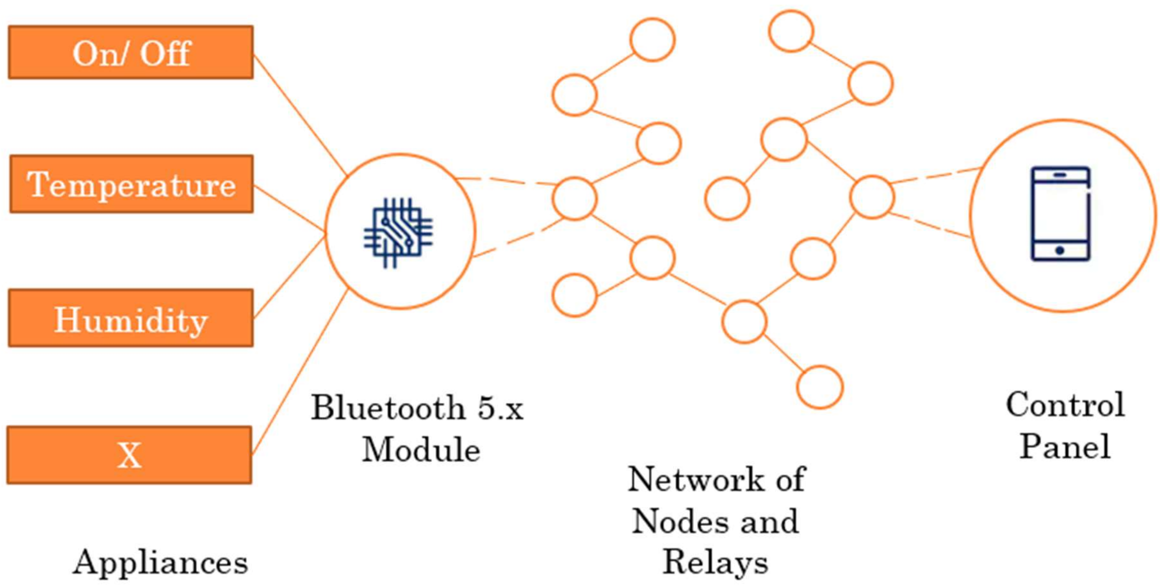

Fig: 2.2: BLE Mesh Network

2.2 Hardware / software resources

Hardware Requirements:

nRF52-DK (nRF52832 Development Kit)	ESP-32	Triac (600 V 4A)
AC-DC Converter (240 V 50Hz to 12V 3W)	LDO Regulator	Buck Converter
AHT21 temperature sensor	PIR sensor	LDR

Software Requirements:

nRF Connect SDK (2.1.0)	nRF Mesh Mobile Application
nRF Connect App	Visual Studio Code
ESP-IDF	Autodesk Fusion 360
Autodesk Eagle	

2.3 BLE Mesh Protocol

At the bottom of the mesh architecture stack, we have a layer entitled Bluetooth LE. In fact, this is more than just a single layer of the mesh architecture, it’s the full Bluetooth LE stack, which is required to provide fundamental wireless communications capabilities which are leveraged by the mesh architecture which sits on top of it. It should be clear that the mesh system is dependent upon the availability of a Bluetooth LE stack.

