Smart-Home Architecture Based on Bluetooth mesh Technology

Qing Wan¹, Jianghua Liu²

¹School of Electronics and Information Engineering, Hubei University of Science and Technology Xiamning, China
²School of Electronics and Information Engineering, Hubei University of Science and Technology Xiamning, China

*Corresponding author e-mail: wanqin_002@126.com

Abstract. This paper describes the smart home network system based on Nordic nrf52832 device. Nrf52832 is new generation RF SOC device focus on sensor monitor and low power Bluetooth connection applications. In this smart home system, we set up a self-organizing network system which consists of one control node and a lot of monitor nodes. The control node manages the whole network works; the monitor nodes collect the sensor information such as light intensity, temperature, humidity, PM2.5, etc. Then update to the control node by Bluetooth mesh network. The design results show that the Bluetooth mesh wireless network system is flexible and construction cost is low, which is suitable for the communication characteristics of a smart home network. We believe it will be wildly used in the future.

1. Introduction

With the continuous progress of information technology, especially the rapid development of electronic technology, Internet of things technology and distributed technology, making the interconnection between things has become the future trend of technological. The traditional home and housing have been unable to meet people's more comfortable, more convenient, more intelligent pursuit of home life, and Smart home will meet people's needs.

Therefore, the smart home is widely concerned by the market because of its broad application prospect, huge potential market demand, and rapid development. The smart home connects a variety of devices in the home through the Internet of Things technology to provide various functions such as home appliance control, lighting control, indoor and outdoor remote control, burglar alarm, environmental monitoring, and HVAC control[1]. In the home network, the interconnection of devices uses a wireless network instead of a wired network to provide greater flexibility and mobility for home devices, eliminating the expense and effort spent on cabling. Because it is in line with the characteristics of home network communications, with the further development of wireless network technology, it will also greatly promote the home network intelligent process[2].

This paper mainly discusses a smart home wireless network based on Bluetooth mesh technology. Bluetooth mesh technology is a two-way wireless communication technology with lower complexity, lower power consumption and lower cost than other traditional short-range communications[3]. Through the Bluetooth mesh technology, the home network can be connected with all kinds of home appliance devices to facilitate the management of home appliance equipment. At the same time,
the sensor node is added to collect the data in the home, such as temperature, humidity, and light. Therefore, the smart home network based on Bluetooth mesh has a great prospect.

2. Systems Overview

2.1. Bluetooth mesh wireless networking technology

On July 19, 2017, Bluetooth SIG announced that Bluetooth technology was beginning to fully support mesh network. The latest Bluetooth Mesh networking technology enables network nodes to relay and route between nodes. This kind of design can realize the Bluetooth wireless signal comprehensive coverage, breaking the traditional Bluetooth short distance. Bluetooth Mesh supports up to 32767 devices in a network, with a maximum network diameter of 126 hops.

The interconnection between these devices allows users to control and manage the entire network from one location to the other without breaking the shortcomings of traditional Bluetooth connections. Bluetooth Mesh network not only can provide many-to-many device transfers, but it also can improve the communication effectiveness of the construction of a wide range of network coverage, that is suitable for the need for thousands of devices connected interactive Internet solutions. This makes Bluetooth Mesh very suitable for use in a commercial or industrial environment with high-density lighting and a large number of IoT sensors.

The Bluetooth Mesh Network is a new network topology for Bluetooth Low Energy (also known as Bluetooth LE) used to establish many-to-many device communications. It allows you to create a network based on multiple devices and can contain dozens, hundreds or even thousands of Bluetooth Mesh devices. These devices can transfer information between each other, no doubt such an application form provide the ideal choice for the building automation, Wireless sensor networks, asset tracking and other solutions.

2.2. Protocol stack characteristics

The Bluetooth Mesh is based on the Bluetooth low energy part of the Bluetooth 4.x Specification and shares the layers with this protocol. On-air, the Bluetooth Mesh physical representation is compatible with existing Bluetooth low energy devices, as mesh messages are contained inside the payload of Bluetooth low energy advertisement packets. However, Bluetooth Mesh specifies a completely new host layer, and although some concepts are shared, Bluetooth Mesh is incompatible with the Bluetooth low energy host layer.

Compared to several other short distance network technologies, Bluetooth Mesh uses the method of flooding to carry forward the information. In this case, it can be interpreted as a network flood, which is to transmit information from one node of the network to the destination node via broadcast. AODV routing method or the Bluetooth Mesh similar to a web-based flood, you need to use the broadcast. Using the network flood, it is not necessary to create and manage complex routing table, routing discovery table, etc., which can save the memory space of network operation through controllable flood messaging[4,5]. At the same time, the nature of the network flood message propagation is Multipath, which ensures that information can be passed to the destination node through multiple routes, which makes the network highly reliable. At the same time, a mesh network can conveniently sample the smart phone as the gateway and does not need to set up the routing gateway node alone.

### Table 1. Three wireless networking technologies.

| network               | IPV6 | Cloud      | connectivity | Theoretical Network | Routing        | Storage space |
|-----------------------|------|------------|--------------|---------------------|----------------|---------------|
| ZigBee                | no   | Gateway    |              | 64000               | Full Routing   | medium        |
| Thread                | yes  | Border Router | Gateway      | 64000               | Full Routing   | height        |
| Bluetooth Mesh        | yes  | Smartphone | Gateway      | 32000               | Managed flooding | low          |
2.3. Network system structure
In the Bluetooth mesh network, node types are divided into: Relay nodes, Low Power nodes, nodes, Friend nodes and gateway nodes[3].

