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# **Fire Fighting System Based on Wireless Sensor Network**

A research Submitted in partial fulfillment for the  
Requirement of the Degree of B.S.c (Honors) Electronics  
Engineering

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## الإستهلال

قال تعالى:

{ يَرْفَعُ اللَّهُ الَّذِينَ آمَنُوا مِنْكُمْ وَالَّذِينَ أُوتُوا الْعِلْمَ دَرَجَاتٍ }

سورة المجادلة - الآية (11)

## الإهداء

إلى التي رأني قلبها قبل عينيها... وحننتني أحسانها قبل يديها...  
إلى شجرتي التي لا تبلى إلى الظل الي أوى إليه في كل حين أُمي الغالية..

إلى من كلله الله بالهبة والوقار

إلى من علمني العطاء دون انتظار

أبي الحبيب...

إلى من يحملون في عيونهم زكريات طفولتي وشبابي

إلى من اكملت معهم شغفي وشغبي

إلى سندي في الحياة اخوتي واخواتي

إلى من تحلو بالإخاء وتميزو بالوفاء

إلى من عرفت كيف أجدهم وعلموني أن لا أضيعهم

إلى اخوتي واخواتي التي لم تلدهم امي ...

اصدقائي

إلى الذين حملوا أقدس رسالة في الحياة

إلى الذين مهدوا لنا طريق العلم والمعرفة

إلى جميع أساتتنا الأفاضل...

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The success and final outcome of this project required a lot of guidance and assistance from many people and we are extremely privileged to have got this all along the completion of my project. All that we have done is only due to such supervision and assistance and we would not forget to thank them.

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## **Abstract**

The aim of this study is to design and develop an autonomous fire fighting system based on wireless sensor network. The system is designed in such a way, that it can detect and fight the fire with quick response. Further, it will sense and communicate information regarding these situations in real time with the server.

The system is fixed with Z- wave smoke sensors and a driver circuit has been integrated for communication in all fire situations through Z-wave technology and data base system. We develop the design based on raspberry pi chip as the micro-controller , the process of data transmission is discussed in detail.

The system has been tested and evaluated, results from the testing system show that wireless fire fighting system achieves the design requirements.

## المستخلص

الهدف من هذا البحث هو تصميم وتطوير نظام مستقر لمكافحة الحرائق يعتمد على حساسات لا سلكية وتصميم النظام بالطريقة التي تسمح له بكشف ومكافحة الحرائق بإستجابة سريعة و بالإضافة الى ذلك سيتم إستشعار الحريق وإرسال المعلومات المتعلقة بحالات الحريق في الوقت الحقيقي الى المتحكم الدقيق تم توصيل النظام مع جهاز إستشعار الدخان وقد تم دمج دائرة تقود الإتصال في جميع حالات إلى قاعدة البيانات من خلال تكنولوجيا موجهة لقد تم تطوير النظام اعتمادا على رقاقة الراسبري باي ووحدة تحكم أساسية عملية انتقال البيانات في النظام تم نقاشه بالتفصيل. النظام تم اختباره وتقييمه, نتائج اختبار النظام تثبت أن نظام مكافحة الحرائق اللاسلكي حقق متطلبات التصميم.

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## LIST OF ABBREVIATIONS

AFFMP	Autonomous Fire Fighting Platform.
A/V	Audio / Video.
COM	Common.
CO <sub>2</sub>	Carbon Dioxide.
CO	Carbon Monoxide.
CSI	Camera serial interface.
CSS	Cascading Style Sheets.
DAQ	Data acquisition System.
DSI	Display Serial Interface.
GND	Ground.
GPIO	General Purpose input/output.
HCL	Hydrogen Chloride.
HCN	Hydrogen cyanide.
HDMI	high-definition multimedia interface.
HTML	Hyper Text Markup Language.
H <sub>2</sub> O	Water.
H <sub>2</sub> S	Hydrogen Sulfide.
I/O	input/output.

IOT	Internet of Things.
IP	Internet Protocol.
IR	Information Retrieval.
LED	light emitting diode.
NC	Normally Close.
NO	Normally Open.
PC	Personal Computer.
PDF	Portable Document Format.
PHP	Hyper Text Preprocessor.
RDBMS	Relational Database Management System
RTC	Real-time Computing.
RTOS	Real time Operating System.
RXDO	Serial Receive.
SBS	Single-board.
SD	Secure Digital.
SOC	system on a chip.
SPI	Serial Peripheral Interface.
SSH	Secure Shell.
TXDO	Serial Transmit.
USB	Universal Serial Bus.
UV	Ultraviolet.

V	Voltage.
VCC	Voltage Power Supply.
WAN	Wide Area Network.
Wi-Fi	Wireless Fidelity.
WSN	Wireless Sensor Network.
XHTML	Extensible Hyper Text Mark-up Language.
XML	Extensible Markup Language.
3V3	3.3 Volt.
5VO	5Volt.

**Chapter one**  
**Introduction**

## 1.1 Preface:

Each year fire kills more than four thousand civilian and a hundred firefighters in the United States alone. It's a dangerous profession that calls for quick decisions in a high stress environment<sup>1</sup>.

Firefighting is the act of attempting to prevent the spread of fire and fight the fire itself<sup>[1]</sup>

Firefighting is everyone's responsibility; therefore we all must know how to react with fire.

Firefighting today still remains a dangerous job especially in indoor environments. Most of the accidents may be avoided by providing fight for the fire using water pump.

The concept of Wireless Sensor Networks (WSNs) is integrating some functionality into one intelligent glove, which has a build-in sensor node<sup>[2]</sup>

So The Automatic fire detection is important for early detection and promptly extinguishing fire. There are examples studies investigating the best sensor combinations and appropriate techniques for early fire detection. These different approaches taken from different backgrounds of researchers dealing with fire, such as computer science, geography and earth observation, and fire safety<sup>[3]</sup> There are many concerns in automatic fire detection, of which the most important ones are about different sensor combinations and appropriate technique for quick fire detection<sup>[1]</sup>



## **1.2 Motivation:**

The main motivation of the system is to develop a wireless fire fighting system that avoid the physical efforts and high cost of installation the wire system. Since there is no cabling needed the system will be easier and quicker to install especially when there is modification happening.

## **1.3 Problem Statement:**

Wired Fire Alarm System has lots of benefits like cheaper devices, reliable power source, No signal interference and spare parts are easier to source, but it is not suitable in industrial manufactures historical buildings and other buildings which are sensitive and need a quick response<sup>[4]</sup>.

The existing firefighting system is purely manual system which means slower response time and recovery mechanism damage, loss of materials and resources, and affects the safety of the human life<sup>[4]</sup>.

## **1.4 Objective:**

The main aim of this project is to enhance and improve the method which used in the buildings for firefighting and that is achieved by the following subobjectives:

- To avoid or reduces the risks which facing the workers in the environment while maintaining quick response.
- To enhance the communication with the building control room and making it more efficient by converting the system to be automatically.

- To decrease the physical effort and the installation cost by using wireless system.

## **1.5 previous studies:**

Many different projects are done in the same field some of them are mentioned below:

### **1.5.1 Wireless Automatic Fire Fighting Surveillance Robot:**

It's an autonomous fire proof rescuer robot. The robot designed in a way that it can traverse through fire and hazardous situation<sup>[5]</sup>.

### **1.5.2 Autonomous fire fighting mobile platform:**

An Autonomous Fire Fighting Mobile Platform (AFFMP) is a tracker which detects and fights the fire source<sup>[6]</sup>.

### **1.5.3 Robotic fighting vehicles:**

It is a vehicle which designed to be used in at some fire locations, like flammable or explosive material storage areas and nuclear power plants, are too hazardous for human firefighters to enter. It fights the fire by water or FOAM gas<sup>[7]</sup>.

