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Bluetooth Low Energy and Cloud based Building Automation System

Siddharthan A[1], Saiprasath R[1], Pavan Kumar Reddy N[1], Parithi R[1], Balaji M[2]

[1]UG Student, Department of Electrical and Electronics Engineering, SSN College of Engineering, Tamil Nadu, India

[2]Associate Professor, Department of Electrical and Electronics Engineering, SSN College of Engineering, Tamil Nadu, India

ABSTRACT

Data sharing for automation and intelligent control has created the demand for robust wireless technologies that can offer a high data rate, greater range and secure transfer of data. Bluetooth low energy is a paradigm for transferring data between two points. Bluetooth has short range, but is highly efficient for devices involved in energy critical and standalone applications. Cloud connectivity is another widely used technology for data monitoring and storage. This work first proposes a building automation system using bluetooth low energy consisting of three separate modules which control certain aspects of a building. To overcome the limitations posed by bluetooth, the system is then connected to a cloud platform for publishing and subscription of real-time variables and for data visualization. Demonstration of a smartphone application is then provided for manual control. The work is demonstrated in real-time with a focus on commercial building automation application.

Keywords—Bluetooth low energy, cloud, automation, smartphone application

I. INTRODUCTION

In the recent years, there has been an increasing necessity for data sharing between devices, both for automation and intelligent control. This in turn has created the demand for robust wireless technologies that can offer high data rate, greater range and secure transfer of data. The interconnection of devices using these technologies has created the Internet of Things (IoT). Current products in themarket largely employ this using WiFi[8].

Bluetooth Low Energy (BLE) becomes an optimal choice for small to medium scale automation solutions [11]. In addition to consuming low power, the technology is already integrated in many smart devices like phones and tablets. Wi-Fi on the other hand, while unreliable for fast and low power standalone applications, is robust in its virtually unlimited range and excellent for devices that are not power critical. This includes lighting and cooling systems which control lights and fans.

This work proposes the use of bluetooth low energy and cloud to automate a commercial building using models that depict the building's requirements. Three modules that depict the control of fan speed, lighting control and motion capture have been fabricated and integrated as a bluetooth point-to-point network. The work then proposes the use of cloud to increase range and robustness and automate lighting and cooling systems. A smartphone application for manual control has also been proposed.
The rest of the paper is organized as follows: Section II covers the building automation application using bluetooth low energy. Section III discusses the prototype results for the same. Section IV and V elucidates the design of cloud-based building automation system and its real-time implementation.Section VI covers the conclusion.

II. BUILDING AUTOMATION USING BLUETOOTH LOW ENERGY

This work uses ESP32 controllers that are interconnected to each other using bluetooth, forming a point-to-point connection. The data to be transmitted is provided by sensors that are interfaced with the controllers(server). Controllers(client) which receive this data process it and use it to control actuators. Hence, each controller is a node. Figure 1 illustrates this connection in a block diagram.

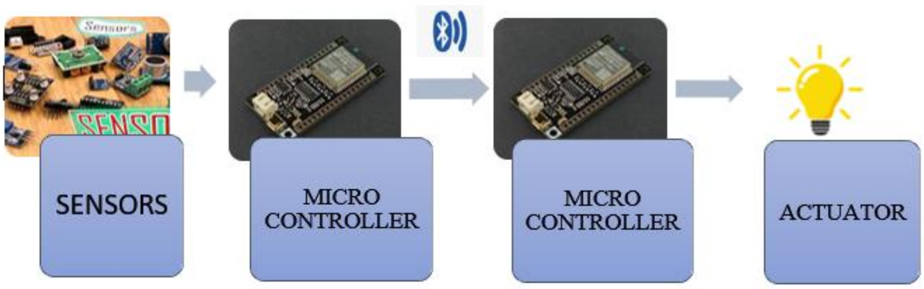

Figure 1. Block diagram of P2P BLE

This work compromises of three individual modules namely,

- Fan (Motor) control using temperature data
- Light control depending on environment light conditions.
- Photo capture using motion sensor

III. PROTOTYPE RESULTS OF BUILDING AUTOMATION USING BLE

When the light intensity was low i.e., the environment was dark, the LED glowed with full brightness as seen in Figure 3. As the light intensity was increased, the LED started dimming. When the light intensity was at the brightest, the LED turned off. A slight delay was observed in dimming or brightening of the LED. Possible cause could be the latency in BLE communication.

