Building a smart-home system for a one-story house in Vietnam

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***Abstract* – This article presents the construction of a smart-home system for a one-story house in Vietnam. This system employs control devices such as relays, buttons, sensors, and even devices to measure voltage, current and power. The resulting system is capable of controlling various devices from multiple locations while maintaining safety. According to panel results, smart home design offers advantages in safety, technicality, and aesthetics along with comparative economic costs in comparison to the traditional approach.**

***Keyword* – Smart-home system, smart-device, embedded system, smart-home device.**

I. INTRODUCTION

In the era of rapidly developing information technology, the application of technology in daily life and industry has become increasingly popular, and many such systems have been developed. SCADA system [1] is used for Control and Data Acquisition in the industry. BMS (Building Management System [2]) is a system for managing the environment and facilities in a building. Smart home is an automation system that monitors and manages devices in a home through the internet. However, these systems are typically designed for specific contexts, with SCADA and BMS being more suitable for industrial and commercial settings, while most existing smart home systems cater to high-end customers with expensive houses and apartments.

This article aims to introduce a smart home system that is specifically designed for one-story houses in Vietnam, which are common and popular among the civilian population. The proposed system is based on Zigbee [11], a wireless communication standard commonly used in smart home systems. This system comprises different devices that are interconnected and communicate with each other using Zigbee protocol. Moreover, the system also allows users to control devices remotely through the internet, which greatly enhances the convenience and flexibility of managing their homes.

In this system, different types of devices are used, including temperature sensors, relay, button and calculating energy. These devices communicate with each other and with the outside world through a G-Hub, which acts as a central control unit. The G-Hub connects to the internet through a Wi-Fi connection, allowing users to control the devices from anywhere using a website.

In conclusion, the proposed smart home system is tailored to meet the specific needs of one-story houses in Vietnam. By utilizing Zigbee wireless communication protocol, this system offers users a convenient and flexible way to manage their homes remotely.

II. BUILDING A SMART-HOME SYSTEM

A. Proposed communication system

This study proposes a smart home system architecture comprising various components, such as G-Hub, node sensors, node relays, node buttons, node relay Ade, MQTT, and a web page, that work together seamlessly to enable efficient communication, control, and automation of devices in a household.

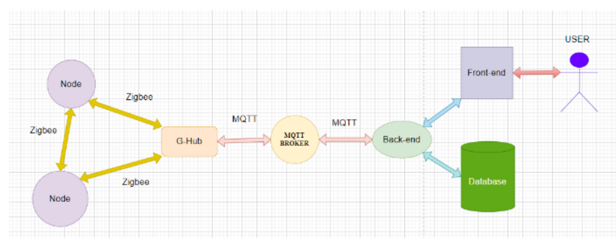

Fig. 1. Proposed communication system

The system illustrated in Fig. 1 employs Zigbee network as a means of communication between devices within a household, while MQTT (Message Queue Telemetry Transport) protocol is utilized for devices to communicate with the external world. This integration enables the system to collect, process, and transmit data from various devices within the premises to the outside world, thereby providing convenience and reliability to its users.

Users interact with the system through a user-friendly website designed to provide a seamless experience. The back-end takes responsibility for coordinating data to ensure smooth flow and operation. On the other hand, the front-end displays relevant information to users, allowing them to monitor and control the connected devices remotely. Finally, the database serves as a repository for all data gathered by the system, ensuring that it can be efficiently accessed, analyzed, and secured. The advanced functionality and convenience offered by this system make it a valuable addition to any modern smart home.

B. *Design system*

a) *Zigbee Microcontroller*

Zigbee [11] is a communication protocol developed based on the IEEE 802.15.4 wireless communication standard. This protocol was created to serve applications that require low cost and low power consumption but must be flexible in a wide range.

The Zigbee sz1v5 CC2530 2.4G module features a 2.4GHz IEEE802.15.4 RF transceiver that is compatible with the protocol. Its data transmission rate can reach 250Kbps, while it boasts a Flash memory capacity of 256KB and a RAM capacity of 8KB. Additionally, it supports UART communication.

