Smart fire monitoring system with remote control using ZigBee network

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ABSTRACT

There are several differences between the two types of alarm systems, conventional systems and addressable systems. It is important to carefully determine the introduction of a fire alarm system according to the installation environment. Talking about the main difference relates to how the connected device communicates with the main control panel by sending a signal. Cost is another factor that can be a determinant of your chosen fire alarm system. In this paper, we proposed smart addressable fire detection system. In the proposed system, IoT was used and the network was constructed using ZigBee module. In the configured network, it consists of a local server and a control server. The local server controls the addressing sensor and sends the information obtained from the sensor to the control server. The control server receives data transmitted from the local server and enables quick fire action. In the actual implementation, the local server used the Lycra controller and ZigBee module. In addition, the control server used the Raspberry Pi and ZigBee modules and connected to the Ethernet so that the administrator could monitor or control the local server.

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1. INTRODUCTION

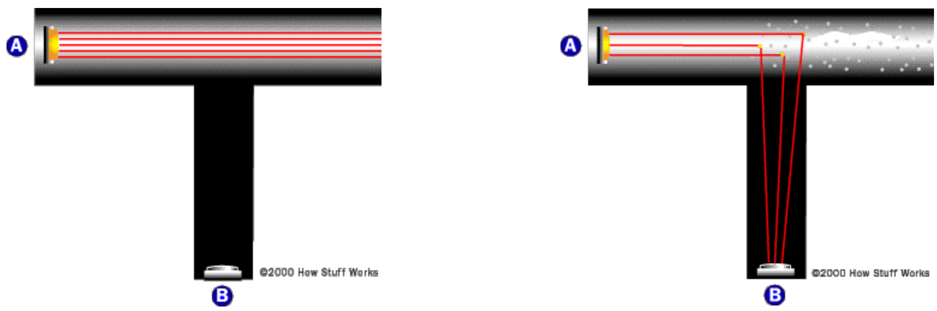
The fire alarm system can be roughly divided into two types. The first is a traditional fire alarm system and the second is an addressable fire alarm system. In a traditional fire alarm system, each alarm device is connected to the control panel using its own wiring. However, in the addressable fire alarm system, each alarm device is connected by loop wiring. That is, all the alarm devices are connected to the control panel with one wire. In the two fire alarm systems, it is the same that the alarm device is connected to the main control panel [1, 2]. Addressable fire alarm system uses SLC (Signaling Line Circuit) to connect between the alarm devices or the control panel. Based on the SLC, the alarm device sends current to the control panel. Internally, each addressed fire alarm device sends a binary code. The binary code is generated through various voltage changes in the alarm device. The addressing fire alarm system uses a mini computer to convert the transmitted binary code [3–5]. Addressable fire alarm systems provide more functionality and flexibility than traditional fire alarm systems. By adding new modules and additional circuit boards, the existing system can be further expanded, and remote transmission functions, remote power control, and conventional area monitoring can be performed [6, 7]. The advantage of this system is that, according to the design of the addressable fire alarm system, more information can be transmitted to the control panel compared to a conventional fire alarm system that can only detect a single signal. Addressable fire alarm systems can use digital data transmission technology to provide a much wider range of information sent to the control panel. It has also been improved that an addressable system can recognize the location of a device that needs it, or identify an important condition and deliver that information to the user [8–10]. The latest version of addressable fire alarm system can also deliver the amount of smoke or heat the detector detects. This avoids the situation where the device is going into an alarm mode unnecessarily. The addressable fire alarm system allows you to pinpoint the location where the fire originated and immediately reach the site and stop, making it easier to control the fire. If you are using an existing system, it will take time to identify and determine the cause of the fire, especially unless the firefighter is in a very small area. With an easy-to-handle fire alarm system, firefighters instantly know the cause of the fire [11–13]. In this paper, we propose a smart addressable fire detection system. In the proposed system, IoT was used and the network was constructed using ZigBee module. In the configured network, it consists of a local server and a control server. The local server controls the addressing sensor and sends the information obtained from the sensor to the control server. The control server receives data transmitted from the local server and enables quick fire action. In the actual implementation, the local server used the Lycra controller and ZigBee module.

2. RELATED WORKS

The fire alarm system consists of a fire detection sensor (smoke sensor, heat sensor, infrared sensor), a control panel, and an alarm system. This chapter looks at the components of the fire alarm system.