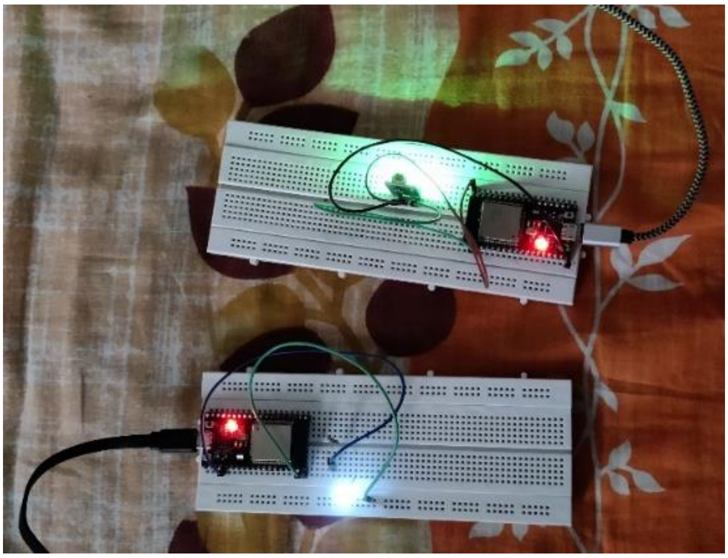

Figure 3. Photosensor in dark environment

Since a temperature variation from 30 ºC to 40 ºC was available, motor was made to vary its speed from 0 rpm to maximum speed (6000 rpm) within this range. When temperature was at 30 ºC, the fan didn't run. As the temperature increased above 32 ºC, the fan started run with increasing speed. As the temperature neared 40 ºC, the fan reached its maximum speed.

When there was no movement in the range of the PIR sensor, the camera was idle i.e., no photo was taken (Figure 4). When movement was introduced in the PIR sensor's range, the camera flashed indicating that a photo was taken (Figure 5). The photos were viewed (for verification) using SD card in which the ESP cam stored the captured photos. This can be used for security purposes.

