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Designing and Development of Bluetooth Based Mesh Network Logger

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Abstract— Across the world, numerous time synchronization systems are being developed for large data networks, enabling the delivery of highly precise time down to sub-second intervals. This thesis discusses the integration of Bluetooth Low Energy (BLE) technology with sensors and cloud platforms to enable efficient data communication and storage. BLE has gained popularity due to its low power consumption and low cost, making it a suitable option for battery-powered IoT devices. Sensors equipped with BLE can communicate data to a nearby gateway, which in turn sends the data to the cloud for storage and analysis. This enables real-time monitoring and remote management of IoT devices. The paper also explores cloud platform that can be used to store, manage, and analyze the data collected from the sensors. A prototype system was developed to demonstrate the integration of BLE sensors with a cloud platform. The results show that BLE is a viable option for IoT device communication, and cloud platforms provide an efficient solution for storing and analyzing large amounts of sensor data. The study also involved long-term tests to collect data on Bluetooth low energy mesh characteristics, with an algorithm developed to determine signal travel time within the mesh network.

Keywords: *IoT, Bluetooth Low Energy, Mesh, synchronization, ESP32, Sensors, Cloud Platform*

I. Introduction

With the introduction of Bluetooth Low Energy (BLE) in 2010, constrained devices gained access to a wireless point-to-point communication standard [1]. BLE has become a ubiquitous wireless communication technology found in smartphones due to its numerous advantages over other communication technologies, including low power consumption, security, and versatility, making it a popular option for connecting with smart devices. The development of many-to-many BLE mesh technology is revolutionizing the IoT ecosystem, enabling the control of smart devices to create smart homes, offices, and industries [2]. However, to incorporate smart devices into the mesh network, security credentials and configuration information must be provided to each device.

II. BLE Background -A

A. *Bluetooth Low Energy(BLE)*

B. *BLE Mesh*

BLE-Mesh is an IoT application that utilizes Mesh networking to connect multiple Bluetooth Low Energy (BLE) devices, creating a powerful, integrated, and range-extending network with true two-way communication. This technology allows multiple devices to be efficiently controlled and monitored within a secure network.

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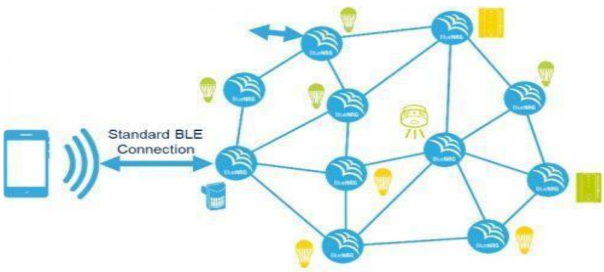

Fig 1. BLE Mesh

C. *BLE Mesh Provisioning*

Provisioning refers to the authentication and provision of basic information regarding a BLE mesh

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network to a device, which must undergo provisioning to become a node. Once provisioned, a node is capable of transmitting or receiving messages in the BLE mesh network. A Provisioner is a node responsible for adding a device to a mesh network and managing the allocation of addresses to ensure that no duplicate unicast addresses are allocated. After authenticating the device, the Provisioner invites a non-provisioned device into the mesh network, converting it into a mesh node. Provisioners are typically smartphones or other smart computing devices. Making the entire system autonomous by integrating the provisioning capability into an embedded board has reduced costs and enhanced security with minimal input required from the user.[4]

Fig 2. Embedded Provisioner in BLE Mesh Network

III. Related Work

BLE, also known as Bluetooth Low Energy or Bluetooth Smart, has become a leading low-power wireless technology, thanks to its ability to enable low-energy communication between devices like smartphones, sensors, wearables, and more.[5] The Internet Engineering Task Force (IETF) has recently developed an adaptation layer to support IPv6 over BLE, making it possible to connect BLE devices with the Internet of Things (IoT). One such application is the creation of a BLE-based mesh network logger, which can collect and store data from multiple devices within the network. In this literature review, we will discuss the research related to BLE-based mesh network loggers.[6]

