



SMART
ALARM

S.M.A.R.T. Alarm:

Smoke Monitoring and Reactive Tasking Alarm

Senior Design 1
Project Documentation
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Group A

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1.0 Project Description

This paper describes the S.M.A.R.T. Alarm System project. This begins by describing our motivation for creating this project, based on our realization that a major improvement could be made in a device and system as common place as fire alarms, and how this could save a lot of lives if implemented correctly. Following this, the goals and objectives for the system are described in detail, and from this the function of the system is derived and described for further understanding of what the systems is meant to do. A block diagram for the hardware is included for better understanding on how the fire alarm and central processing hub will interact with each other and how each will perform its defined functions. Lastly, a section is designated for the operations manual for the S.M.A.R.T. Alarm System that serves as instructions for the installation, maintenance and general use of the system.

2.0 Motivation

In today's day and age, technology advancements are occurring at a rapid pace. There are new inventions being created every minute improving people's lives and making the world a better and safer place. Our group saw that while technology is advancing and becoming a bigger part of our everyday lives, one piece of technology that has not seen a major improvement in decades is the smoke and fire alarm. This device is a standard in everyone's homes, offices, hotels and all other major buildings that we spend time in every single day but has been neglected as far as engineering advancement and innovation is concerned. The smoke and fire alarm that you have inside your house is essentially the same one your parents had inside theirs. We think we can do better. When looking at the average use case of a smoke detector, it was discovered that while they are useful, these devices do not provide the user with an abundance of information. Frequently, someone would hear the alarm go off and just frantically run to wherever they believe to be the nearest and safest exit without much of a plan. This scenario has the potential for disaster when you consider that there could be multiple people inside the building who do not know their way around and could be endangering themselves. Individuals could be wasting valuable time or be heading in a direction that is dangerous. We believe that a smoke alarm with improved functionality can help to eliminate this scenario and make everyone's lives easier, and most importantly, safer. This can be achieved by creating a more connected fire alarm system. When the location of a fire is a factor in directing evacuation of a building, communication between the detection system and alarm system can provide crucial, life-saving information.

2.1 Goals, Objectives, and Function

The goals for the smart smoke and fire alarm are to make an affordable, customizable, connected system of smoke alarms that alert employees and residents of the safest and fastest exit of the building in the case of a fire emergency. We would like this system to not be that much more expensive than existing options to convince the

market to adopt our system. In the event of an emergency, these smoke alarms would sound off in an order that would lead people to the closest and safest exit. Users would just have to follow the sound that is projected from these alarms until they reach the exit to the building. These smoke alarms would be dynamic in the sense that they adapt to where the fire is located. This means that if a smoke alarm that is in the middle of a hallway goes off, people on the left of that area would be directed to the exit that is closest on their side of the fire while people on the right of that area would be directed to the exit that is closest on the other side of the fire while nobody is directed through the dangerous area. The system would also be able to handle hallway intersections and other confusing areas. This allows for residents to know where the fire is and what areas to avoid. For people that have hearing issues, these alarms will also have a visual display using light-up arrows that will point individuals in the direction they should go to exit the building. This also allows for better handling of confusing areas where sound alone could be confusing. This system should be achieved by mapping the building layout using a custom-made application during set up of these alarms, creating spatial awareness for each of the fire alarms, while using an algorithm to signal each alarm which is the best exit direction relative to its position. Our final goal is to focus on the ease of installation of our system. This system needs to be simple enough to install so that specialists are not required to configure, set up, and install these fire alarms. An effective ease of installation would ensure that almost anyone would be able to adapt our system into their building plans.

2.2 Block Diagram (Hardware)

The layout of the S.M.A.R.T. Alarm system consists of two types of devices, a central processing hub, known as “The Hub” and each Fire Alarm. The Hub will consist of a main alert computation system that includes the CPU for this device, which will be able to process any information received from the Fire Alarms in the same system through a wireless communication network, therefore The Hub will also require a communication module component in order to receive and transmit this information. The Alert Computation System will be in charge of using the data received and making any decisions necessary for the system, and instruct each individual alarm of the appropriate response in its specific case based on location. This Alert Computation System is also in charge of creating any alarms and pushing them to any users in charge of maintenance of the system so that they may perform any maintenance required. The Hub will receive Power from an AC outlet connected to the building’s power grid. The figure below show you a breakdown of how the fire alarm system works between the alarms themselves and the central hub.