Fig. 2. Module Zigbee sz1v5

The Zigbee microcontroller serves as the fundamental component of the network nodes, acting as the medium through which information is transmitted between nodes and G-Hub.

b) *G-Hub*

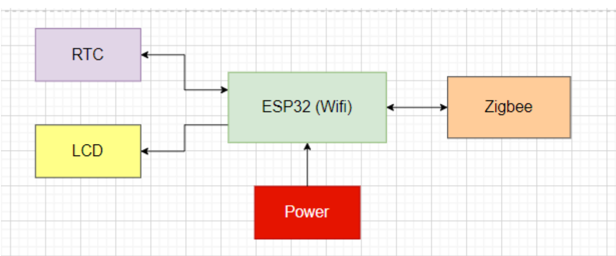

Fig. 3. G-Hub hardware diagram

G-Hub is a critical component of our system architecture and consists of five primary components: ESP32, Zigbee, Power, RTC, and LCD. It serves as a Zigbee network coordinator and a protocol converter between Zigbee and MQTT networks, enabling communication between the two.

The main microcontroller ESP32 serves as the central controller of G-Hub, facilitating inter-component communication and serving as the MQTT interface for the system. To optimize its performance, ESP32 utilizes FreeRTOS, a Realtime operating system designed for small-scale microcontrollers and events with rigid time limits. This combination allows G-Hub to divide its program into tasks, enhancing operational efficiency.

Fig. 4. Esp32

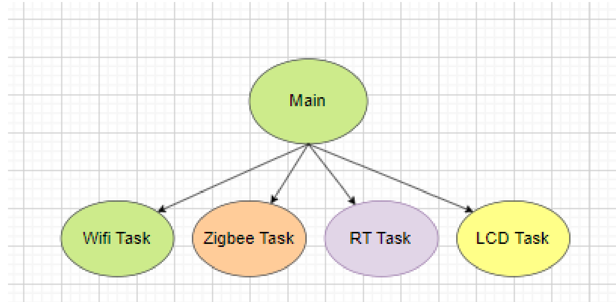

Fig. 5. ESP32 tasks

To keep track of real-time information, the RTC is responsible for maintaining accurate time and sending it to the ESP32 when required. The LCD, on the other hand, is responsible for displaying the relevant information provided by the ESP32.

In summary, G-Hub is a sophisticated system comprised of carefully selected components, working together in harmony to enable smooth communication between the Zigbee and MQTT networks. Its powerful microcontroller, optimized through the use of FreeRTOS, ensures efficient task division and operation.

c) *Node Sensor*

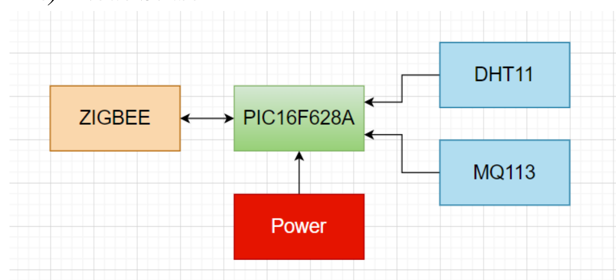

Fig. 6. Node sensor hardware diagram

The Node Sensor is an essential component of a sophisticated system designed to monitor and collect important environmental data, including temperature, humidity, and air quality. By collecting and transmitting this data to G-Hub for storage and display, the system enables users to gain valuable insights into their environment and make informed decisions based on the information collected.

Fig. 7. Pic16f628a

The main microcontroller Pic16F628a [8] is an 18-pin Flash-based member of the versatile. It acts as a central controller. It is responsible for controlling the operation of nodes.

To accurately measure temperature and humidity levels, the system incorporates DHT11 [15] sensors. These sensors can provide measurements of these vital environmental factors, enabling users to

Fig. 8. DHT11

track changes in temperature and humidity over time and adjust their environment accordingly.

In addition to temperature and humidity sensors, the Node Sensor also utilizes MQ113 sensors for air quality testing. These sensors can detect a wide range of harmful airborne substances, including NH3, NOx, Alcohol, Benzene, smoke, CO2, and more.