In July 2017, Bluetooth SIG released the official Bluetooth mesh, which is built on BLE 4.x and allows data to be broadcasted over Bluetooth low-energy to specified addresses.[7] According to Ericsson's whitepaper about mesh published in 2020, the Bluetooth Mesh Profile standardizes a full stack connectivity solution for mesh networking, making it applicable for IoT use cases.[8]

Several surveys have been conducted on Bluetooth-based mesh loggers. Seyed Mahdi Darroudi and Carles Gomez developed a survey on BLE mesh networking, providing a taxonomy of BLE mesh network solutions and reviewing the solutions' advantages and drawbacks. Flooding-based and routing-based schemes were identified as two solution categories that use advertising channels and data channels, respectively, for data transmission.[9]
Lin, Hsin-Changa, Chen Ming-Jenc, and Huang, Jung-Tanga developed a smart healthcare system that collects physiological information from interconnected IoT-based devices and transmits it to a cloud database for analysis. The system enables real-time monitoring of the elderly's localization, activity pattern, and health status, providing early detection of health risks.[10]

Sayeed et al. developed a BLE-based system for remote monitoring of patients' vital signs, focusing on those living in rural areas. The system combines pulse rate and body temperature sensors to sense the patients' vital signs and allows for remote care from a distant place.[11]
In conclusion, BLE-based mesh network loggers have been extensively researched for various applications such as monitoring indoor air quality, structural health, and livestock health. The research has shown that such systems can operate for several months on a single battery and can transmit data over a range of up to 100 meters. The accuracy of the sensor readings has also been shown to be high. The proposed systems provide a low-power and low-cost solution for data collection and storage in various applications.

IV. Experimentation Methodology

The ESP32 microcontroller is used to acquire data from the sensors, communicates with other mesh nodes using BLE, and stores the data in its internal flash memory or on an SD card as shown in figure (5b) and (5c) respectively. The Li-Ion battery provides power to the circuit and the TP4056 ensures

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that the battery is charged and maintained at the proper level. The LCD display provides a user interface for the mesh logger and allows for real-time monitoring of the system status.

A. Block diagram

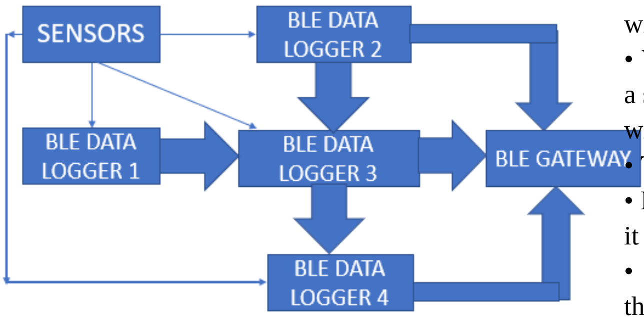

Fig 3. Block diagram of Development of Bluetooth Low Energy based Mesh Network Logger.

A BLE transceiver for wireless communication within the mesh network, various sensors for data logging and acquisition, and a power source such as a battery for each mesh node as shown in the block diagram (figure 3). The BLE transceiver, in this case, the ESP32, provides wireless communication capabilities using the Bluetooth Low Energy (BLE) protocol, allowing the mesh nodes to communicate with each other. The sensors, which can include temperature, humidity, pressure, and other types, are responsible for collecting data and logging it for later analysis. The power source provides the necessary power to operate the mesh node, which can be a battery or another suitable power source. The combination of these components provides a complete solution for building a BLE-based mesh network with data acquisition capabilities.

B. Algorithm

The DHT11 temperature and humidity sensor sends data to Node1.

• Node1 acts as a server to send the data further using BLE (Bluetooth Low Energy).

• Firstly, it scans all other nodes to get their RSSI value.

• RSSI (Received Signal Strength Indicator) values are a measurement of how well a device can hear a signal.

• We will filter the RSSI values of our node, and if it is close, it will connect to that node.

• Suppose the nearest node is Node2. Now Node2 will act as a client to receive the data from Node1.