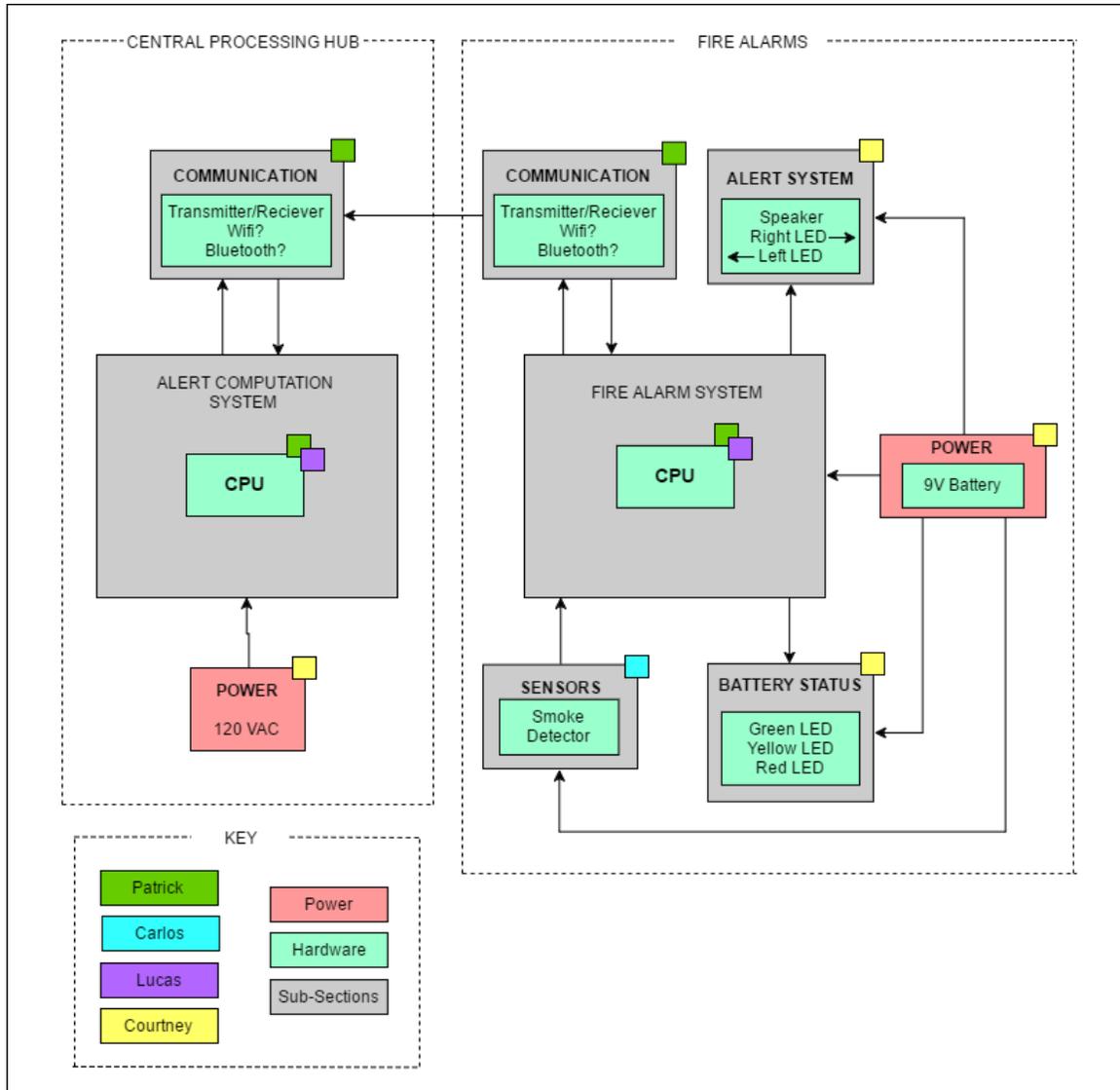


Figure 1: S.M.A.R.T. Alarm System Block Diagram

The Fire Alarms consist of several component blocks. The Fire Alarms will rely heavily on the communication module that allows wireless communication between the alarms and The Hub. This communication component block will be in communication with the Fire Alarm System that contains the CPU of the device. This component block will make any decisions for the individual alarms, including but not limited to deciding whether the data received from the Sensors block requires alerting The Hub of a potential fire, checking the Power Status block for the status of the primary AC power and the backup 9V Battery Power. The Fire Alarm System Component block is also in charge of managing the Alert System Component block in case it receives a message from The Hub that the fire alarms should sound, this message will also tell the CPU how to direct users in case of fire through the Alert System Block. Ideally, in the actual system there will be several of the Fire Alarm Devices communicating with The Hub, and for the purposes of

demonstrating the project, the final project product will contain 5 Fire Alarm devices and one Central Processing Hub to manage them.