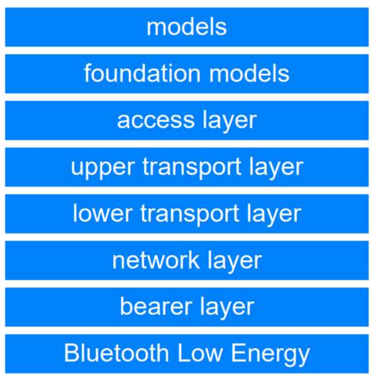

Fig: 2.3: BLE Mesh Architecture Stack

- Bearer Layer: Mesh messages require an underlying communications system for their transmission and receipt. The bearer layer defines how mesh PDUs will be handled by a given communications system. At this time, two bearers are defined, namely the Advertising Bearer and the GATT Bearer. The Advertising Bearer leverages Bluetooth LE's GAP advertising and scanning features to convey and receive mesh PDUs.
- Network Layer: The network layer defines the various message address types and a network message format which allows transport layer PDUs to be transported by the bearer layer. It can support multiple bearers, each of which may have multiple network interfaces, including the local interface which is used for communication between elements that are part of the same node.
- Lower Transport Layer: The lower transport layer takes PDUs from the upper transport layer and sends them to the lower transport layer on a peer device. For longer packets, which will not fit into a single Transport PDU, the lower transport layer will perform segmentation, splitting the PDU into multiple Transport PDUs. The receiving lower transport layer on the other device, will reassemble the segments into a single upper transport layer PDU and pass this up the stack.
- Upper Transport Layer: The upper transport layer is responsible for the encryption, decryption and authentication of application data passing to and from the access layer. It also has responsibility for transport control messages, which are internally generated and sent between the upper transport layers on different peer nodes. These include messages related to friendship and heartbeats.
- Access Layer: The access layer is responsible for defining how applications can make use of the upper transport layer.
  This includes:
  Defining the format of application data.
  Defining and controlling the encryption and decryption process which is performed in the upper transport layer.
  Verifying that data received from the upper transport layer is for the right network and application, before forwarding the data up the stack.
- Foundation Models: The foundation model layer is responsible for the implementation of those models concerned with the configuration and management of a mesh network.

- Models: The model layer is concerned with the implementation of Models and as such, the implementation of behaviors, messages, states, state bindings and so on, as defined in one or more model specifications. Tuning connection parameters significantly are several steps required after waking up the Low Power Node.

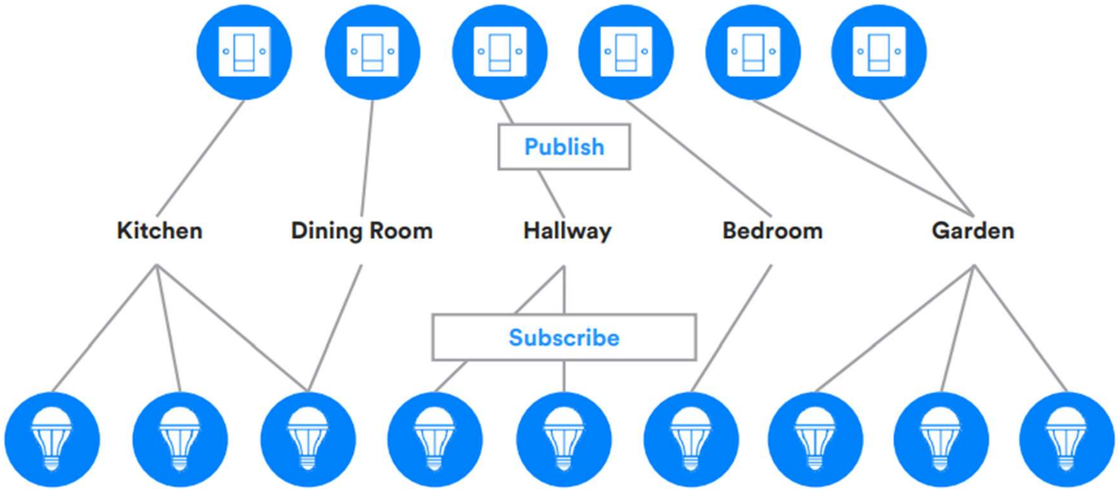

Fig: 2.4: Pub-Sub Model

Fig. 2.4, the Pub-Sub Model shows Publishing and subscribing to groups to communicate to connected nodes. This allows for communicating same message to multiple elements in the same group.