Fig. 9. MQ113

Overall, the Node Sensor represents a significant step forward in environmental monitoring, providing users with insights into their surroundings and empowering them to make informed decisions on how to optimize their life and workspace.

d) Node relay

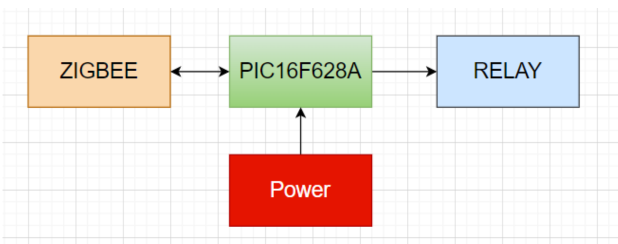

Fig. 11. Node relay hardware diagram

The Node Relay serves as the central control unit for various household devices, including lights and fans. It is responsible for toggling the on/off state of these devices and transmitting their status to the G-Hub platform.

The primary microcontroller utilized in this system is the Pic16F628a, which is also employed by the Node Sensor. The relay component facilitates the switching of equipment that is under the control of the microcontroller.

Overall, the node relay enables efficient management of household appliances.

Fig. 10. Relay SRD-05VDC-SL-C

e) Node button

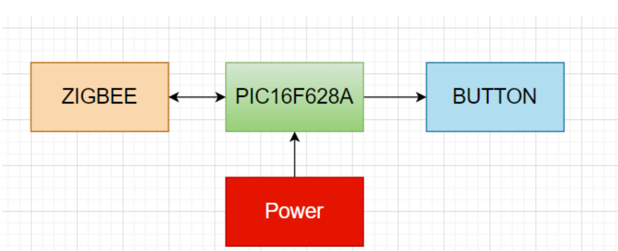

Fig. 11. Node button hardware diagram

The Node Button serves as an interface between the user and the Node Relay system, providing a simple mechanism for controlling linked devices. Upon establishing a connection between the button and the relay via a web page, users can toggle the on/off state of associated appliances by pressing the button.

The primary microcontroller utilized in this system is the Pic16F628a, which is also employed by the Node Sensor and Node Relay. The button component serves as a key user input device, allowing for manual control of devices that are linked to the system.

In summary, the node button enables convenient and intuitive management of household appliances.

f) Node relay Ade

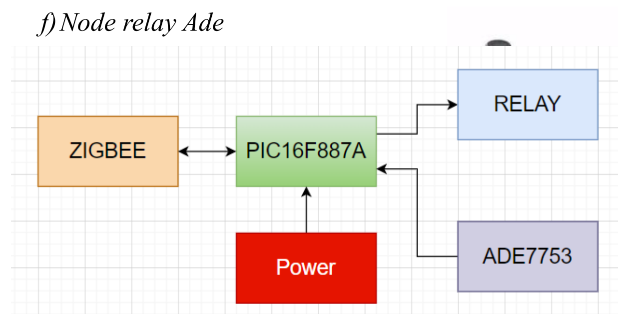

Fig. 14. Node relay Ade hardware diagram

The Node Relay Ade serves as a vital component for controlling various devices within a household, enabling users to toggle them on or off at their convenience. In addition to its switching capabilities, this device also possesses the ability to accurately calculate important electrical parameters such as power, voltage, and current.

At the heart of this system lies the Pic16F887 microcontroller, an 8-bit chip manufactured by Microchip. This powerful microcontroller enables the Node Relay Ade to execute complex commands with ease, ensuring that all connected devices operate smoothly and efficiently.

Fig. 15. ic ade7753

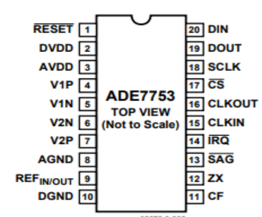

Fig. 16. ade7753 pinout

To facilitate the measurement of electrical parameters, the Node Relay Ade relies on the ADE7753 integrated circuit. This innovative component includes both voltage and current transfer circuits, enabling it to accurately determine the energy consumption of each connected device. By leveraging this advanced technology, users can gain valuable insights into their energy usage patterns, helping them make more informed decisions about how to optimize their energy consumption in the most efficient and cost-effective manner possible.

In conclusion, the Node Relay Ade is a powerful and versatile device that offers users exceptional control over their household devices. With its advanced microcontroller and integrated circuitry, this device is capable of accurately measuring important electrical parameters, allowing users to track and optimize their energy usage over time. Whether you're looking to reduce your carbon footprint or simply want to save money on your monthly electricity bill, the Node Relay Ade is an excellent choice for anyone seeking greater control over their home's power consumption.

g) MQTT

MQTT [4] is a publish/subscribe mechanism protocol, where the client machine can publish or receive messages. It facilitates easy communication between multiple devices.

