Design and Implementation of a Smart Fire Alarm System Based of Wi-Fi over Long Distance (WiLD)

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Abstract
This research is developed for the users to sense the occurrence of fire in different locations such as factories, houses, ….etc, using fire detecting system. The fire detector indicates the location of fire and produces alarm in the fire location and the center of fire fighting based WiLD. The signal transmitted from fire location to the center of fire fighting, where a fire sensor connected to the microcontroller that was interfaced to the local server which will transmit the status of the location continuously to the central sever in the center of fire fighting.

Keywords: Xbee, Fire alarm system, Microcontroller, WiLD

تصميم و تنفيذ منظومة إنذار الحرائق الذكية بالاعتماد على الشبكة اللاسلكية للمسافات الطويلة

المستخلص:
تم تطوير نظام يحس الحريق في المواقع المختلفة مثل المصانع والمنازل والمحال التجارية، باستخدام نظام تحديد موقع الحريق (WiLD) بالاعتماد على تحديد منطقة الحريق بموقع واحد، وتم إصدار أرسل رسلة عبر الشبكة اللاسلكية (central sever) من الخادم المحلي (local server) إلى الخادم المركزي، من مركز اطفاء الحرائق وترتب محسسات الحرائق بالمحيط الدقيق.
Addressable fire alarm systems assign each initiating device a discrete and unique identification (address). In addition to the address, the panel will usually have the ability to have a tag to further identify the address (i.e. Address 1, Front Lobby, back door, hallway, etc). Some addressable systems consider each point as a separate zone. Addressable devices are similar to conventional devices in that they are either in alarm or in a normal condition.

Addressable systems utilize a Signaling Line Circuit (SLC) to communicate with detectors, modules and auxiliary devices to complete the system. These types of systems have more versatility and features compared to the conventional systems. Modules and additional circuit boards allow the addressable systems to expand and perform more remote relay functions, dry contact monitoring, remote power control, releasing service and conventional zone monitoring. [1][2]

The addressable systems also allow for mapping of inputs to outputs. This allows the end-user to control the panel in such a way that specific smoke detectors can control certain output functions.

Addressable fire systems have a number of advantages over conventional systems. The wiring for each zone must return to the panel on conventional systems, whereas the addressable systems use a single pair of wires and connect to all of the initiating devices and control modules on the addressable system. In addition, when a trouble occurs with the addressable system, the information from the panel will help the installer determine where the problem has occurred, if a
device is missing or if the wrong type of device is installed. Conversely, the conventional system will show a trouble condition and the zone where the trouble occurred. Also, when a device reaches the alarm level, the conventional system will give the area of alarm, the addressable system will tell what device is in alarm and where that device is located. Smoke detection has become a fundamental component of the active fire protection strategy of most modern buildings, particularly residential occupancies.

2. Background and Related Work
Forest fires are one of the main causes of environmental degradation nowadays. The current surveillance systems for forest fires lack in supporting real-time monitoring of every point of the region at all time and early detection of the fire threats[3]. In rooms of Sharda University, Greater Noida, India the design and deployment of wireless sensor network is used for campus monitoring. With the help of Passive Infrared (PIR) sensor, temperature sensor, and humidity sensor, an effective utilization of energy resources has been implemented. The security of campus against intruders moving in laboratories, class rooms, staffrooms or washrooms etc. after working hours and fire alarm are also provided by this system[4]. Indonesia has been suffered from forest fires. The recent fires in logger-over forest, peat land, and plantation should be classified into one of human-made disasters. In recent years, fires in Indonesia occurred mainly in peat land area and become one of international serious issues due to haze and CO2 emission. One strategy to detect and monitor peat-forest fires in Central Kalimantan, Indonesia is to use a Wireless Sensor Networks (WSNs), which contains miniature sensor nodes to collect environmental data such as temperature, relative humidity, light and barometric pressure,
and to transmit more accurate information to fire-fighter and remote monitor[5].

3. Fire Detection and Alarm System Basics
The fire alarm system consists of:
1. Fire detectors (with can be smoke detector, heat, or Infra-Red detectors), 2. control unit, 3. alarm system

3.1 Smoke Sensor
The smoke sensor provides a mean to detect smoke and to serve as an early fire warning. The basis of the smoke sensor is a T-shaped chamber figure 1 with an infrared LED that emits a beam of light across the horizontal portion of the chamber. When smoke enters the chamber, however, the smoke particles scatter the light and some amount of light hits the sensor.[6]

![Figure 1: Smoke sensor](image)

3.2 Temperature Sensor[7]
Heat detectors are the oldest type of automatic fire detection device. They began development of automatic sprinklers in the 1860s and have continued to the present with proliferation of various types of devices. Heat detectors that only initiate an alarm and have no extinguishing function are still in use. Although they have the lowest false alarm rate of all automatic
fire detector devices, they also are the slowest in fire detecting. A heat detector is best situated for fire detection in a small confined space where rapidly building high-output fires are expected, in areas where ambient conditions would not allow the use of other fire detection devices, or when speed of detection is not a prime consideration. Heat detectors are generally located on or near the ceiling and respond to the convected thermal energy of a fire. They respond either when the detecting element reaches a predetermined fixed temperature or to a specified rate of temperature change. In general, heat detectors are designed to operate when heat causes a prescribed change in a physical or electrical property of a material or gas, as shown in figure 2.