## **1.6 Proposed Solution:**

Converting from manual detection to automatic detection using smoke sensor to detect fire, and use wireless technology to detect the exact location of the fire, also use a suitable material for fire extinguishing depending on the type of building and the property inside it.

## **Methodology followed:**

The system will be implemented in hardware using different devices.

Those devices are:

- Smoke sensor.
- Raspberry pi.
- Z-wave stick.
- Water pump
- Contactor.
- Sprinkler.
- Alarm.

Those devices will be connected to perform the intended task which fire sensing.

## **1.7Thesis Organizations:**

### **Chapters:**

Chapter Two is a theoretical background definition of fire sensors and there types and also devices related to the firefighting systems.

Chapter Threedescribes how to connect thesensors using (Raspberrypi)boardand sending the result by web server.

Chapter Four discusses the results of hardware circuit.

Chapter Five draws the conclusion and the future ideas that can be performed.

**Chapter two**  
**Literature review**

## **2.1 Introduction:**

This chapter overviews various technologies and techniques that have been employed for use in firefighting system. It also reviews the principles of sensors and the principles of web technologies. This was done with the aim of providing guidance to certain design decisions for later use throughout the project.

## **2.2 Firefighting System:**

This section discusses the main component of the firefighting system.

### **Fire detection devices:**

As a rule fire detection devices are divided into two basic types:

Manually actuated and automatically actuated devices <sup>[8]</sup> <sup>[9]</sup>.

Manually actuated devices also known as “Fire alarm boxes” are located near the exits and in many cases look like the red button on the wall. Somebody should push the button in a risk of a fire. But it will be late when somebody push the button after seeing the flame <sup>[9]</sup>.

Modern automatically actuated fire alarms are used to detect fire at the earliest possible stage.

They were produced for working 24 hours per day without any human intervention <sup>[9]</sup>.

## **2.3 Sensors:**

There are 4 basic types of automatic alarm-initiating devices are designed to detect, smoke, heat, fire gases, and flame <sup>[10]</sup>.

### **2.3.1 Smoke Alarm:**

Also Known as smoke detectors, these devices are one of the best early-warning devices of a fire that why we choose it as our main sensor in our design. It designed to sense low levels of smoke and sound an alarm [10].

There are two type of smoke alarm one has built in alarm which alerts people around it. Other connected to the building's fire alarm system [10].

When this detector senses smoke, it may either sound an alarm in the room, or send a signal to the building fire alarm system.

Smoke alarms are located in areas where they cannot be set off accidentally by steam from showers or from cooking smoke <sup>[10]</sup>.

Smoke detectors have 2 main types:

- Photoelectric Smoke Detectors.
- Ionization Smoke Detectors <sup>[10]</sup>.

### **2.3.2 Heat detectors:**

Usually use in places where smoke detectors cannot be effective like kitchens. Heat detectors react at fixed temperatures or when heat is rising at a certain rate to provide detection in these areas.

Smoke sensors have heat detectors as part of their design to provide dual protection [10].

It has 4 main types:

- Fixed Temperature Heat Detector.
- Rate of Rise Detector.

- Rate Compensation.
- Line Type Detectors.

### **2.3.3 Fire Gases Detectors:**

When a fire burns, it changes the makeup of the atmosphere within the space <sup>[10]</sup>. Depending on the fuel, some of the gases released by the fire including the following:

- Water vapor (H<sub>2</sub>O).
- Carbon dioxide (CO<sub>2</sub>).
- Carbon monoxide (CO).
- Hydrogen chloride (HCL).
- Hydrogen cyanide (HCN).
- Hydrogen fluoride (HFL).
- Hydrogen sulfide (H<sub>2</sub>S) [10].

### **2.3.4 Flame detectors:**

The appearance of the flame is a stage after the smokes or gases and has the highest degree of dangerousness.

There are 3 basic types of flame detectors also known as light detectors:

- Detecting light in the ultraviolet wave spectrum (UV detectors).
- Detecting light in the infrared wave spectrum (IR).
- Detecting both types of light.

## **2.4 Fire Alarm System Structure Design:**

There are 3 main designs for the fire alarm system:

- Conventional Analogue.

- Addressable Analogue.
- Wireless Fire alarm system [10].

### **Conventional vs. Addressable Fire Alarm System:**

There are several differences between conventional & addressable fire alarm system:

- Addressable give information's about individual detectors whereas conventional systems only give information about give information about specific circuits (zones).
- Addressable allow text label to allow easy identification of any event.
- Most addressable systems allow early warning
- Addressable systems have a real time clock [10].

We choose addressable fire alarm system to be implemented in our system design because it's more effective.

## **2.5 Embedded and Real Time systems:**

### **2.5.1 Embedded systems:**

An embedded system is a specialized computer system that is part of a larger system or machine. Embedded systems can also be thought of as information processing subsystems integrated in a larger system.

Some embedded systems include an operating system<sup>[11]</sup>.

#### **Embedded systems functions:**

- Monitor the environment:
- Embedded systems read data from input sensors.
- Control the environment:



- Embedded systems generate and transmit commands for actuators.
- Transform the information:
- Embedded systems transform the data collected in some meaningful way, such as data compression/decompression <sup>[12]</sup>.

There are many categories of embedded systems for communication devices to home appliances to control systems.

In our daily life we use many embedded systems like Digital alarm clock, cellular phone, microwave oven, coffee machine and refrigerator <sup>[12]</sup>.

### **2.5.2 Real-time systems:**

Real-time computing (RTC) or reactive computing describes hardware and software systems subject to a "real-time constraint", for example from event to system response. Real-time programs must guarantee response within specified time constraints, often referred to as "deadlines". The correctness of these types of systems depends on their temporal aspects as well as their functional aspects. Real-time responses are often understood to be in the order of milliseconds, and sometimes microseconds. A system not specified as operating in real time cannot usually guarantee a response within any timeframe, although *typical* or expected response times may be given [13].

There are two types of real-time systems: reactive and embedded. Reactive real-time system involves a system that has constant interaction with its environment.

- An embedded real-time system is used to control specialized hardware that is installed within a larger system [13].
- A hard Real time system should always respond to an event within the deadline or else the system fails and endangers human lives

but in soft real time system, failing to meet the deadline produces false output and does not endanger the human lives and our designed embedded system is a soft real time system <sup>[14]</sup>.

The major part of this project is the hardware model consisting of a sufficient sensor with embedded system.

Embedded systems are computer in the widest sense. Based on functionality and performance requirements, embedded systems can be categorized as, Stand-alone system, Real time system, Networked information appliances and Mobile devices. Every embedded System consists of custom-built hardware built around a central processing unit (CPU). This Hardware also contains memory chips onto which the software is loaded. The software residing on the memory chip is also called as the firmware <sup>[14]</sup>.

## **2.6 Microcontrollers:**

There are a lot of types of microcontrollers:

### **2.6.1 Arduino:**

Arduino is an open source electronics platform based on easy to use hardware and software. Arduino boards have ability to do many jobs like reading inputs light on a sensor, finger on a button, or a Twitter and turn it into an output activating a motor, turning on an LED, publishing something online. By changing the instructions the microcontroller board is being controlled to do actions as needed <sup>[15] [16]</sup>.

#### **Features of Arduino:**

- Inexpensive
- Cross-platform

- Simple, clear programming environment
- Open source and extensible software Open source and extensible hardware.