The system under study comprises two primary clients - back end and G-Hub. To exchange messages between these clients, a broker was employed. The test.mosquitto.org broker was utilized for experimental purposes. This free broker allowed us to assess the communication performance between the clients without incurring any additional costs.

h) Web Page

When building a website or web application, it is essential to understand the different components that make up its structure and functionality. Two of the most critical parts of any website are the front-end and back-end.

The front-end [13] refers to the visible and interactive portion of a website that users can see and interact with. It includes the graphical user interface (GUI) and command line features like menus, text, images, videos, and more. Essentially, the front-end is what users experience when they visit a website.

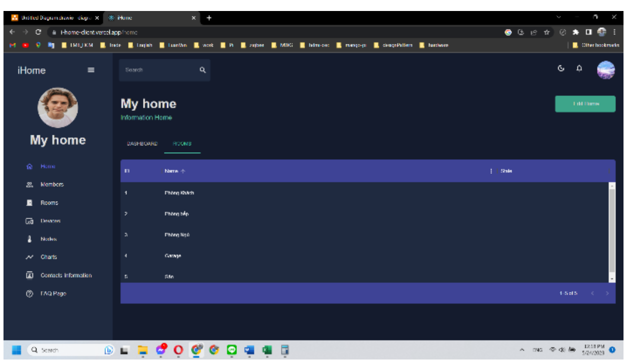

Fig. 17. Web page

On the other hand, the back-end [13] is the non-interactive part of a website that users cannot see. It is responsible for managing data, processing requests, and generating responses. The back-end usually consists of a server, an application, and a database. Its primary function is to process and store user data and provide that data to the front-end in a format that the user can understand.

One of the central components of the back-end is the database. A database is a structured set of data that is designed to be easily accessed, managed, and updated. It allows developers to store and retrieve information efficiently, enabling the back-end to perform tasks such as user authentication, data validation, and content management.

In summary, both the front-end and back-end are integral parts of any website or web application. While the front-end provides users with a visual and interactive experience, the back-end handles the behind-the-scenes tasks required to make a website function correctly. The database is a crucial component of the back-end, allowing developers to manage and access data efficiently.

More details about web page can be found at: https://i-home-client.vercel.app

C. Build a house using smart home system.

This article presents a novel approach for optimizing the location of nodes in order to enhance convenience and efficiency for users.

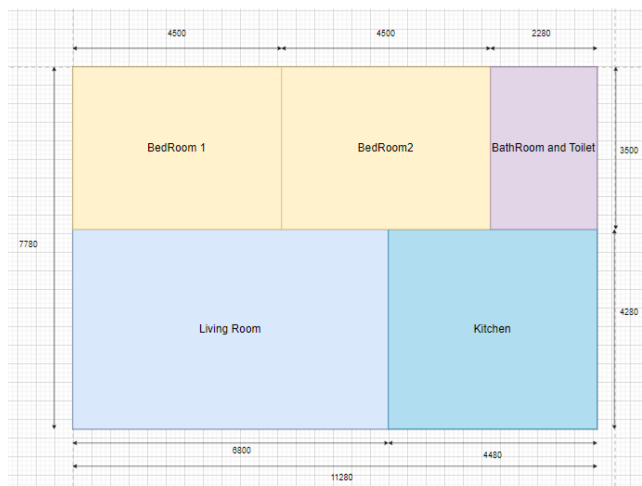

Fig. 18. Example house architecture

For illustrative purposes, the study employs the design of a one-story house located in Vietnam (Fig.18). The electrical signal is transmitted through a central node relay, which then distributes power to individual rooms. Within each room,