3.3 Control Unit [8]
The control unit contains the microcontroller which is the heart of the system. It receives inputs from the receiver, temperature sensor, smoke sensor, and low battery sensor, as well as outputting the appropriate signals and bits to the tone generator and transmitter.
3.4 XBee

An XBee is a self-contained, modular, cost-effective component that uses radio frequency (RF) to exchange data between XBee modules. XBee modules transmit on 2.4 GHz or long-range 900 MHz and have their own network protocols. The XBee module itself is very small about the size of a large postage stamp making it easy to incorporate in small projects like sensor nodes. The modules are also low power and can use a special sleep mode to further reduce power consumption. Although the XBee isn’t a microcontroller, it does have a limited amount of processing power that you can use to control the module. One of these features, the sleep mode, can help extend battery life for battery-powered (or solar-powered) sensor nodes. You can also instruct the XBee module to monitor its data pins and transmit the data read to another XBee module. XBee modules can link a sensor node to a data-aggregator node. While the XBee can be used to read sensor data, its limited processing power may mean it is not suitable for all sensor nodes. For example, sensors that require algorithms to interpret or extrapolate meaningful data may not be suited for using an XBee alone. You may need to use a microcontroller or computer to perform the additional calculations[9].

The XBee modules are branded with a specific serial number or address located on the bottom of the module. This is a bit inconvenient given that you normally cannot see the back of the module when it is mounted. However, you can find the address using either the Digi configuration application or a simple serial terminal application. Figure 3 shows the underside of an XBee module. Notice the numbers printed under the model number.
Figure 3. XBee address printed on the back of the module

ZigBee networks are based on a predefined network stack where each layer in the stack is responsible for a specific transformation of the data messages. Also like other networks, ZigBee networks support message routing, ad hoc network creation, and self-healing mesh topologies. Thus, the radio address and the PAN address are needed to support these features. Support for mesh topologies is made possible with the addition to the different roles that each node (radio) can perform in the network. The following list describes each role in more detail, starting from the most complex.

- Coordinator: A single coordinator is needed for each network. This node is responsible for administering addresses and forming and managing the network. All other nodes search for the coordinator and exchange handshake information at startup.

- Router: A node that is configured as a router is designed to pass on (route) information to other radios. Routers enable the healing of mesh networks by joining networks and exchanging messages from other nodes. Routers are
typically powered with reliable sources because they must be dependable. Thus, a data-aggregation node would be a good choice for the router radio mode.

- **End device**: An end device is a node that sends or receives information to the router nodes and the coordinator. It has an advantage in that less processing is going on, so power consumption is lower. End devices support a sleep mode to reduce power requirements still further. Most of the sensor nodes will be configured as end devices[10], as shown in figure 4.

![ZigBee network topologies](image)

**Figure 4: ZigBee network topologies**

### 3. SYSTEM ARCHITECTURE

The requirement for this research is to design and create a functional smoke detector. After detecting smoke or a high temperature (potential fire), the detector sets on the appropriate alarm sound. The control unit also transmits a control signal to the local server in the network so that this server sends a status massage to the central server continuously where the central
server indicates alarm and provide the location of the fire to the center of fire fighting.

4. Fire Alarm Control Unit
Each location has a fire alarm control unit which was detect the fire and send a status signal of the location to the server via WiFi. In this research both heat and smoke detectors have been used and divided in to eight zones for fire detection as shown in figure 5, and the smoke sensor is shown in figure 6.

![Eight Zones Fire alarm system](image1)

**Figure5:Eight Zones Fire alarm system**

![Smoke sensor](image2)

**Figure 6: Smoke sensor**
The control panel used for controlling and monitoring zones state in the system as shown in figure 7.

Figure 7: Fire alarm control panel

The fire detectors have been used to indicate the status of the system where they send signals to the microcontroller (PIC16F877A). The microcontroller (PIC16F877A) output indicates on a simple LED diode for each zone and two switches; one for resetting the system and the other for power control as shown in figure 8 and the algorithm of the fire alarm system is shown in figure 9. The microcontroller (PIC16F877A) is interfaced with local server (xbee) via USART serial port. Each local server operates as end device. The device waits for data reading request (i.e., polling) from the Coordinator and then responses with the value from the sensors as shown in figure 10, and the algorithm of local server is shown in figure 11.
5. Central Server
The central server is located in the fire fighting center, where the local servers send the status of each area under monitoring continuously with specific algorithm. The central server is operated as coordinator. It collects sensor readings from the sensors back to the user. The function of the collector is divided into two parts: Web-Server and Xbee Interface. These two functions are implemented on the Arduino board. The hardware of the coordinator consists of an Arduino USB Board, Xbee Shield, Alarm indicator and Ethernet Shield, as shown in Figure 12. The Web-Server function uses the <Ethernet.h> library, while the Xbee Interface uses the <Xbee.h> library. The flowchart of the coordinator is shown in Figure 13.

![Fire Alarm Control Unit without Server](image)

**Figure 8: Fire Alarm Control Unit without Server**

![Fire alarm system algorithm](image)

**Figure 9: Fire alarm system algorithm**
Figure 10: Interfacing PIC16f877A with local server

Figure 11: Flowchart of Local server (End Device)
Figure 12: central server (coordinator) of Fire alarm system

Figure 13: flowchart of central server (coordinator)
6. User Interface
The User Interface communicates to the server via Ethernet and displays the result in a web browser. It shows the data from every sensor via Web page in HTTP Response. Arduino works as a Web-Server to generate HTTP page which is displayed by the web browser as shown in figure14.
In this research a prototype of Addressable Fire Alarm based WiLD is shown in figure 15.

7. Conclusion
In this research a prototype of a Smart Fire Alarm based Wi-Fi over Long Distance (WiLD) has been Designed and Implemented based microcontroller and Xbee as sever, detecting the occurrence of fire in different locations using fire detecting system. The fire indicator indicates the location of fire and produces alarm in the fire location and the center of fire fighting based WiLD signal is transmitted from fire location to the center of fire fighting.
Figure 14: User interface web page

Figure 15: Fire alarm system based WiLD
References