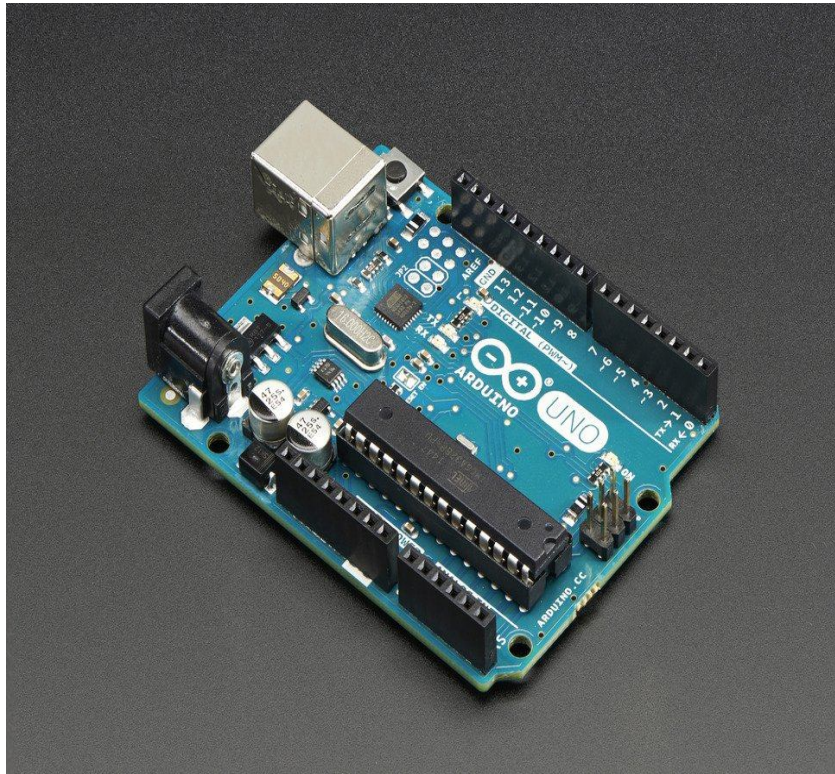


Figure 2.1 shows the Arduino chip <sup>[17]</sup>.

### 2.6.2 Raspberry pi:

The Raspberry Pi chips and ports device looks like a motherboard with the mounted exposed but it has all the components you need to connect input, output, and storage devices and start computing <sup>[15]</sup> Figure 2-4 shows the raspberry pi 2 moduel b+.

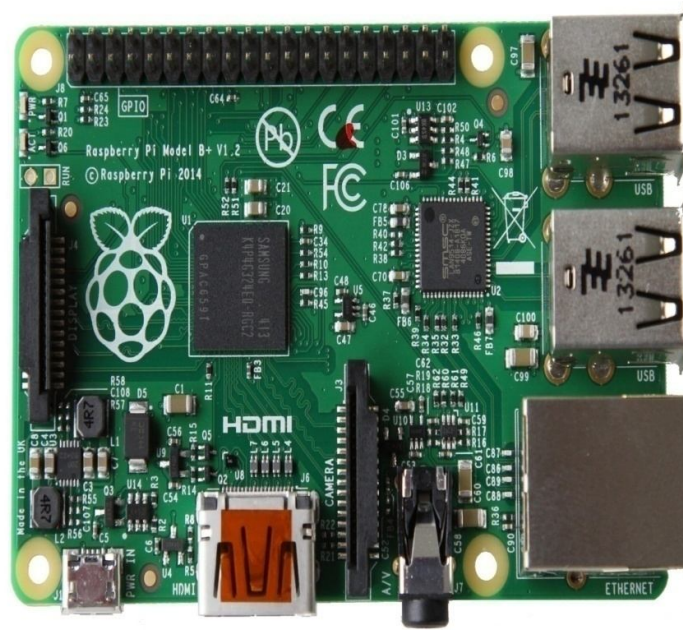


figure 2.2 Raspberry pi 2 model B+ board [18].

Raspberry Pi has two models of the device: Model A, Model B.

The only differences are the addition of Ethernet and an extra USB port on the more expensive Model B [15].

### **Raspberry Pi Basic's:**

Here are the various components on the Raspberry Pi board shows in figure 2-5:

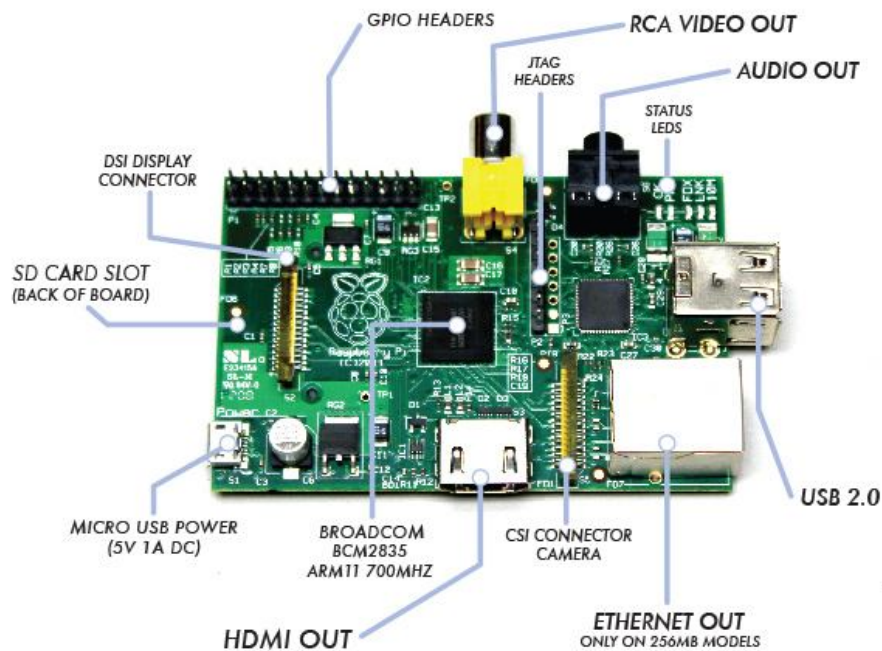


Figure 2.3 various components on the Raspberry Pi 2 board [19].

Some features that are missing, such as Wi-Fi and audio in, can be added using the USB port(s) or a USB hub as needed.

The Raspberry pi's programmability and simplicity make it very like the computers of yore that spawned so many programmers and system hobbyists.

To allow network connectivity for Raspberry Pi model B we attach Ethernet connector or an external Wi-Fi device [15].

## 2.7 Wireless Sensor Network (WSN):

A wireless sensor network (WSN) is a wireless network consisting of spatially distributed autonomous devices using sensors to monitor physical or environmental conditions. A WSN system incorporates a gateway that provides wireless connectivity back to the wired world and distributed nodes <sup>[20]</sup>.

Figure 2.6 will give you a description for the main concept of wireless sensor network.

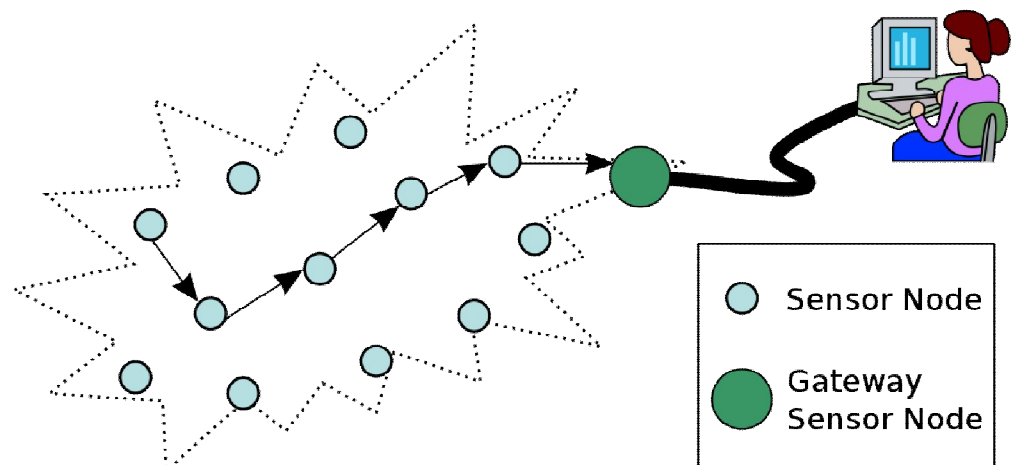


Figure 2.4 shows wireless sensor network [21].