2.3 S.M.A.R.T. Alarm Operations Manual

The S.M.A.R.T. Alarm System is designed with the end users in mind, of which there may be several different roles that could be played, ranging from passive to active in the use of the system. So that the S.M.A.R.T. Alarm system may accommodate the wide range of experiences for different types of users, and the different interactions that will be necessary of them, the system must be as simple to use for installation, maintenance and building evacuation purposes.

2.3.1 S.M.A.R.T. Alarm System and Components

The S.M.A.R.T. Alarm system is comprised of a wireless communication network that contains two types of devices: the Fire Alarm and the Central Processing Hub.

2.3.1.1 Why use wireless communication?

Wireless communication allows multiple different devices to be connected over a wireless network. This allows devices to be self-contained without the inconvenience of communication wires. Moreover, if wires are required for communication, the system is very static. Wireless communication allows for a dynamic system that can grow and change as system requirements change.

The S.M.A.R.T Alarm system will rely heavily on wireless communication, transmitting sensor data to the central processing and direction data back to the alarms. S.M.A.R.T. Alarm is a dynamic system, have different configurations and alarm needs deepening on the building. Wireless communication is a core component of the S.M.A.R.T. Alarm system. The following section will provide information on the aforementioned wireless communication options and will discuss the feasibility of their inclusion in the S.M.A.R.T Alarm system.

2.3.1.2 Wireless Communication Network

The network is created using ZigBee radio modules, for transmitting simple data packets between the Fire Alarms and the Central Processing Hub, as well as having the ability of relaying the data packets from among Fire Alarms in order to extend the coverage area of the system. The use of ZigBee modules is due to the low power consumption compared to Wi-Fi while offering a larger range of transmission than Bluetooth. While providing a rather large ability to add additional nodes to a network, it adds some sort of simplicity in communication; which will consist of data packets that are to be parsed by either the Hub or individual Fire Alarms. Using ZigBee modules allows a certain level of security that would otherwise be harder to achieve if using Wi-Fi or Bluetooth methods, in order to avoid false alarms or the interception of alert packets by a third party.

ZigBee communication is great for small scale projects that need wireless communication. ZigBee was designed to be simpler and less expensive than other wireless PANs. ZigBee involves a mesh network which is a type of network that relies on

relaying data from node to node. A mesh network can transfer this data by using either a flooding method or a routing method. The routing method propagates a message from one router node to the next, until it reaches its destination. The flooding method is a process in which a data packet is sent out from a coordinator and sent through every outgoing node in the network. The S.M.A.R.T. Alarm will utilize both routing and flooding transmission methods. It will use a routing method to send Smoke Alarm sensor data to the coordinator, using the fastest transmission path possible. Once the coordinator receives this data, it will do the necessary calculations and exit route mapping and send the alarm and direction packets out to all the alarms in the system using the controlled flooding technique. The combination of these two routing methods will ensure the S.M.A.R.T. Alarm works properly and efficiently in alerting the inhabitation of a building of a potential fire.

For this project we will be using the generic mesh networking. The mesh networks will allow the use of ZigBee routers to extend communication at a network level to facilitate messages through the system. Where each ZigBee router has a specific address that will be used to send messages to a specific alarm. Every ZigBee network must have one coordinating device which essentially creates the network environment, control over the network parameters and basic maintenance of the system. The hub (raspberry pi) will act as the coordinator for the ZigBee mesh network, and all routers (alarms) will “join” the proper network with the appropriate channel settings. The figure below shows what a Mesh network looks like.