Using Low Power nodes as indoor environmental monitoring nodes, they only need lithium-ion battery to work for several years. External temperature and humidity sensors, light sensors and PM2.5 sensors can monitor indoor temperature, humidity and light parameters. Low Power node is connected to the network through Friend node.

Node is only connected to the mesh network using a GATT bearer. The relay node is the ability to receive and retransmit mesh messages over the advertising bearer to enable larger networks. A mesh gateway is a node that is able to translate messages between the mesh network and a non-Bluetooth technology. A node may be able to send and receive mesh messages through a mesh gateway while not in the range of any of the Relay nodes.

![Figure 1. Bluetooth mesh Network Route Map](image)

3. Systems Design

3.1. Hardware Design
BLE mesh environmental monitoring node hardware design module as shown in figure 2 below, as the end of the wireless sensor node, the node requirements belong to Low Power nodes[6] in a mesh network, Power consumption is Low, in the form of broadcast request access networks. The core of this node uses the nrf52832 processor and designs coupled matching antennas to launch the bluetooth broadcast. At the same time, the low-power node uses the battery power supply, which can be made up of 3 sections 5V battery. To further reduce the volume, the miniature button cell can also be used. Data acquisition part is responsible for sending data collected information processor; this part uses multiple sensors module: the temperature and humidity sensors, PM2.5 sensors, light sensors, so the indoor environmental monitoring nodes is an embedded microcontroller processing platform[7,8].

The collected data is transferred to the core processor for processing. These parameters can be displayed directly on the nodes through OLED displays. On the other hand, the data is distributed to the device control node. The equipment control node calculates the data of multiple monitoring nodes and realizes the estimation of the state of the environment to adjust the corresponding equipment[9]. For example, according to the value of light intensity, to adjust the intensity of the curtain or indoor light. Different types of sensors can be added according to the actual application. In a mesh network, We used node as the control node.
Figure 2. Environmental monitoring node

The system design center node is the interaction node of the whole system and the external network, as shown in figure 3. In the BLE mesh network, the core processor by coupling antenna receives the Bluetooth data through a RS232 connection to the computer, or through the SPI interface to connect WIFI module for remote statistics and control access to a remote server. Access to the mobile phone network through the GPRS module, and send SMS messages to the user remotely. We used gateway node as the center node.

Figure 3. Center node

3.2. Software Design

Example applications can be built using either CMake or SEGGER Embedded Studio. Mesh provisioning is used to provide new devices with the information they need to join a network. A device can be either a provisioner or a provisionee. In the provisioning process, a new device is provided with a network key, an address, and a device key, which is a special key only used for private communication between the provisioner and the provisionee.

The workflow of the join the network software is shown in Fig 4. The initialization step is common for both the provisioner and the provisionee role. Remote provisioning (PB-Remote) allows a provisioner to provision devices outside its radio range. This is done by using mesh nodes to relay provisioning messages to a node within range of the device that is to be provisioned.
The workflow of the terminal monitoring software is shown in Fig 5. The terminal monitoring node first initializes the sensor. The sensor is used to detect the data of the sensor after its initial success. Because there are multiple data, you need to read them in turn and store the data. When full data is read, then apply to join mesh network. When the network is successfully purchased, the stored data group is transferred to the control node or center node.

3.3. Monitoring results and analysis

The intelligent home control system of design includes 8 monitoring nodes, 2 relay nodes, 4 control nodes and a central node. The 8 monitoring nodes are arranged in a 20-square-meter room, monitoring the temperature, humidity, lighting intensity and PM2.5 in the room. The three control nodes control the intensity of light, air conditioning and air purifier respectively.

| Table 2. Nodal monitoring value. |
|------------------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| Numble              | Node 1         | Node 2         | Node 3         | Node 4         | Node 5         | Node 6         | Node 7         | Node 8         |
| temperature         | 26.3°C         | 25.8°C         | 26.5°C         | 26.8°C         | 26.2°C         | 26.1°C         | 26.2°C         | 26.5°C         |
| humidity            | 25%            | 27%            | 28%            | 30%            | 33%            | 28%            | 31%            | 28%            |
| photometric         | 90lm/m²        | 92lm/m²        | 95lm/m²        | 85lm/m²        | 91lm/m²        | 87lm/m²        | 89lm/m²        | 87lm/m²        |
| pm2.5               | 79ug/m3        | 78ug/m3        | 82ug/m3        | 75ug/m3        | 72ug/m3        | 77ug/m3        | 74ug/m3        | 77ug/m3        |

Temperature and humidity sensor DHT11 digital temperature and humidity module, humidity accuracy of +/-5% RH, temperature accuracy in +/-2 °C. Light intensity is directly monitored by photosensitive resistance, and PM2.5 monitoring adopts sharp PM2.5 dust sensor. The monitoring range is within 10m. The Bluetooth signal strength can be maintained at -65db, and the indoor mobile Bluetooth can be successfully connected to mesh network, and the real-time monitoring data can meet the design requirements.

4. Conclusion

This paper designs a smart home control system based on Bluetooth mesh network, and introduces the application of mesh network in the smart home from the aspects of system structure, hardware design, and software design. Bluetooth mesh technology works as a more cost-effective networking solution, especially for short range of small areas of communications and control. Compared to the traditional
short-distance network, it has the specific lower power consumption, lower cost. The system can be accessed using mobile devices such as mobile phones with Bluetooth BLE functions.

At the same time, it can also meet the data output and input of various sensors, as well as control commands and information requirements. This system uses high integration nrf52832 Bluetooth chip as the core processor, can easily access third-party sensors, execute device or the low bandwidth data source. The system has a great development space in the field of home automation. By further designing and joining the routing node of the remote network, we can make the design have higher economic value and better application prospect.

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