2.1. Smoke Sensor

The smoke sensor detects smoke in a fire place and serves as an early fire alarm. Figure 1 illustrates the structure and operation of the smoke sensor. In Figure 1(a), the light source (A) is located and emitting light to the right. And in the position (B) of Figure 1(a), a photo sensor that detects light is located. In this state, the photo sensor does not detect light. As shown in 1(b), when smoke enters the pipe, smoke particles scatter light and receive light at position (B) [14]. However, the smoke sensor has two problems. First, if too much smoke is generated, the light is blocked, and the photo sensor may not receive the light. The second problem is that the smoke sensor is not sensitive [15].



(a) (b) Smoking state

Figure 1. Structure of smoke sensor
(a) In case of normal, (b) In case of fire

2.2. Temperature Sensor

Temperature sensor has been used for the longest time among the sensors used in automatic fire detection devices. The thermal sensor began in the development of an automatic sprinkler in 1860 and has been developed into various types of devices to date. The heat detecting device uses only a heat sensing sensor to detect heat internally, and does not provide a fire extinguishing function, but has been used until recently [16]. Also, among the automatic fire detectors, the fire detection rate is slow, but the false alarm rate is low. The thermal sensing device can be used when the fire detection device in the surrounding environment cannot be used or when the detection speed is not important. It is also useful when high power fires are expected in confined spaces. The heat detector is usually mounted on the ceiling inside the building and detects the heat of the fire. An alarm is generated when the temperature sensor approaches a preset temperature value or matches a preset temperature change rate. The heat sensor is rounded so that it can be attached to the ceiling as shown in Figure 2. The manufactured sensor detects heat according to changes in the physical and electrical properties of an object or gas [17].

Figure 2. Examples of smoke and temperature sensor

2.3. Fire alarm control unit

The fire alarm panel is the control component of the fire alarm system and is called the fire alarm control panel (FACP) or fire alarm control unit (FACU). The most important role of this panel is to receive the data sensed by the fire detection device. In addition, it monitors whether the fire detection device is operating normally and performs automatic control when a specific situation occurs. It also provides the transmission of the information needed to prepare the facility in a predetermined order [6, 9]. In the control unit inside the panel, there is a built-in micro-controller that plays a key role in the system. The micro-controller receives data from various detectors and controls the necessary devices according to the situation. Panels are divided into conventional panels, addressable panels, coded panels, multiplex systems, etc.

2.4. Zigbee

ZigBee uses radio frequency (RF) and can transfer data between ZigBee modules. In addition, it can be configured as an independent module and has a low cost of configuration. The ZigBee module has its own protocol and uses a frequency of 2.4 GHz in short range and 900 MHz in long range. The ZigBee commercial module is as small as a regular coin and can be configured as a small system such as a sensor node [17, 18]. A ZigBee module is designed with low power in mind and a special power saving mode can further reduce power consumption. Using sleep mode among functions, it is possible to increase the battery life of sensor nodes that use batteries or use solar power. Also, the module itself is not a micro-controller, but it has a small amount of processing power to control the module. A ZigBee module can be controlled to read data received from the internal data pin and transmit data to other ZigBee modules. The sensor node can be connected to the data collection node by utilizing the ZigBee module. Data can be read by direct sensor control using the ZigBee module, but it is not suitable as a sensor node because of insufficient processing power[18, 20, 21]. ZigBee network layer is responsible for the mechanism for joining or leaving the network, providing security for transmission frames, and routing to nodes that want to send frames. In addition, the NWK layer is responsible for finding and managing routing paths between devices, and managing neighboring devices. ZigBee Coordinator's network radar is responsible for starting a new network and also assigns addresses to devices that have joined the network. Figure 3 shows a network that can be configured with Zigbee. And the following describes the components of the network.

- ZigBee End device (ZED): ZED is node that send and receive information to and from routers and coordinators. ZED is operated at low power, resulting in low power consumption. It also supports sleep mode, reducing power requirements. In the network configuration, most sensor nodes are configured as ZED [19].

- ZigBee Coordinator (ZC): This node performs internal address management and network type management functions. Also, all nodes in the network search for the coordinator at the start and share the handshake information. Each network requires one ZC.