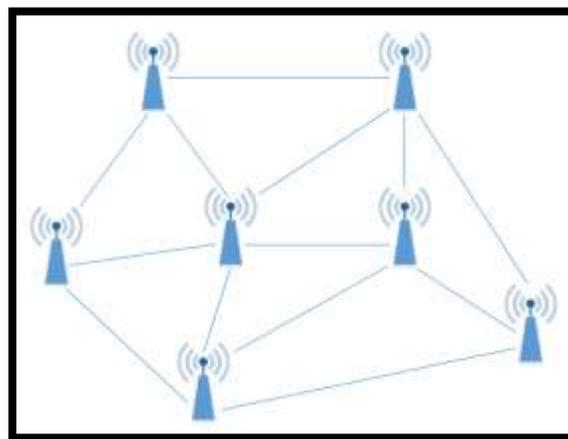


Figure 2: ZigBee Star Network (left), ZigBee Mesh Network (right)

2.3.2 Smoke Sensor

The sensor that we chose to use in the S.M.A.R.T. Alarm is the MQ-2 sensor. This sensor has the ability to detect several types of gases: Hydrogen, Liquified Petroleum Gas, Carbon Monoxide, Alcohol, Smoke and Propane. The type of gas detected is transmitted by the analog output of the sensor as a certain range of values for each gas, it however cannot detect more than one gas at a time. This requires the sensor to be calibrated to detect a certain gas, in the case of this project the gas would be smoke. Following this combustible gas and smoke will be easily and accurately detected for concentrations in the rate 300 to 10,000 ppm. The quick detection by the sensor coupled

with the simplicity of implementation and use make this sensor the best option for this project.

2.3.3 Fire Alarms

The Fire Alarms used by the S.M.A.R.T. Alarm system are fully original and designed by the S.M.A.R.T. Alarm team. These Fire Alarms are designed after extensive research taking into account several factors including maximized warning time, effectiveness of alarm, ease of installation and ease of understanding the evacuation procedure. Each alarm consists of a communication component using the ZigBee modules for communication with the Hub in case of fire as well as communication between Fire Alarms in order to relay the evacuation procedure calculated by the Hub. They also consist of a fire detection component that is constantly sampling the air in the vicinity of the individual Fire Alarm, and will send out a warning packet to the Hub in case of detection. If an alert signal is sent by the Hub to the Fire Alarms, the alarm component will warn the occupants of a building through audio and visual signals. This consists of a buzzer or speaker that will play a loud enough noise to ensure acknowledgement by occupants, this sound will echo from Fire Alarm to Fire Alarm in the direction of the nearest safe exit to a building, thus directing evacuees using audio cues. In addition to the sound emitted by the Alarms, each alarm will also include three arrows lights that consist of LEDs, one for that points right, one pointing left and one that tells evacuees to turn around. Only one of these arrows will light up when the alarm is sounding and will serve as a visual cue for evacuees to follow.



Figure 3: MQ-2 Flammable Gas & Smoke Sensor (printed with permission of Polulu.com)

2.3.3.1 Fire Alarm configuration

We configured the alarms to be able to work with different structures of the building, as in a straight line, T shape hallway, and L shape hallways. So, depending on the type of structure and hallways that is in the building we created an algorithm for each type of hallways. When the S.M.A.R.T. Alarm is triggered, evacuee's will be directed away from the fire, depending on the shape of the structure the will move either to the left or right, whichever is in the opposite direction.

2.3.4 Central Processing Hub

The Central Processing Hub, or the Hub, serves as the coordinator for the whole system, and is what makes the S.M.A.R.T. Alarm system smart. The Hub is tasked with coordinating communication with the Fire Alarms and between the Fire Alarms, if necessary. This would occur in the case of receiving a warning signal from one or more Fire Alarms, and in that case the Hub would calculate the best paths in case of fire from each Fire Alarm and send a signal giving each individual Fire Alarm directions. The Hub consists of a Raspberry Pi that can be connected to a monitor or be used through remote desktop, and comes pre-loaded with a custom program that can be used to configure the location of the fire alarms at installation. Following this the hub will monitor the Fire Alarms

for any issues or errors including a loss of power or issues with components. In case of receiving a warning signal from a Fire Alarm, the best exit routes will be calculated and the proper signals will be sent to each individual Fire Alarm in order to properly warn the evacuees.

2.3.5 Users

The S.M.A.R.T. Alarm system has 3 different types of users, defined as any third party that interacts with the system for different purposes. The three types of users are the installation user, the maintenance user, and evacuees. Many times the installation user and the maintenance user may be the same person, as well as an evacuee, however for the purposes of explaining these roles and how they interact with the system they will be treated separately.