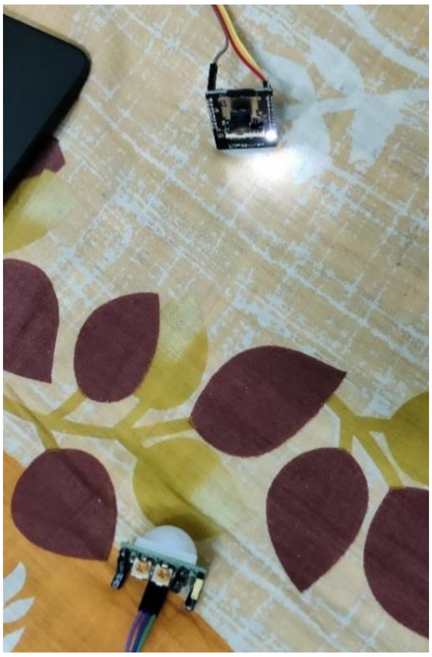

Figure 4. PIR-No movement detected

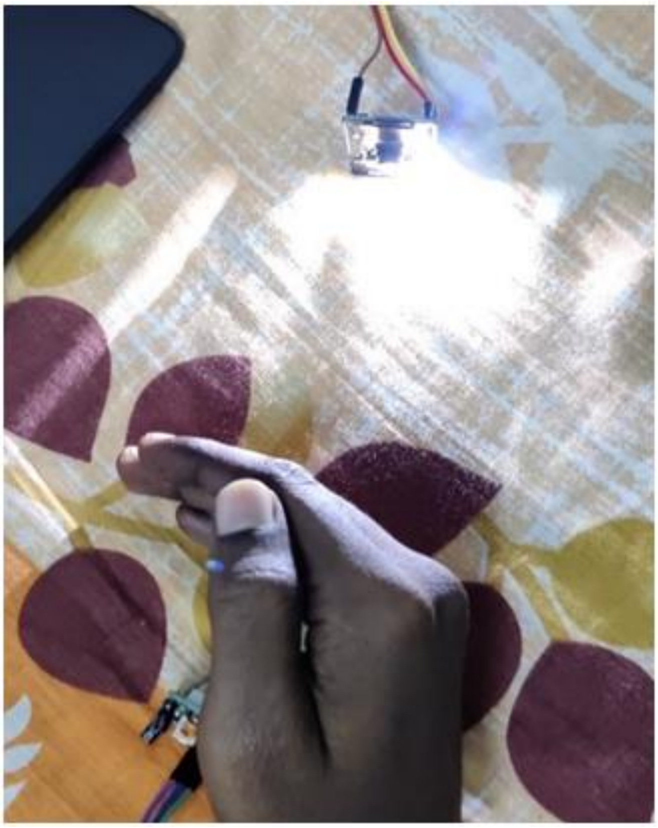

Figure 5. PIR-Movement detected

IV. CLOUD-BASED BUILDING AUTOMATION SYSTEM

This work proposes a building automation model for controlling the lighting and cooling systems by implementing cloud technology.Figure 6 shows the connectivity between sensors and actuators. The sensors publish the sensed values through controllers to the cloud. The actuators subscribe to these variables and process them as required.

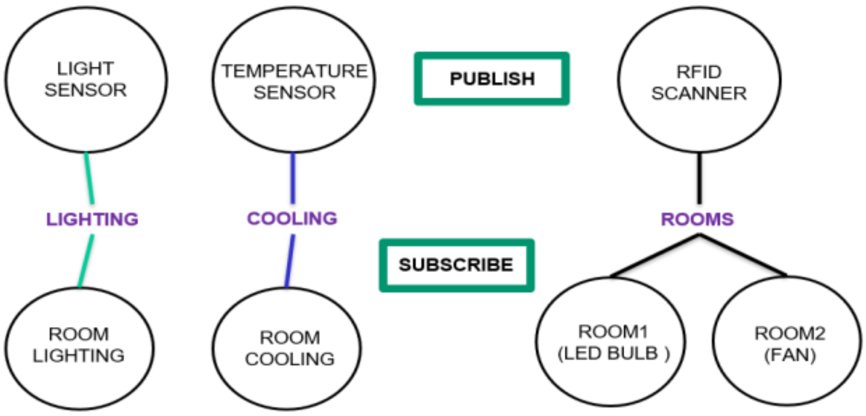

Figure 6. Block diagram of cloud-based automation system

Brightness of the environment is determined using LDR sensor and classified as dark or light. This data is then published to the cloud. The light state, ON or OFF, is set by the controller which subscribes to this data.

A temperature sensor captures the temperature of the surroundings and publishes this value to the cloud. The fan speed, 0 through 4, is set by the controller which subscribes to the temperature value.
A preference-based mechanism is created using a RFID scanner. Depending on a RFID tag scanned, light state or fan speed is set according to the user's preference. This preference is set by the user beforehand.
Smart phone application which was designed acts as a means for manual control according to the user's needs.
Figure 7 illustrates a typical commercial building automation system. The sensors are placed on the periphery of the building to sense real-time environmental conditions. RFID reader is situated at the entrance like in most offices. A centralized fan control room would control fans present in the corridors.