- ZigBee Router (ZR): ZR acts as a router to temporarily transmit data from other devices. It uses less memory and costs less than ZC. ZR needs to operate reliably inside the network, so stable power is supplied. A router can maintain a mesh network while joining the network to the network and sharing information between nodes.

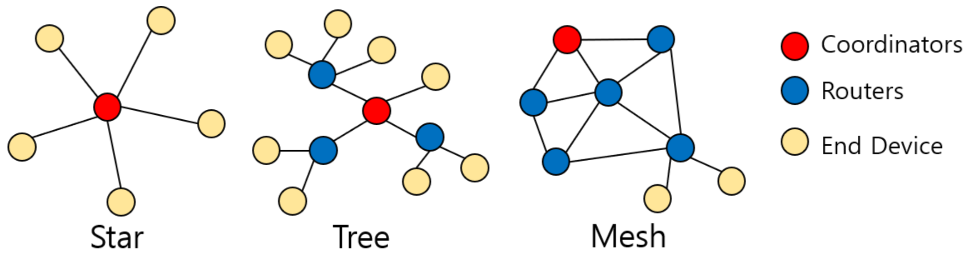


Figure 3. Structure of ZigBee networks

3. SYSTEM DESIGN

3.1. Addressable fire alarm control unit

If a fire occurs by installing a fire alarm control device in a location where fire detection is required, status information is transmitted to the server using WiFi [14,20,21]. In this study, 8 to 10 fire detectors were used, and the products used in the experiment are shown in Figure 4.

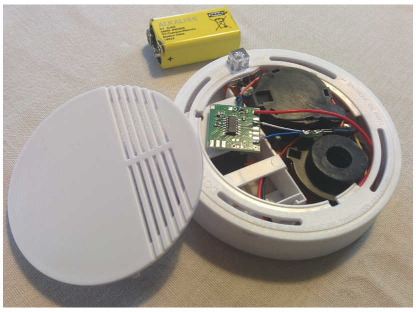


Figure 4. Inside of smoke sensor

In this study, a PIC16F877A microcontroller was used to design an addressable fire detector [22]. Table 1. shows a specification of PIC16F877A microcontroller. The fire detector detects the fire, sends a signal to the micro-controller, and after receiving the signal, uses the LED to indicate that a fire has occurred in the area. And the microcontroller was equipped with two switches. The first switch is used as a power switch, and the second switch is used to reboot when the system operates abnormally. Figure 5 shows the fire detection algorithm.

Table 1. Specification of PIC16F877A

Item	Value
Prgram memory type	Flash
Program memory size	14KB
CPU Speed (MIPS/DMIPS)	5
Digital Communication Peripherals	1-UART, 1-SPI, 1-I2C-MSSP
Timers	20

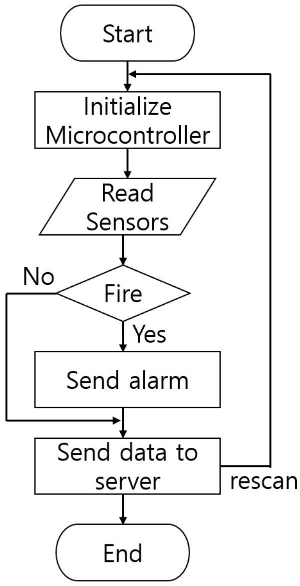


Figure 5. Flowchart of fire alaram conrol unit

The addressing fire detection device was implemented using a microcontroller. To implement a local server, Digi's XBee module was used [23]. The fire detection device information obtained from the microcontroller was transmitted to the local server using the USART serial port. The local server connected to the microcontroller operates as an end device. The fire detection device produced transmits the acquired information to ZC after receiving the request from ZC. The fire detection system produced in the study is shown in Figure 5. The role of the local client is shown in Algoritm 1.

Algorithm 1: Role of local server

```
while wait for signal do
    read request;
    if number of sensor then
        read sensor data;
        send data to control server;
    end
end
```

3.2. Control server for fire fighting center

In the implementation of the paper, the control server is located in the fire center and receives fire detection data transmitted from the local server. The local server continuously monitors the fire in a specific area and transmits the acquired information to the control server. The central server acts as a coordinator among the ZigBee network components. The central server periodically receives sensor data from the local server. The control server was implemented using Raspberry Pi and ZigBee modules. Figure 8 shows the control server implemented [24–26]. The control server is largely divided into two functions. The first is the web server function and the second is the ZigBee control part. In the web server, local servers can be controlled remotely. In the control server, each sensor on the local server can be individually turned on or off. ZigBee receives information obtained from sensors on the local server is shown ini Figures 6 and 7. The operation of the central server is shown in Algorithm 2.