The power of sensor network nodes is usually provided by batteries, so the transmission distance of WSN nodes is short. The sensor network nodes are both transmitter and receiver <sup>[20]</sup>.

The first sensor network node, the source node, sends data to a nearby node for data transmission to the gateway <sup>[20]</sup>.

One of the differences between WSNs and traditional wired networks is the instability of wire-less communication. In WSNs, the communication between nodes is susceptible to interference and occlusion, resulting in

signal transmission failure, but the traditional network is a stable wired network, which data will only be lost due to congestion [20].

## **2.8 Wi-Fi Technology:**

Wi-Fi is a short name for Wireless Fidelity. Wi-Fi is a technology that uses radio waves to provide network connectivity. A Wi-Fi connection is established using a wireless adapter to create hotspots areas in the vicinity of a wireless router that are connected to the network and allow users to access internet services. Once configured, Wi-Fi provides wireless connectivity to your devices by emitting frequencies between 2.4GHz - 5GHz, based on the amount of data on the network [22].

## **2.9 Web Technologies:**

Web development involves the creation of dynamic and static web pages, content management and database management [23].

### **2.9.1 CSS:**

CSS stands for Cascading Style Sheets and it describes how html elements are to be displayed on screen, paper, or in other media.

It saves a lot of work. It can control the layout of multiple web pages all at once.

#### **Why Use CSS?**

It used to define styles for your web pages layout and variations in display for different devices and screen sizes [23].

### **2.9.2 HTML:**

HTML stands for Hyper Text Markup Language.

HTML is the standard markup language for creating Web pages.

HTML describes the structure of Web pages using markup. Its elements are the building blocks of HTML pages.

Browsers do not display the HTML tags, but uses them to determine how to display the document <sup>[23]</sup>.

### **What can HTML do?**

We can add paragraphs of text, lists (both numbered and bulleted), tables, quotations, headlines, also we can add links in the documents to lead readers to other web pages and add images to make the pages more visually interesting <sup>[23]</sup>.

### **2.9.3 PHP:**

PHP is an acronym for "PHP Hyper text Preprocessor". It is a widely-used, open source scripting language.PHP scripts are executed on the server. PHP code is executed on the server, and the result is returned to the browser as plain HTML <sup>[23]</sup>.

### **What Can PHP Do?**

- PHP can generate dynamic page content.
- PHP can create, open, read, write, and close files on the server.
- PHP can collect form data.
- PHP can send and receive cookies.
- PHP can add, delete, and modify data in your database.
- PHPcan restrict users to access some pages on your website.
- PHP can encrypt data.



- With PHP you are not limited to output HTML. You can output images, PDF files, and even flash movies. You can also output any text, such as XHTML and XML <sup>[23]</sup>.

#### **2.9.4 MySQL:**

MySQL is the most popular Open Source Relational SQL Database Management System. MySQL is one of the best RDBMS being used for developing various web-based software applications.

#### **MySQL Features:**

MySQL is a fast, easy-to-use RDBMS being used for many small and big businesses [23].

#### **2.9.5 JavaScript:**

- JavaScript is the programming language of HTML and the Web.
- JavaScript is easy to learn.
- This tutorial will teach you JavaScript from basic to advance <sup>[23]</sup>.

#### **Why Study JavaScript?**

To use it program the behavior of web pages <sup>[23]</sup>.

## 2.10 Related work:

There are lot of studies were done in the fire automation system which designed as vehicles, smart robots and tracks all of them work autonomously without human intervention.

### 2.10.1 Wireless Automatic Fire Fighting Surveillance Robot:

It's an autonomous fire proof rescuer robot. The robot designed in a way that it can traverse through fire and hazardous situation.

It sense and communicate information regarding these situations in real time with the server. The robot is fixed with multi-sensors which carried a driver circuit has been integrated for communication in these hazardous situations through Zigbee and a data acquisition system (DAQ) [24].

Figure 2-7 shows the main block diagram of DAQ

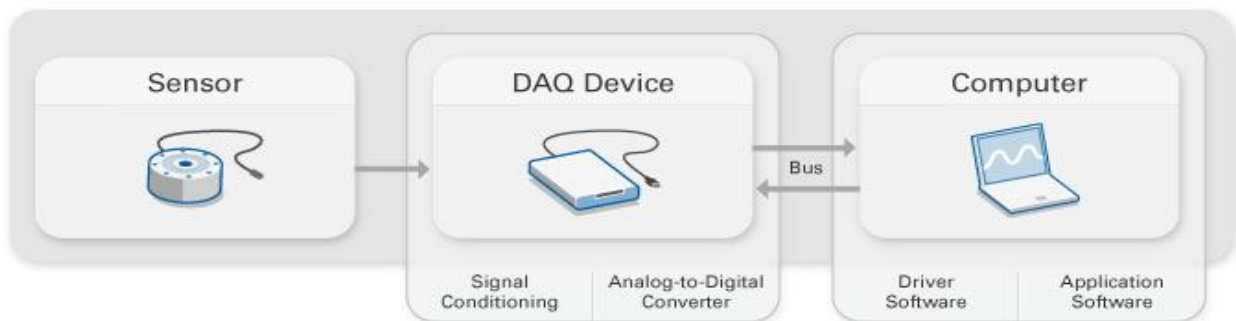


Figure 2.5 DAQ [24].

From the figure above we clearly understand the main role of DAQ

The robot is designed such that it can traverse into the fire and send information regarding the fire behavior and also the images of the victim's location by using a camera. There is a mathematical model which describes the dynamic behavior of robot motion which is done [24].

### **2.10.2 Autonomous Fire Fighting Mobile Platform**

It got its important in fire-prone area by implemented a mobile robot to perform this task.

A mobile robot is equipped with the basic fighting equipment that can patrol through the hazardous site via a guiding track with the aim of early detection for fire. When the fire source is being identified, the flame will be promptly extinguished using the fire extinguishing system that is mounted on its platform. The patrolling movement is guided by a set of lines with the use of a conventional line [25].

To detect for fire source, the input from flame sensors were finely-tuned in relation to the surrounding area, external interference and the mobility of the AFFMP prior the deployment of the platform.

To monitor for hazardous site via patrolling process, it aids to share out the burden of fire-fighters in fire fighting tasks as the fire-fighters can safely delegate the fire fighting tasks to AFFMP.

### **2.10.3 Robotic fighting vehicles:**

It used in at some fire locations, like flammable or explosive material storage areas and nuclear power plants, are too hazardous for human firefighters to enter.

FireRob is a firefighting vehicle that a single operator can direct on the ground by remote control. It extinguishes fires without

intervention of firefighters without intervention of fighters with high-pressure cannon on a hydraulic arm that pumps water up to 55 m away [26].

Other smaller, remote-controlled vehicles have been adapted to fight fires, such as Segway's water cannon prototype which is remotely-operated vehicle, and others that also contain cameras, high-pressure hoses, and remote operation.

Fire-rob is the only that integrates hydraulic arm blade, grip, and other tool attachments for path clearing in difficult terrain or inaccessible areas, and carries its own water and foam tanks <sup>[26]</sup>.

**Chapter three**  
**Hardware design**

### 3.1 General description of system

Firefighting system divided into two main subsystems:

- Fire alarm system
- Firefighting system

Fire alarm system:

A fire alarm system has a number of devices working together to detect and warn people through visual or audio appliances. In our project the alarm system includes: z-wave smoke sensor, microcontroller and a sound alarm.

Firefighting system:

After the fire occurred and the controller receive the signal from the smoke sensor ,The Raspberry pi shut down the electricity , and use a water pump to limit the distribution of the fire and fight it.