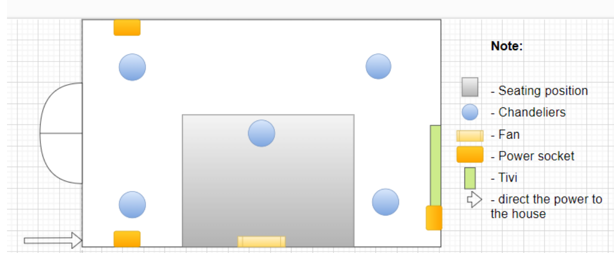

Fig. 19. Device location in living room

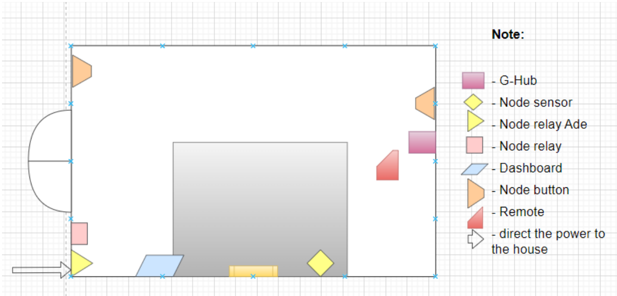

Fig. 20. Node location in living room

there is a dedicated relay node that possesses sufficient channels to accommodate all devices within that particular space. This innovative approach represents a significant advancement in the field of node optimization and has promising implications for enhancing user experience and accessibility in various settings.

The total node relay ade connected from the outside electricity and out to the rooms.

The node relay takes power from the total node relay ade and connects it to the devices in the room.

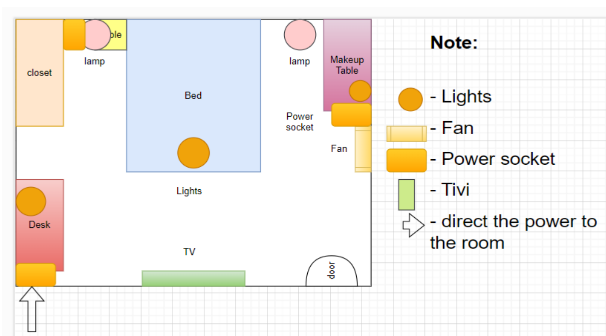

Fig. 21. Device location in Bedroom

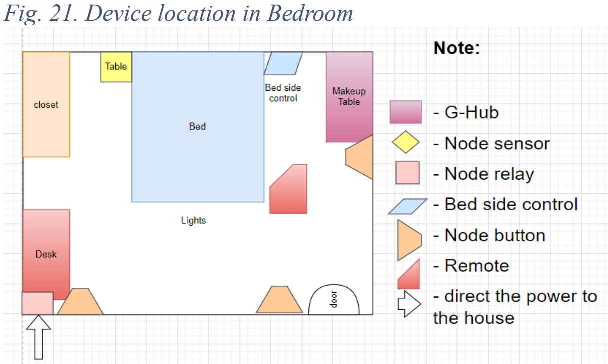

Fig. 22. Node location in Bedroom

To control these devices, we have developed two interfaces: a dashboard and a remote. The dashboard is a fixed interface that can be affixed to the side of a seat or wall within the room. It includes buttons for controlling each node relay and the devices connected to them.

The remote, on the other hand, is designed to be carried around the room and allows for convenient control of devices from anywhere within space. Like the dashboard, it includes buttons for controlling each node relay and the devices connected to them.

Finally, we have developed a node button that is mounted on the wall next to each device to be controlled. This provides a convenient and intuitive way for users to control individual devices without having to navigate menus or search for the device within the dashboard or remote interfaces.

These two designs serve as illustrations of the proposed design plan for the living room and bedroom. The other rooms in the house will follow a similar design approach. Additionally, depending on the user's requirements, it is possible to incorporate multiple node relay ade to enhance the monitoring capabilities of the device being controlled. This would allow for greater control and oversight over the system's operation, ensuring that it always functions optimally. By customizing the relay node setup, users can tailor the design to their specific needs and preferences, resulting in a more personalized and efficient home automation system.

Overall, our system provides a comprehensive and flexible solution for controlling power distribution and devices within a room. By incorporating multiple interfaces and a range of control options, we aim to make the system user-friendly and accessible to a wide range of users.