2.4 Results

Achieved a working prototype for the following:

- Smart switches controlled using BLE Mesh Network
- RSSI+PIR based occupancy detection
- Temperature sensor-based Fan speed control
- LDR based luminous intensity control
- Remotely controlling cross-vendor IR devices i.e., lights, TV's, AC, DVD player etc. (Unified IR remote control)

The drive link below includes all resources for the project:

https://drive.google.com/drive/u/0/folders/1mCpGgrcGGKms6gKpepMsZKcLhM2qIpVM

CHAPTER 3

Features and Pricing

Features:

- Light control: We can control the lighting in each room or set the night lamps using RSSI based occupancy detection.
- Mood lighting: Multi colour lights which can be set as pre-sets by user. It may be manually or automatically controlled. Various modes can be programmed in it like sunrise, sunset, Night mode etc.
- Fan: The user can control the fan speed and turn it on/off directly from his phone instead of going to the switch board manually. It can also be set to use the thermal sensors to automatically sense the presence of the user and set the fan speed according to the user's set temperature requirements.
- Battery Operated Sensor Systems: Battery powered devices such as sensors used for soil monitoring in gardens can make use of sleep modes to save power and use friend node to relay messages to and from the network.
- Power Saving Features: Low Power Nodes (LPN) allow for very low energy consumption. Surveys and researchers suggest that lighting solutions save upto 10 to 20 percent energy.

Table 3.1 below shows the expected cost for complete solution provided.

Component	Cost (Retail)	Cost (Wholesale)
ESP32	240	100
Antenna	20	20
AC-DC	180	120
Buck Converter	40	40
LDO Regulator (AMS117)	15	3
Miscellaneous (RLC)	100	60
PCB (2 switch standard board)	200	100
Constant Cost	650	450
TRIAC - Standard socket	10 / switch	5/switch
Optocouplers	40/set of triac	15/switch
Additional Cost per switch	50 / switch	20/switch
AHT21	90	60
LDR	10	5
Additional Sensors	100	65

Table 3.1: Expected Cost

CHAPTER 4

Target Audience

Targeted Market:

- This product is made to replace insecure Wi-Fi based and costly smart switches which only provide the functionality to turn on or off the switch wirelessly with the help of your phone.
- As this product runs mainly on BLE mesh based local network and can be built in very less cost hence people in rural areas where Wi-Fi services are not always present or reliable can use this product.
- This product is also targeted to people who have already adapted various smart IoT devices but are frustrated due to using various apps and protocols of depending on the vendor's implementation.
- Up to 20% cost savings can be observed for Villa/Mansion owners in lighting or electric appliance bills.

Standout reasons to buy this product:

- Our product provides additional features such as proprietary occupancy detection, temperature-based fan control and universal IR based remote comptroller compared to smart switch products currently present in the market.
- We also provide local and secure communications compared to Wi-Fi based high cost/insecure similar products currently present in the market.
- Our product can convert normal (dumb devices) switches into smart devices w/o needing to replace current redundant systems which have already been implemented in various houses.
- Our product can easily be implemented in rural areas using BLE mesh where continuous Wi-Fi reception and data connectivity is not available.
- Our product is highly modular, and this network of smart switchboxes can together make a whole network of devices controlling all appliances inside a house.
- The product is scalable as adding and provisioning of new nodes connected to the smart switch is a simple process.

CHAPTER 5

Future Scope & Way Forward

- Creating Scenes: Scenes can be implemented as part of the network. Consider a 'Alarm' scene for example, curtain controllers can be synced with the user's alarms to automatically open curtains when the alarm rings to help the user wake up. Simultaneously, appliances like fans/AC units can be automatically switched off and coffee machine can be activated.
- BLE - Wi-Fi coexistence Node: Specific appliances which already are Wi-Fi compatible can be connected to the network by configuring one of the nodes in the network to a coexistence node. This allows for ease of integration into existing systems and can unify the smart home market into a single ecosystem that is compatible with multiple protocols.
- Development of Proprietary application for user control.
- Countries like Canada require continuous heating solutions such as running hot water pipelines inside walls to heat the whole house. Our solution can be tuned to detect occupants and consistently heat only those areas whilst other areas can be heated to some moderate range of +-10^0 C. This conserves electricity and fuel for heating and pumping hot water continuously in the whole house which can result in saving more than 9% energy of current usage.

  (Reference:https://energyinformatics.springeropen.com/articles/10.1186/s42162-018-0022-6)