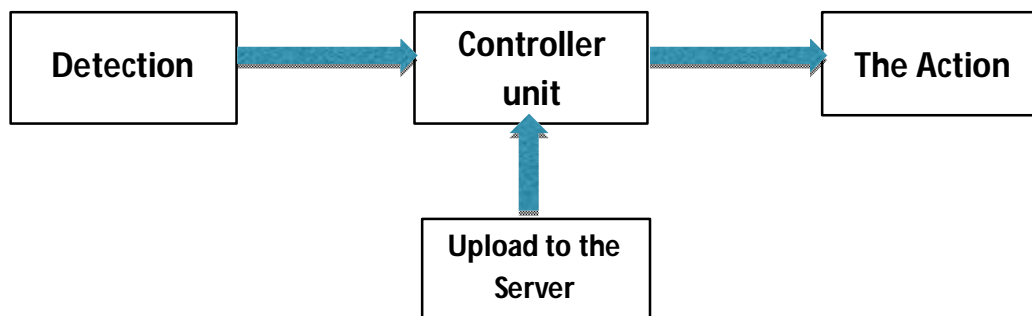


Figure 3-1 System Block Diagram

**Detection:**

In detection we used z-wave smoke sensor to detect the fire. In case of fire occurs the sensor will be activated and it will transmit the signal to a Point that called module sensor, and the module sensor will path the single to the main controller.

**Controller:**

The unit used as the main controller is Raspberry pi 2 module b+.

**The actions:**

The output actions will fight the fire by water pump.

**Upload to the server:**

All data that come out from the controller will be uploaded to the web server.

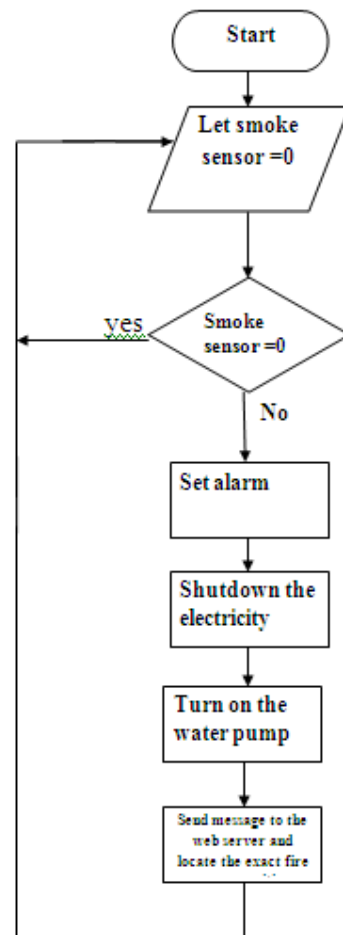


Figure 3-2 System Flow Chart

### 3.2 Z-wave Mesh Network:

We use Z-wave mesh as a totally wireless technology to connect the raspberry pi with the z-wave smoke sensor. We selected the z-wave technology to use in this project because it is wireless, very robust and based on standard.



## **Network devices:**

There are two main devices that make up a z-wave network: controllers and slaves. Slaves are end point devices, they can only respond to messages sent by controller. In this case the slave is the z-wave smoke sensor. The z-stick has three operating mode: inclusion, removal and serial API.

## **Z-stick:**

We use Aeon labs z-stick to include the z-wave smoke sensor to the network. Z-stick is a self-powered USB adapter with remote network capabilities to include/remove z-wave devices.



Figure 3-3 Aeon labs z-stick [27]

## Create z-wave smart home hub using raspberry pi:

To setup a Fire fighting system Hub we have to use the open source Home Assistant platform. The Home Assistant platform is a fully featured home automation hub that integrates with trillions of Smart Home technologies. And we will be using it to control Z-Wave devices.

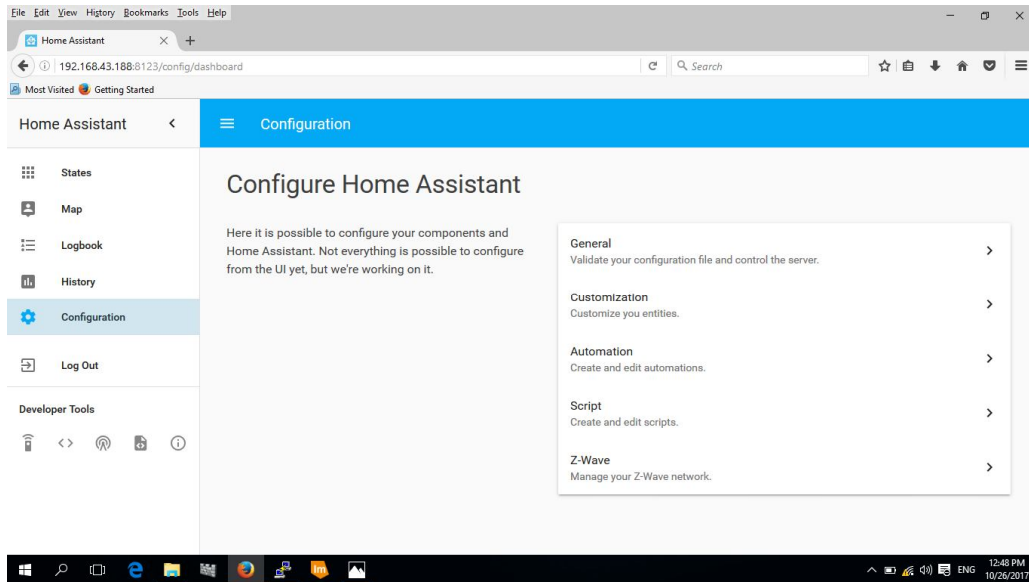


Figure3-4 shows the Home Assistant platform

### First step:

Connect the raspberry pi to our Z-Wave USB dongle, and the Wi-Fi dongle. After that you have to install Home Assistant, will install home assistant using the all-in-one installer by writing this command in the command line.

```
$ wget - Nnv https://raw.githubusercontent.com/home-assistant/fabric-home-assistant/master/hass_rpi_installer.sh &&  
bash hass_rpi_installer.sh
```

After installation process has finished go ahead and reboot the raspberry with:

**[\$ sudo reboot]**

### **Configuring the Z-Wave component and your USB stick:**

The last step of enabling the Z-Wave component for Home Assistant is configuring the component and telling home assistant where to find the Z-Wave USB stick. First find the Z-Wave USB device; on your Raspberry Pi you can list the USB devices using the following command:

**[\$ ls /dev/ttyACM\*]**

### **Add Z-Wave device to network:**

Put your Z-Stick into inclusion mode. To include z-wave smoke sensor to the network:

- First unplug the z-stick from the USB connector and press the large button on the z-stick, the z-stick LED will start to blink.
- Second go to the z-wave smoke sensor press and release the bottom.
- The z-stick LED will blink rapidly for several seconds and will glow for three seconds and finally return to slow blinking state. The smoke sensor has been added to the network.

### **Control your devices:**

Access your Home Assistant interface on: <ip address of Raspberry Pi>:8123

Your new Z-Wave device(s) should now be automatically discovered and you can control your device in your web interface.

### 3.3 Hardware Design

Hardware design contains many parts as below:

#### 3.3.1 Main Controller

The Raspberry Pi is a series of small single-board computers (SBC), which is a complete computer built on a single circuit board, with microprocessor(s), memory, input/output (I/O) and other features required of a functional computer.