D. *Smart home design compared to traditional home design.*

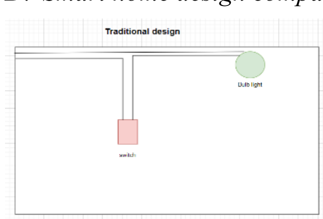

Fig. 23. Traditional design

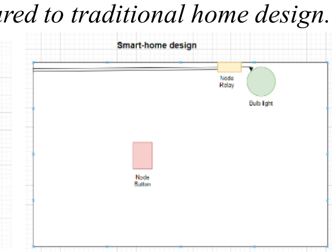

Fig. 24. Smart home design

a) Safety

The traditional design for household electrical switches poses a significant risk to users due to the direct exposure to hazardous 220V power supply when operating switches. This traditional approach can lead to accidental electrocution, which poses a severe threat to human life. However, the proposed smart home design significantly reduces these risks by limiting user contact to a non-lethal 5V electrical supply, thus enhancing the overall safety of the system.

b) Technicality

Controlling devices across multiple locations presents challenges with the traditional design for household electrical switches. The proposed smart home design offers an effective solution by enabling easy control of devices in various settings. This enhancement in control convenience is a notable advantage of the proposed design over the traditional approach and is made possible through the use of cutting-edge technology such as wireless communication protocols and internet-based connectivity. As a result, the proposed smart home design provides users with greater flexibility and convenience in managing their electrical devices, thereby enhancing the overall user experience.

c) Economy

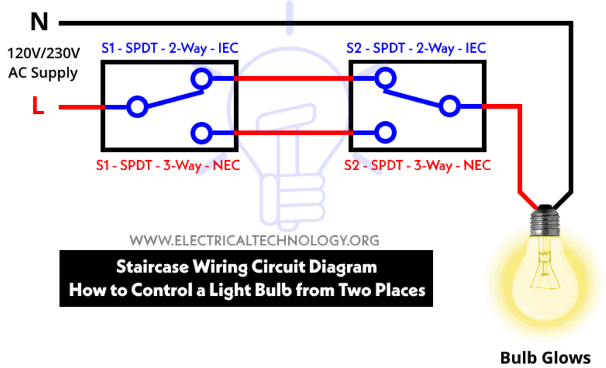

Fig. 25. the traditional way of designing 2 control places.

For the purposes of economic comparison, this study will introduce two remotely controlled systems to operate both design options. The bedroom will serve as the basis for the design.

In Fig.25 [14], it is the traditional way of indoor wiring to control two places.

Device	Place 1	Place 2
Lights	Near door	Bedside
Lights Desk	In Desk	Bedside
Lamp	(No use)	Bedside
Lights Makeup Table	In Makeup Table	Bedside

Table 1: device list place control

Choose the type of wire [10] that costs 4280 VND for both designs. According to our calculations, the number of wires needed in traditional design is 94.5m and in smart home design is 37.3m.

The traditional approach required a wire cost of 404,375 VND, 3 pole switches costing 175,000 VND, and three switch boxes priced at 30,000 VND, resulting in a total cost of 610,000 VND. The smart home design required a wire cost of 160,000 VND, a node relay costing 175,000 VND, and two node buttons priced at 300,000 VND, resulting in a slightly higher total cost of 635,000 VND. However, the benefits of smart home design can outweigh the extra cost. Smart homes provide the convenience of controlling devices from smartphones or laptops through a website.

Despite this cost difference, the benefits of control convenience and adaptability inherent in the smart home design offer promising future applications.

d) Aesthetics

The conventional wiring scheme requires the wiring to pass through the switch before reaching the light bulb, necessitating measures such as wall excavation. However, the