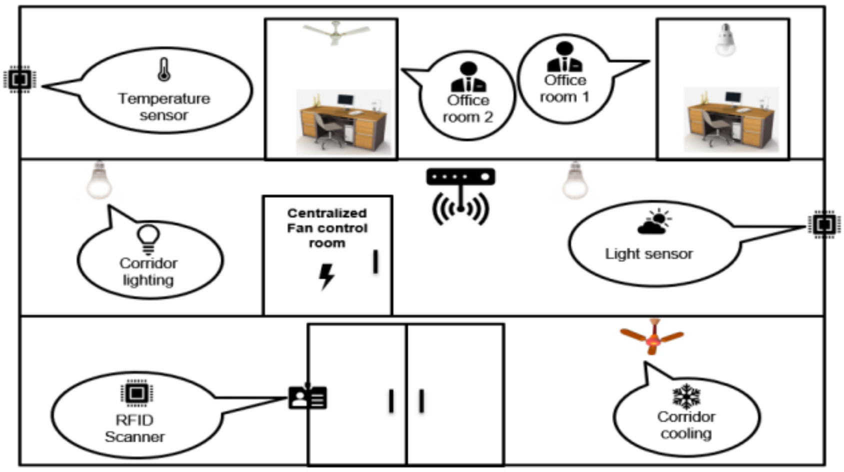

Figure 7. Typical commercial building automation system

V. REAL-TIME IMPLEMENTATION OF SYSTEM

The LDR circuit in Figure 8 was tuned to the ambient environment light conditions after which the circuit correctly detected if the environment was dark or bright and the LED bulb circuit turned ON and OFF correctly.

Figure 8. LDR sensor circuit

The fan speed control circuit, illustrated in Figure 9, was connected to an actual ceiling fan and was observed to run at the set speeds, when controlled by the temperature sensor as well as by the smartphone application.

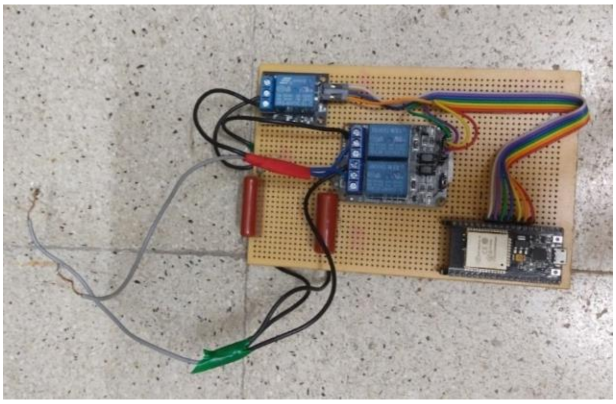

Figure 9. Fan speed control circuit

RFID reader and tags were used to set the light and fan to a particular state depending on which tag was scanned. When tag 1 was scanned, the light bulb turned ON and when tag 2 was scanned, the fan ran at speed 2. Figure 10 shows the RFID reader scanning a tag.

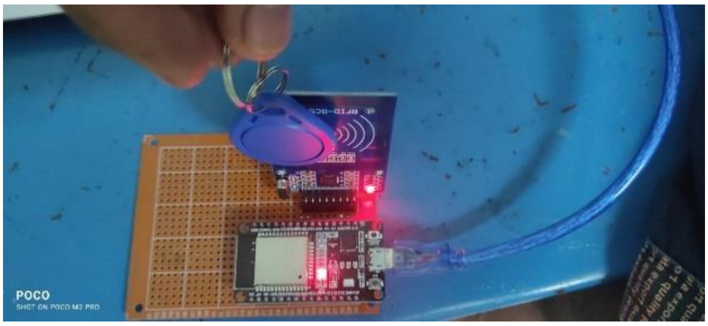

Figure 10. RFID reader and tag circuit

The smartphone application designed provided a manual override function by which the user could set the light state and fan speed based on their preference. Figure 11 illustrates the control of light state screen.

Figure 11. Light control screen

The UBIDOTS cloud provided a visual representation of all the variables used in the system by means of a dashboard. Appropriate widgets were used to graphically represent the variables like temperature and the state of light.

VI. CONCLUSION

Bluetooth low energy (BLE) is a technology that enables us to interconnect and establish communication between two devices. This work first implemented a BLE point to point (P2P) communication in three modules. The prototype was tested and all three modules successfully established a BLE P2P communication.

The limitations of the range imposed by BLE has been overcome by using cloud connectivity. This virtually gives unlimited range provided the devices have an internet connection. The sensors published the sensed values to the cloud which could also be seen by the user through the dashboard provided by the cloud platform. The actuator devices subscribed to these variables and accordingly controlled the state of the light and fan. The designed smartphone application also has been successfully tested when it overrode the values published by the sensors.

The system has been tested in a real-time scenario and has been found to be a viable option for commercial automation applications.

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