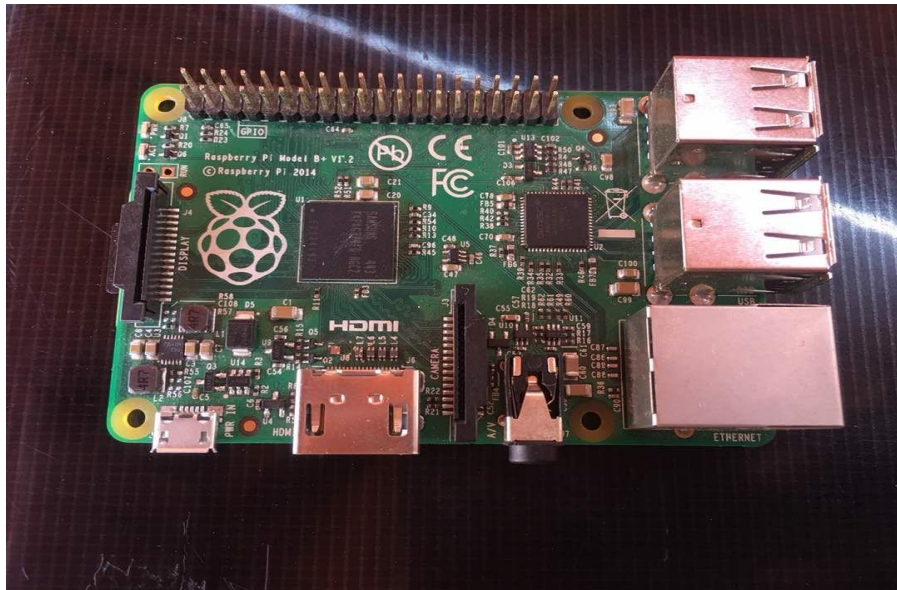


Figure 3-5 Raspberry pi modules B+

#### Programming of actual Raspberry pi:

To program the raspberry pi and make it work we need to download the operation system of the raspberry pi (Raspbian.os) on the pc, then uploading it from PC by using USB cable to the SD card and plug the SD card to the raspberry pi. After that we can use SSH to control the raspberry pi from the PC. In the command line we write the

main code that controls all the devices in the control panel through connecting them with GPIO pins.

## Raspberry Pi2 GPIO Header

Pin#	NAME		NAME	Pin#
01	3.3v DC Power		DC Power 5v	02
03	GPIO02 (SDA1 , I <sup>2</sup> C)		DC Power 5v	04
05	GPIO03 (SCL1 , I <sup>2</sup> C)		Ground	06
07	GPIO04 (GPIO_GCLK)		(TXD0) GPIO14	08
09	Ground		(RXD0) GPIO15	10
11	GPIO17 (GPIO_GEN0)		(GPIO_GEN1) GPIO18	12
13	GPIO27 (GPIO_GEN2)		Ground	14
15	GPIO22 (GPIO_GEN3)		(GPIO_GEN4) GPIO23	16
17	3.3v DC Power		(GPIO_GEN5) GPIO24	18
19	GPIO10 (SPI_MOSI)		Ground	20
21	GPIO09 (SPI_MISO)		(GPIO_GEN6) GPIO25	22
23	GPIO11 (SPI_CLK)		(SPI_CE0_N) GPIO08	24
25	Ground		(SPI_CE1_N) GPIO07	26
27	ID_SD (I <sup>2</sup> C ID EEPROM)		(I <sup>2</sup> C ID EEPROM) ID_SC	28
29	GPIO05		Ground	30
31	GPIO06		GPIO12	32
33	GPIO13		Ground	34
35	GPIO19		GPIO16	36
37	GPIO26		GPIO20	38
39	Ground		GPIO21	40

**Figure 3.6 GPIO pin descriptions [27]**

### 3.3.2 Smoke sensor:

Zipato Smoke Sensor (Z-Wave) is designed to give early warning of developing fires by sounding the built-in alarm horn, based on Z-Wave technology. Z-Wave is a wireless communication protocol designed for remote control of appliances in residential automated homes.

This product can be included and operated in any Z-Wave network with other Z-Wave certified devices from other manufacturers and/or other applications.

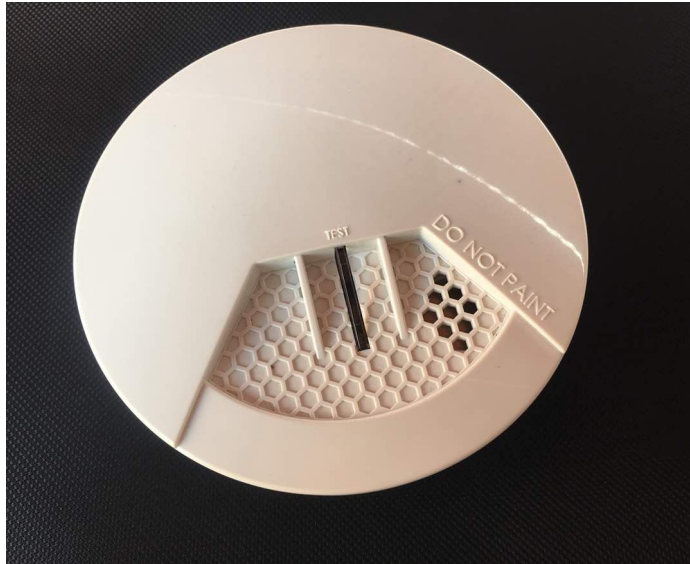


Figure 3-7 Zipato Smoke.

Features:

- Built in sound alarm.
- Removable ceiling bracket.
- Low battery auto report.
- Low power consumption.
- Low power indication.
- LED Power indication.
- Easy installation and relocation.
- Elegant design.
- Higher output power to enhance the communication range.

### 3.3.3 Relay module:

Generally relay are designed to operate from a particular supply voltage often 12V or 5V, In this case we use single channel relay module.They are suitable for driving high power electric equipment



Figure3-8 signal channel relay module

We use a relay to control high voltage with low voltage by connecting it to Raspberry Pi. So we can control any device by connecting a raspberry pi with relay module. The Single Relay Board can be used to turn devices on/off while keeping them isolated from your controller.

### 3.3.4 Contactors:

A contactor is an electrically controlled switch used for switching an electrical power circuit. A contactor is typically controlled by a circuit which has a much lower power level than the switched circuit. When a relay is used to switch a large amount of electrical power through its contacts, it is designated by a special name: contactor. Contactors typically have multiple contacts, and those contacts are usually (but not always) normally-open, so that power to the load is shut off when the

coil is de-energized. Perhaps the most common industrial use for contactors is the control of electricity.

In this case we used three-face 380V contactor connected with relay to control 220v water pump to fight the fire when signal of smoke comes.



Figure 3-9 three face 380V contactor



### 3.3.5 Water pump:

We use AD 1000D Submersible Pump, which is widely used in firefighting systems to limit the distribution of the fire and fight the fire.



Figure3-10AD-1000D Submersible Pump

Feature:

- professional manufacturer of submersible pumps
- self-priming jet pump
- centrifugal pumps
- diesel engine pump
- Shield circulating pumps as well as automatic boosting pump.

Table 3-1 water pumps parameters:

Raspberry pi		Relay module
Pin 17	3V3	VCC
Pin 9	GND	GND
Pin 22	GPIO 25	OUT

To control the pump we connect the raspberry pi with relay module, which is connected with contactor. When signal of fire come the output value of pin 22 will become 1 (high) and the water pump will start working.

### 3.3.6 Sound Alarm:

We use a bell as a sound alarm to warn the people when the fire occurs.

Table 3-2 sound alarm parameters:

Raspberry pi		Relay module
Pin 1	3V3	VCC
Pin 6	GND	GND
Pin 12	GPIO 18	OUT

To control the alarm we connect the raspberry pi with relay module, when signal of fire come the output value of pin will become 1(high) and the bell will start working.

### **3.4 Web Server Configuration**

To create a web server using raspberry pi, its code should be included within the main code, when included it will generate a web page. The way to access the page is through its IP address, using typical web browser. In this work the IP address is 192.168.43.188.

**Chapter four**  
**Results & discussion**

## 4.1 Overview:

This chapter verifies the previous setups and checks the efficiency of the proposed technology. An automatic fire alarm system is designed and developed based on wireless sensor networks. Prototype system tests show that the system provides early detection and extinguishing of a fire disaster so that damages will be reduced effectively.

## 4.2 Result of z-wave configuration:

After we installed the home automation platform and reported the raspberry pi then we enables the z-wave component and we check that the z-wave component is activate.