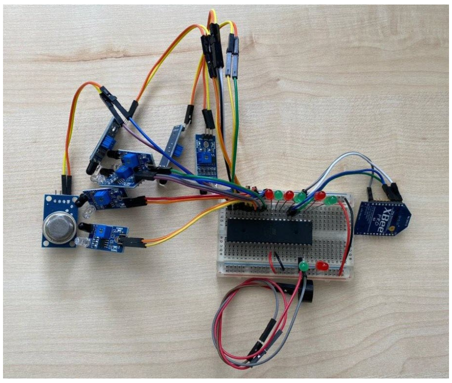


Figure 6. Fire alarm control unit using microcontroller

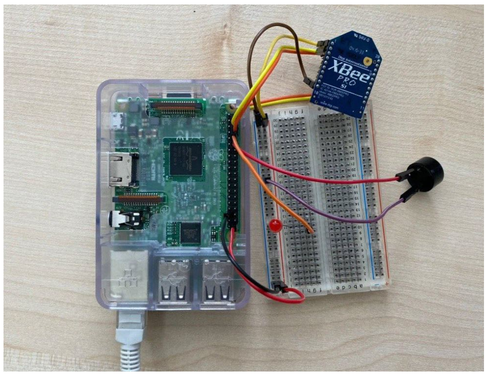


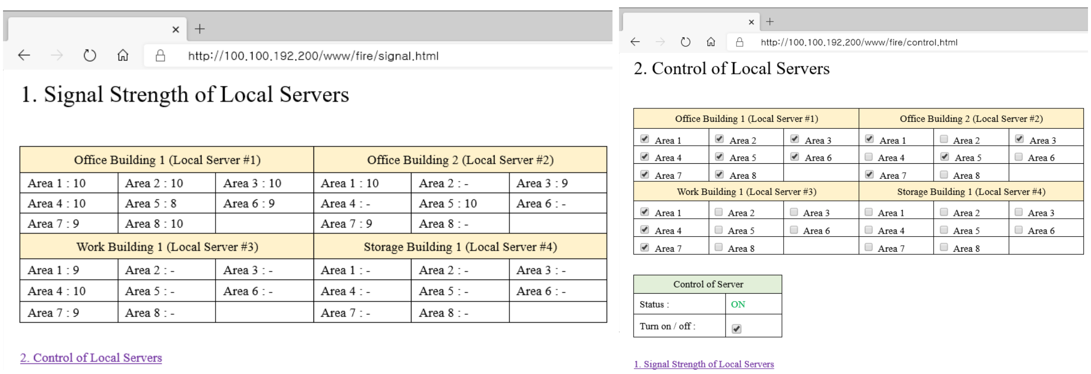
Figure 7. Control Server using ZigBee Module

Algorithm 2: Role for control server

1 select sensor address;
2 request for sensor data;
3 wait for acknowledge;
4 **if** *correct acknowledge* **then**
5 | update web server;
6 **else**
7 | goto line 1;
8 **end**

3.3. Web server

Raspberry Pi 3B+ and Apache were used to configure the web server. It is possible to check the information of the local server in various environments by connecting the control server that selected Raspberry Pi to the wired Internet. In this way, the control server administrator and the general user can use a mobile phone or computer to monitor the operating status of the local server or control sensors. The sensor data of the local server are displayed on the web page as shown in Figure 8(a). And Figure 8(b) shows a web page that allows you to control the local server. In this web page, it is possible to control the operation of each sensor in the local server.



(a) (b)

Figure 8. Controlling the local server and data verification,
Web page for displaying signal strength, (b) Web page for controlling local server

4. CONCLUSIONS

In this paper, we proposed an addressed fire detection system using IoT system and ZigBee module. The proposed system consists of a local server and a control server. The local server uses a microcontroller to control up to 8 sensors and monitors the fire. When a fire is detected through the sensor, environmental information is transmitted to the control server. ZigBee module was used to send data to the server. The control server was implemented using Raspberry Pi and ZigBee modules. The control server can receive data transmitted from the local server and monitor the current status using a web server. It is also possible to control the local server on the web page provided by the control server.

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