• When the data is transferred to Node2, it will act as a server to send the data, repeating steps 3, 4, and 5. It will search for the nearest client.

• This is the BLE mesh network.

• If any node finds the Gateway via the shortest route, it will directly connect to it.

• The Gateway will send data to ThingSpeak that is the cloud platform where data analyzation and visualization is done.

C. Flowchart

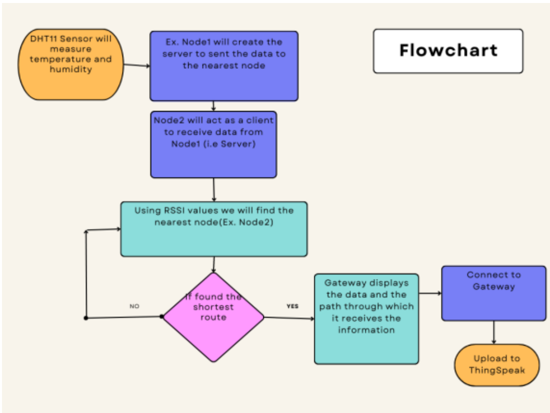

Fig 4. Flowchart

V. Experimental Setup

A microcontroller is needed to make a BLE compatible. Microcontroller, such as the ESP32, is a key component for building the mesh nodes. A BLE transceiver, such as the ESP32, for communication within the mesh network. Sensors such as temperature, humidity, pressure, etc., for data logging and data acquisition. A power source, such as a battery, for each mesh node. Connectors and a printed circuit board (PCB) for connecting all the components together. Debugging and programming tools, such as a J-Link, for debugging and programming the microcontroller. A data storage solution, such as an SD card, for storing the logged data. A housing for each mesh node to protect the

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components and provide a convenient form factor for deployment. The ESP32 microcontroller is at the center of the circuit and communicates with the other components. The Li-Ion battery provides power to the circuit and is managed by the 5V power boost module i.e., charging protection board HT4928S/SW8208S battery charger IC. This manages the charging and discharge of the Li-Ion battery. The LCD display is used to display information and status updates from the mesh logger. The representation is shown in the implementation figures of BLE Data Logger and BLE Gateway.

A. *Implementation*

BLE Logger

Particularly pertinent for Bluetooth technology are data loggers, which make use of episodic or recurring transmissions of modest amounts of data. Breathalyzers, thermometers, and monitors for your heart rate and blood pressure are among more items that are suitable for Bluetooth. Users of data loggers can gain tremendously from Bluetooth adoption through simple operation, convenient data access, and effective data gathering and management. Bluetooth enables rapid wireless transmission of environmental data from data loggers to mobile devices without the need for cables, internet connections, pairing, or computer software.

BLE Gateway

A Bluetooth Low Energy gateway connects smart devices to that product. It makes it possible to upload data from Bluetooth devices to the cloud. These gadgets could either be Bluetooth low energy beacons or sensors. A Bluetooth Low Energy gateway needs to be connected to or paired with Bluetooth-enabled devices in order for it to function. The gateway can send data from the connected device to the cloud thanks to this connection. When this information reaches the cloud server, it immediately registers the Bluetooth device that is connected. The Bluetooth Low Energy gateway will then start looking for any nearby Bluetooth devices. When it detects a gadget in its vicinity, it gathers all information including its features.