2.3.5.1 Installation User(s)

The installation user, or installer, will interact with the system during installation of the fire alarms. This role may vary, as there may be several installers with different roles in the overall installation of the system. However, the main objectives of the installers are to place the Fire Alarm devices in the appropriate locations according to NFPA standards, as well as setting up the Central Processing Hub in an appropriate location meeting several constraints for the location. The installer is also in charge of configuring the Hub software, according to the layout of the building and location of the Fire Alarms, using a custom program with a graphical user interface, created by the S.M.A.R.T. Alarm team.

2.3.5.2 Maintenance User(s)

The maintenance user, or maintainer, will interact with the system on a daily or weekly basis depending on the needs of the system. Depending on the maintainer's preferences, his role may be very active or rather passive. This user is tasked with ensuring that the alarms are all connected to the network and that there are no issues detected with the individual alarms or the whole system. Depending on the issue, the maintainer may choose to address it him/herself or make a service appointment with the S.M.A.R.T. Alarm system. The maintainer may choose to receive email alerts, sent by the Hub automatically, regarding any issues detected by the system's maintenance relevant monitoring, such as power monitoring or sensor malfunction monitoring, as an alternative the maintainer may actively monitor the status of each alarm and the system using the custom program installed on the Hub.

2.3.5.3 Evacuee(s)

The evacuee will interact with the system, seldom, and only in case that the alarm system is triggered by the detection of fire and the alarm signal being sent by the Hub. In this case the evacuee, is only charged with evacuating the building as quickly as possible, while following common emergency evacuation procedure, by following the arrows on each fire alarm station in the building and the echoing sound of the system that will lead to the closest exit to safety for the evacuees at their given location.

As previously discussed whether the installer or maintenance user are the same person or different people we wanted the process to be simple and easy going as possible. Where all the installer has to do is to make sure to set up the hub and position the alarms in the right way. While for just the maintenance we allow the system to be set up to send out alerts is any maintenance needs to happen or if anything is wrong with the

system. Being able to receive those alerts will make keeping the maintenance of the system as easy as possible. The following subsection will go through the process of how the alarm will work when a fire does happen and the alarm is set off.

2.3.6 In Case of Fire

When one of the Fire Alarms in the S.M.A.R.T. Alarm network detect fire and send a warning signal to the Hub, the Hub will parse the packet received with the location of the fire alarm(s) in distress. Using this information, the Hub will calculate a packet to send to each individual alarm with its instructions for how to direct evacuees, in accordance with the optimized evacuation plan calculated by the S.M.A.R.T. Alarm software.

The Fire Alarms will cease any sensing/detecting activity when in alert mode, and will only serve to alert evacuees on their best exit route. These alarms will continue to sound and signal the nearest safe exit, until they receive a stop signal. The only way to send a stop signal is by accessing the Central Processing Hub and selecting the “Stop Alarm” function in the S.M.A.R.T. Alarm software. This should be done in the case of a false alarm or in case the fire is out.

Alternatively, if something happens to the Hub during the emergency, and the Hub cannot boot. Each alarm should be reset manually using the reset button on the outside of the casing of the Fire Alarm.

In the event that the Hub sends an alert signal to the individual Fire Alarms, the Hub will also alert emergency services in the area of the fire and thus providing a faster response time to the fire emergency. Notifications will also be sent according to the maintainer’s preferences, so that all parties involved may be notified of the emergency situation. When emergency services and the maintainer are notified of the fire, the location of the Fire Alarms that first detected the fire within the building will also be disclosed, so that emergency services may be able to find and exterminate any fire as quickly as possible. This is similar to a method already in place in several newer alarm systems, and even some older ones, that will notify emergency services of the location of a fire. This is a practice that is especially helpful in large buildings, where the fire may not be obvious through external observation and knowing where it is can lead to saving lives by saving precious time in an emergency situation.

3.0 Conclusion

The S.M.A.R.T. Alarm system integrates several component and devices that implemented properly can save countless lives in the face of danger, and provided a much-needed upgrade to the way fire alarm systems communicate and coordinate evacuation in a building. Throughout this project, the number one objective in mind for our team was creating a product that will result in saving as many lives as possible by ensuring fast response times and an organized and intuitive manner for evacuating a building. The users that is in charge of maintaining the system are also in mind, so that the task of system maintenance is one that will not take much time out of their day, and will prove to be easy to use and convenient depending on their needs