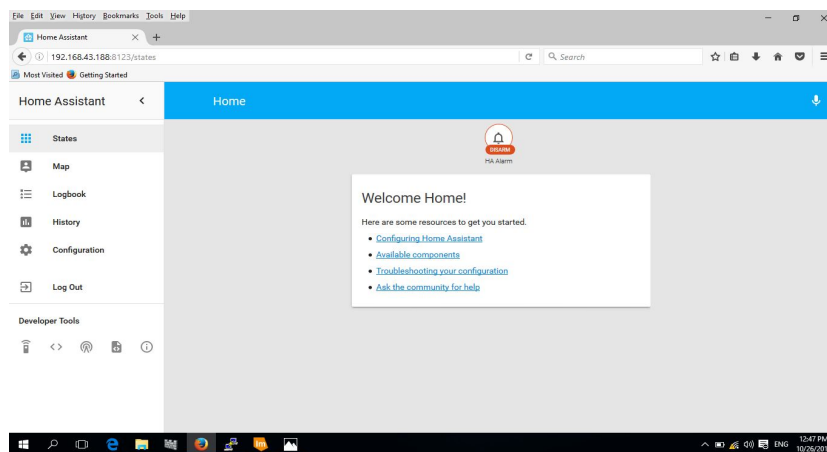


Figure 4-1 show home automation platform

Z-Wave fire fighting system using Home Assistant and the Raspberry Pi is now configured and ready to use.

## 4.3 Result of z-stick inoculation mode:

In order to transmit smoke signals timely and accurately in the fire alarm systems, design one kind of wireless fire detection and alarm

system, which is based on the wireless sensors network technology, z-wave. The testing design starts with generating a connection between the raspberry pi and a z-wave smoke sensor using z-stick. In figure 4.1 the connection between the raspberry and z-wave smoke sensor using z-



stick.

Figure 4-2 connection between raspberry pi and smoke sensor.

As we saw the connection between the raspberry pi and the z-wave smoke sensor is successfully done.

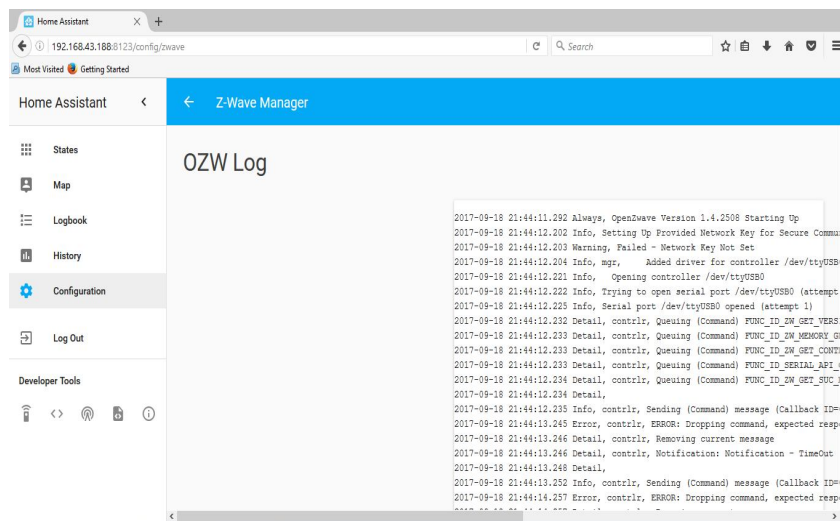


Figure 4-3 show z-stick inclusion mode

As we saw now z-wave smoke sensor included to the z-wave network so that the smoke sensor status can be seen for here.

#### 4.4 Result of the website:

The fire fighting system is connected to the building control room where there is an online website activated in a personal computer when fire occurs the website default page change and the top view of the building displayed showing information and location for the fire exact place. This design with the characters of low price, high efficiency and reliable, has a certain market figure 4-4 the website default page



Figure 4.4 default page

This figure shows the personal computer default page in the control room.

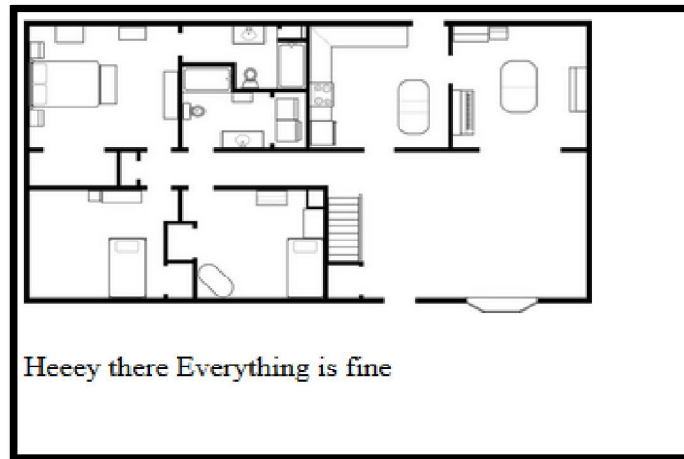


Figure 4.5 the website result in case no fire

The figure illustrated what happen if anyone in the control room presses the button on the he default page to check either there is fire or not, in case there is no fire the website will tell that everything is fine.

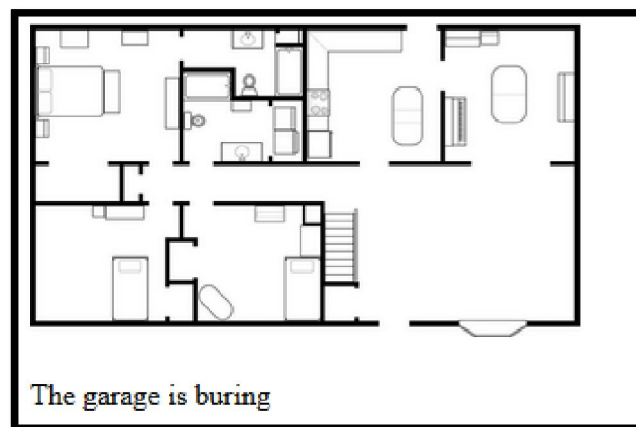


Figure 4.6 the website result in case there is fire

The figure illustrated what appear in the control room when fire occurs



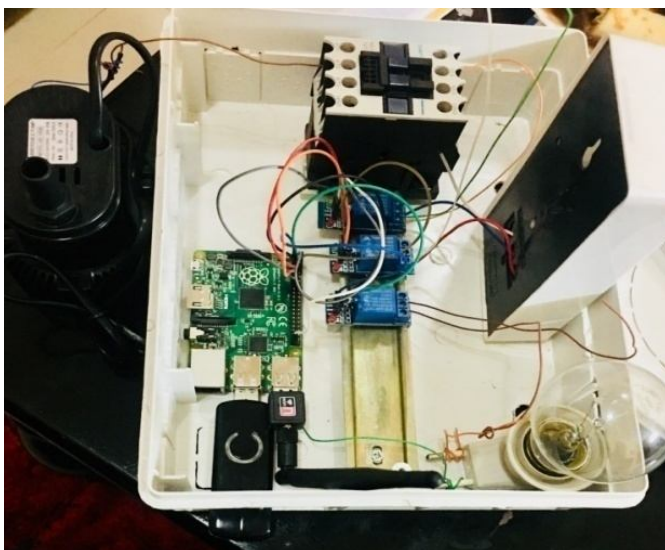


Figure 4.7: The result of the hardware design in case of fire

#### **4.5 Result of fire fighting system:**

When a large amount of smoke occurs the smoke sensor detects the smoke and transmitted the signal to sensor module, then the sensor module gave micro-controller a signal, depending on that signal the result of the proposed design is shutting down the electricity, the pump start working and the alarm sound rang all at the same time. Figure 4.7 the result of the hardware design in case of fire.

The above figure shows a successful testing result of fire fighting system. It seems that the system does not respond if the fire generates very small smoke.