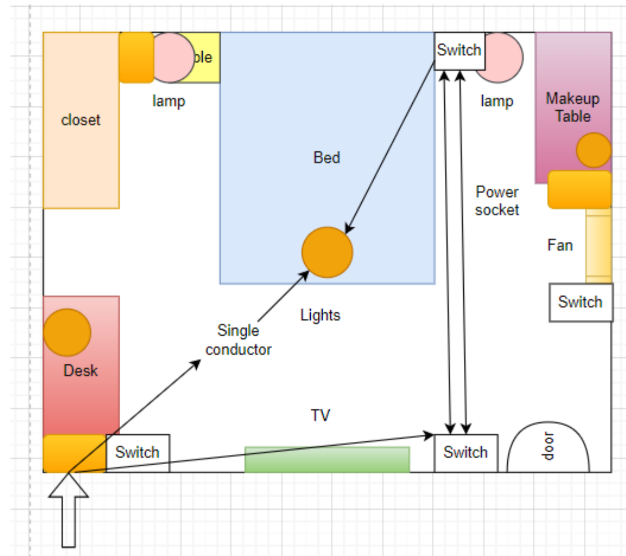

Fig. 26. An example in traditional design

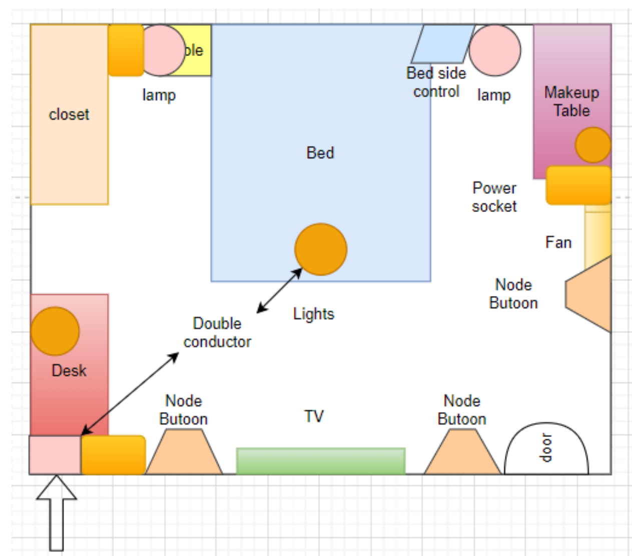

Fig. 27: An example in smart home design

proposed design only mandates a node relay anywhere between the source and device. Consequently, the wiring measures required for the traditional approach are eliminated, providing an additional benefit to the proposed design.

Smart together, our findings indicate that the proposed smart home design offers advantages in safety, technicality, and aesthetics along with comparative economic costs in comparison to the traditional approach.

III. TYPICAL EXPERIMENTS

To evaluate the functionality of this system, we have designed a model consisting of two rooms. Each room contains two devices with different designs. On one side of the model, all node relay ade are utilized for controlling and monitoring these devices. On the other side, node relays are employed to reduce costs while still achieving smart home benefits. This model serves as a testbed for assessing the effectiveness and efficiency of the proposed system.

Fig. 28. Panel demo

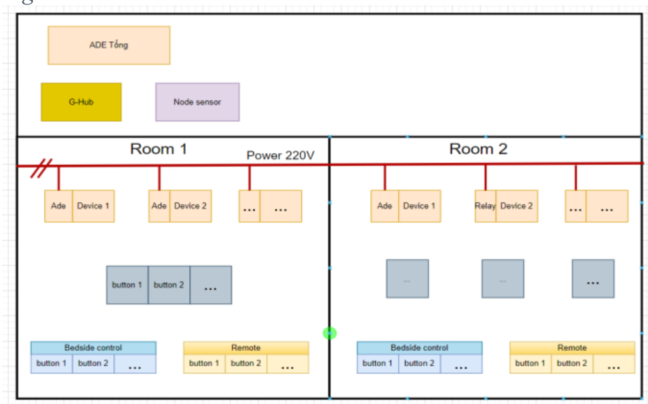

Fig. 29. Placement of demo nodes

The results of our study indicate that a smart device can be controlled by various buttons and is accessible from both mobile phones and laptops. The integration and interoperability of the system components provides users with greater flexibility and control over their smart home devices.

IV. CONCLUSION AND FUTURE WORK

Smart home design offers advantages in safety, technicality, and aesthetics along with comparative economic costs in comparison to the traditional approach. The potential benefits of smart home technology make it a worthy investment for those seeking to improve their quality of life.

Further investigations are required to gain a more profound comprehension of how smart home systems can be customized to decrease costs and size, or augment functionality within household environments. Numerous advancements have been made in this domain, which necessitate further exploration. For example, the usage of data obtained from household devices can facilitate the creation of models that identify optimal utilization patterns for devices and predict potential near-future equipment failures. Furthermore, it is practicable to detect alerts associated with anomalous power consumption patterns of particular appliances.

In addition to current advances, an opening exists to create new interconnected smart home devices that offer added value. One example of such a device could be combining a human sensor with a relay, which may potentially enable greater automation and efficiency when managing household functions. Further study into the potential of these devices may lead to the development of innovative solutions that drive the continuous evolution of the smart home industry.

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