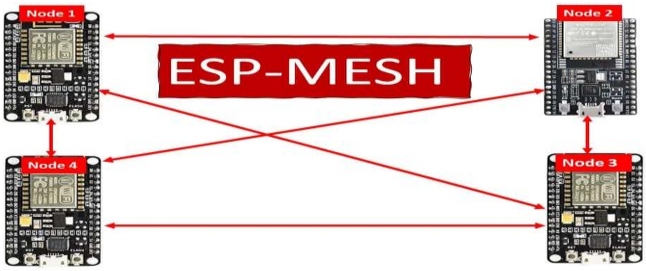

Fig 5a. ESP32 acting as Logger and providing a Mesh Topology

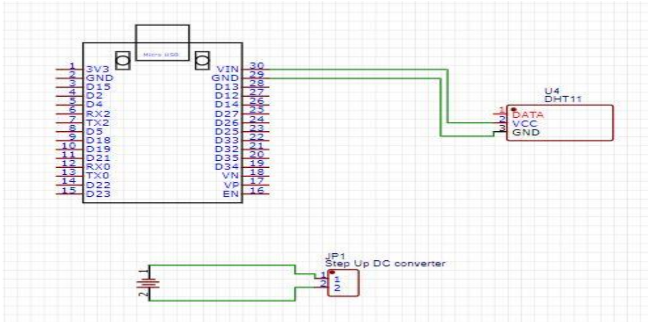

Fig 5b. BLE Data Logger

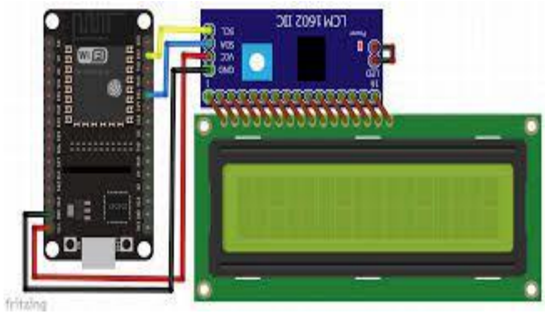

Fig 5c. BLE Gateway

B. *Cloud Platform*

ThingSpeak is a cloud-based service that allows sensors, instruments, and websites to transmit data, which is then stored in either private or public channels. Private channels are used to store data by default, although public channels can be utilized to share data with others. The service serves as an IoT analytics platform that allows live data streams to be gathered, visualized, and analyzed in the cloud. By posting data to ThingSpeak, instant visualizations of the data can be generated.

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VI. DEPLOYMENT OF BLE MESH IN OPEN MINES

BLE mesh loggers are being used more frequently in open mines for a variety of purposes, including environmental monitoring, equipment tracking, and worker safety. Due to the existence of obstructions and interference, open mines can be difficult locations for wireless communication. BLE mesh technology, on the other hand, is made to get around these problems by enabling gadgets to connect in a mesh network and interact with one another despite obstacles. In open mines, BLE mesh loggers can be installed in a variety of positions to track the temperature, humidity, gas levels, and other environmental factors. They can also be fastened to machinery to track performance, usage, and upkeep requirements. BLE mesh loggers can also be used to track a worker's whereabouts and guarantee their safety in dangerous regions.

To resist the extreme circumstances in the mine, it's critical to choose devices that are tough, dust-proof, and waterproof while deploying BLE mesh loggers. To avoid interfering with other mining equipment or endangering workers, it's also critical to make sure that any wireless devices used in a mining setting adhere to local laws and safety standards.

VII. RESULT

This project has resulted in the development of a prototype for a mesh network logger based on Bluetooth low energy technology. The potential applications for this device are numerous, ranging from industrial automation to healthcare and environmental monitoring. The main outcome of the project is the successful creation and testing of a logger that can collect and record data. This achievement is particularly noteworthy because it enables precise data synchronization between different devices and sensors within the network. The ultimate impact of this project will depend on how the prototype is refined and utilized in practical situations.

VIII. CONCLUSION

In this thesis, we conducted real experiments to evaluate the performance of Bluetooth Mesh (BLM) technology and its suitability for monitoring applications and suitable to deploy in hazardous area like open mines. We found that BLM is better suited for low-rate applications such as sporadic or event-driven monitoring. As a future work, we plan to explore the impact of the Time-to-Live (TTL) parameter of the flooding mechanism and sub-networking feature on packet delivery performance. Despite the limitations we encountered, the future prospects for Bluetooth low energy-based mesh network logger remain promising. With the increasing prevalence of IoT devices and sensors, there is a growing need for reliable and low-power wireless communication technologies. Bluetooth low energy technology is widely used in IoT and is expected to continue to gain popularity in the future.

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