**Chapter five**  
**Conclusion & recommendations**

## **5.1 Conclusion:**

Wireless sensor networks are increasingly applied in the field of fire fighting system. Especially in the large structures building with multiple businesses, it has advantages that traditional detection systems lack. To detect and fight the fire in the building in a more timely and precise way, we pointed out unique advantages of for a fire fighting system based on a z-wave wireless sensor technology that we designed. In other words, The wireless fire fighting system constructed based on z-wave overcomes the limitations of the cable alarm system because wireless z-wave technology is a robust based on standard and long life technology, has a components that are easily purchased and available from reliable manufacturers. And system installation does less damage to buildings, conveniently to place nodes and maintenance. This design is suitable for various occasions, especially for fire control in museums, ancient building group, with a wide application prospect. The main objective of the system is achieved, Prototype system tests show that the system provides early detect of the fire so that damages will be reduce effectively.

## 5.2 Recommendations:

In order to improve the proposed design and making it efficient there is additional work still can be done.

- Implementing both smoke and heat sensors in the system , so the system can give quick and accurate response when the two of the sensors sense a single of heat or smoke, that makes the system very efficient to handle the false alarms.
- Create an Application which anyone can easily install it. When fire occurred the application send a notification to warn the User about The Fire and Give the User an Accurate description To the Fire Place
- Replacing the raspberry pi 2 with raspberry pi 3, which is offers a higher level of performance than any other raspberry pi boards, and has a built-in wireless connectivity.

## **Reference**

## Reference:

- [1] Xiaodong Jiang, Nicholas Y. Chen and others “Context-aware Computing for Firefighting”.
- [2] Chunlei An, Andreas Timm-Giel, “Applying Wireless Sensor Networks in Fire Fighting”, 2011
- [3] Al-Karaki, J.N., Kamal, A.E , “Routing techniques in wireless sensor networks” , 6-28-2004
- [4] <http://www.assured-ltd.co.uk/blog/wired-vs-wireless-fire-alarms/>
- [5] B. Madhevan, R. Sakkaravarthi , “Modelling, Simulation and Mechatronics Design of a Wireless Automatic Fire Fighting Surveillance Robot” , 2017
- [6] Nam Khoon, Patrick Sebastian and others, “Autonomous Fire Fighting Mobile Platform-1Teh”, 2012
- [7]<https://www.asme.org/engineering-topics/articles/automotive/robotic-firefighting-vehicles>
- [8] <https://www.firesafe.org.uk/fire-alarms/>
- [9] <http://www.argusfire.co.nz/types-of-systems/fire-alarm-systems.aspx>
- [10] Hussam Elbehiery, Developed Intelligent Fire alarm system, October 2012
- [11] [https://en.wikipedia.org/wiki/Embedded\\_system](https://en.wikipedia.org/wiki/Embedded_system)
- [12] [Philip J. Koopman, Jr](#) , “Embedded System Design Issues”
- [13] [https://en.wikipedia.org/wiki/Real-time\\_computing](https://en.wikipedia.org/wiki/Real-time_computing)
- [14] Kanaka Juvva,” Real-Time Systems” .
- [15] Simply Raspberry pi , Abdallah Mohammed Abdallah
- [16] <https://www.arduino.cc/en/Guide/Introduction>
- [17] <https://cdn-shop.adafruit.com/970x728/50-06.jpg>
- [18] [https://www.raspberrypi.org/app/uploads/2014/07/rsz\\_b-.jpg](https://www.raspberrypi.org/app/uploads/2014/07/rsz_b-.jpg)

- [19] <http://jeffskinnerbox.me/images/raspberry-pi.jpeg>
- [20] <http://www.ni.com/white-paper/7142/en/>
- [21] <https://upload.wikimedia.org/wikipedia/commons/thumb/2/21/WSN.svg/1200px-WSN.svg.png>
- [22] <http://ccm.net/faq/298-what-is-wifi-and-how-does-it-work>
- [23] <http://W3Schools.com>
- [24] B. Madhevan, R. Sakkaravarthi, “Modelling, Simulation and Mechatronics Design of a Wireless Automatic Fire Fighting Surveillance Robot”, 2017.
- [25] Al-Karaki, J.N., Kamal, “Routing techniques in wireless sensor networks: a survey. J. IEEE Trans. on Wireless Communications”, 6-28-2004.
- [26] Nam Khoon, Patrick Sebastian, “Autonomous Fire Fighting Mobile Platform-1Teh”.
- [27] Donald Norris , “Raspberry pi projects for the EVIL GENIUS” , 2014.

# **Appendix**



## APPENDIX A

Python code that guide the smoke sensor signal to do reactions as response to fire.

```
import time
import RPi.GPIO as GPIO
GPIO.setmode(GPIO.BOARD)
GPIO.setup(12,GPIO.OUT)
GPIO.setup(22,GPIO.OUT)
def uf ():

    file =
open('/home/homeassistant/.homeassistant/OZW_Log.txt')
    t = file.readlines()
    file.close()
    return (t)

t=0
#time.sleep(8)
while(1):
    e=uf()
    x=len(e)-2
    try:

        r,w=e[x].split("D")
        r=r[:-7]
    except:

        r,w="n"
    if(t==r):
        file=open("/var/www/html/status.txt","w")
        file.write("1")
        file.close()
        pass
    else:
        if(r[0]==2):
            print("new")
        else:
            print("noth")
        file=open("/var/www/html/status.txt","w")
        file.write("1")
        file.close()
        GPIO.output(12,GPIO.HIGH)
        GPIO.output(22,GPIO.HIGH)
    time.sleep(8)
    #negative
    GPIO.output(12,GPIO.LOW)
    GPIO.output(22,GPIO.LOW)
    time.sleep(8)
    t=r
```

## APPENDIX B

Html code that represent default page in the control room.

```
<!DOCTYPEhtml >
<html >
<head>
<style>
a:link , a:visited {
background-color: #44336;
color:white;
padding: 14px 25px;
text-align: center;
text-decoration: none;
display: inlineblock;
}

a:hover , a:active {
background-color: black;
}
</style>
</head>

<bodybackground="incaseburning.PNG">

</body>
</html >
```

## APPENDIX C

Html + PHP code that represent the default page in the control room connect with button to check the building and show the fire place in case of fire.

```
<!DOCTYPEhtml >
<html >
<head>
<style>
a:link , a:visited {
background-color: #443366;
color:white;
padding: 14px 25px;
text-align: center;
text-decoration: none;
display: inlineblock;
}

a:hover , a:active {
background-color: black;
}
</style>
</head>

<bodybackground="defaultpage.PNG"onload="readTextFile()">
<h1style="color: black; text-align= center; font-size=500%; "> Fire fighting
System </h1>
<pstyle="color:white; text-align= center; font-size=300%; ">
Smart and quick response </p>
<a href="nofire.html" target=_blankstyle: text-align=center; font-size=300%; >
<b><i> for buliding details </i></b></a>

<script>

function readTextFile()
{
    setInterval (myfunction, 3000);
    function myfunction(){
var rawFile = new XMLHttpRequest();
    rawFile.open("GET", "status.txt", false);
    rawFile.onreadystatechange = function ()
    {
if(rawFile.readyState === 4)
    {
if(rawFile.status === 200 || rawFile.status == 0)
    {
var allText = rawFile.responseText;
if(allText==1)
        {
            window.location="fire.html";
        }
    }
    }
    }
    rawFile.send(null);
```

```
}  
}  
</script>  
</body>  
</html>
```

## APPENDIX D

Html codes that represent the building top view in case no fire.

```
<!DOCTYPEhtml >
<html >
<head>
<style>
a:link , a:visited {
background-color: #44336;
color:white;
padding: 14px 25px;
text-align: center;
text-decoration: none;
display: inlineblock;
}

a:hover , a: active {
background-color: black;
}
</style>
</head>

<bodybackground="NOfire.PNG">

</body>
</html >
```