AUTOMATED FAULT TOLERANT FIRE DETECTION AND WARNING COMMUNICATOR SYSTEM

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ABSTRACT

The scope of our project is to notify the owner of the premises and the fire department immediately after the sensors detect any fire or gas leakage in the property. The notification is sent through Internet of Things (IoT)Internet cloud and Short Message Services (SMS). The problem solved by our system is to have a quick automated warning alert to the fire department, the owner of the premises, and the neighbours to reduce the losses. In case of fire, a buzzer will get activated and a fast-automated alert notification will be sent via IoT Internet cloud and SMS to the owner and fire department. The fire department system will notify the buildings near to the fire location. The system will then wait for an acknowledgment from the fire fighters and the owner. If no response, repeated notifications will be sent until the system receives an acknowledgment from the mentioned entities to ensure the warning alert is noticed by them.

KEYWORDS

Fire alert system, Fire warning communicator system, acknowledgment mechanism, fire station system

1. INTRODUCTION

1.1 Background

Fire accidents may happen every day, at any time, with anyone all over the world. These fires cause human lives loss together with a huge resources damage and destruction. Damages are more, especially in cases where no fast and direct communication is taken to inform and notify the nearest fire station in order to directly deal with these sensitive emergency situations. The National Centre for Statistics and Information (NCSI) stated that one fire happens every three hours in Oman [1]. NCSI also reported that 4,157 fires were recorded in Oman during 2016; out of these fires 1,100were broken out in residential houses[2].During these types of fire accidents, the losses can be reduced by quickly informing the fire station about the fire accident.

1.2 Problem Statement

When people leave their facilities, either for a short or long period, they are unable to know what may happen there. Fires always take place suddenly and without someone being prepared to it, or even expecting it. In many cases fire broke out at the time when the owners are away from their own facility. In other cases, the owners may be sleeping or not able to reach their phones in order to inform the civil defence. Our proposed system which is automated fault tolerant fire detection

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and warning communicator system, will be able to address such cases directly, without the need of any human action in notifying the fire department. The system will help in reducing the losses.

1.3 Main Objective

The main goal of our proposed project is to instantly send the fire warning information to the civil defence / fire station when the system detects the fire, smoke or harmful gases. The system will communicate directly with the authorities involved in the fire response, such as the civil defence, the owners of the facility, and nearby buildings for evacuation if needed. The fire accident notification to the fire department takes place at an early stage to help prevent the expansion of the fire and to take a quick action in putting it out.

1.4 Significance of The Project

Our proposed system has the ability to send a quick automated notification to the fire station, the building owner and the neighbors immediately after detecting a fire, smoke and gas leakage in the building. The system also sends the location of the fire to the fire station. The system is fault tolerant as the notification will be delivered through Internet of Things (IoT) cloud in the Internet and Short Message Services (SMS) through Global System for Mobile communications(GSM). The system uses acknowledgment mechanism to ensure that the owner and the fire station have received the notification. The neighbors near the location of fire will be notified by the system in the fire station by voice call. Our system will be more useful in saving lives and reducing the damages caused by fire especially in the case of the owners are asleep or in the case where the owners are away from their own facility, during the fire breakout.

1.5 Scope of The Study

The proposed system, Automated fault tolerant fire detection and warning communicator system, is appropriate for various buildings sizes and kinds. Each premise can have its own installation that depends on its structure. However, the system design does not cover the open-door areas. The system has two main goals: the first goal is to make sure that an action is taken to prevent the fire by using automated direct notification to civil defense, while the second goal is to reduce the amount of resources loss and victims as much as possible by using automated notification to the owner of the facility and the neighbours of fire location.

1.6 Structure of Report

The rest of the report consists of 4sections which are: literature review, system analysis & design, results analysis and conclusion. In section 2, literature review discusses about the similar existing projects' background, which includes 13 different previously proposed systems related to this project. The design objective is explained in section 3. This section also briefly explains the project development which includes information on how the proposed project will work and an overview on the different hardware parts which will be used. The results analysis is done in section 4. The section 5 includes recommendations with the conclusion.

2. LITERATURE REVIEW

2.1 Introduction

This section contains 3 subsections: A general introduction indicating our main aim from exploring and comparing similar systems. The second subsection provides an overview on the

previous projects and research made in fire detection and communication field. The third subsection mentions the limitations or drawbacks we found after exploring different techniques. This study allowed us to clearly identify which approach is the most appropriate for our research investigation in fire detection and communicating field. We reviewed the systems and projects that already exists, compared between their different features and abilities, and observed their stated drawbacks or limitations. After observing the various methodologies and techniques used, we were able to identify areas of contribution for improving the fire response mechanism.

2.2 Similar Systems and Projects Exploration

2.2.1 Smart Safety Monitoring System of Dubai Civil Defense

Dubai Civil Defense has offered a system in [3], which detects a fire with the help of Smart Monitoring System and emergency operation center using Machine to Machine technology (M2M). In this system, when a fire is detected by the relevant sensors an automatic and fast alarm containing the exact location will be send to the central control center which will send a direct response to the nearest fire station and fire engines. The system also takes an immediate action to stop the fire from spreading using Fire water tanks and pumps.

These are some drawbacks and limitation for the above system, it is hard to construct and to implement. It mostly targets new buildings. It can't be installed in places where through-wall ducting is prevented such as historical buildings and Archaeological sites. The system relies on 24hr/7days available central control center which needs human interaction. The system has no communication with any of nearby building.

2.2.2 An Intelligent Fire Alert System using Wireless Mobile Communication

In [4] the author has proposed a system which makes use of temperature and smoke sensor to detect fire emergency situation and sends a wireless response to a server computer and server mobile which will instantly inform up to 5 remote authorized users by an SMS or a call. The authorized user has complete access to the system where the user takes appropriate actions such as turn on or off alert notification, modify the threshold and reset the system.

The system lacks direct automatic communication with the civil defense station as they have no specific system to receive and interpret the signal. The system does not communicate with the nearby buildings. The computer server used in the system could be it-self affected by the fire, on the other hand it is not efficient to have a separate server for each installed system.

2.2.3 Design of Wireless Automatic Fire Alarm System

The system in [5] has developed a set of wireless automatic fire alarm system which uses low power and wireless communication protocol. It uses multiple routers which receives wired or wireless signals from Controller Area Network (CAN) bus or fire alarm controller. The routers send these signals to three different branches: one of these is fire detector which triggers an alarm, the other branches are facility monitoring and output module, and finally the signal will be sent to a call center operated manually. The limitations and drawbacks of this system are denoted by its disability in having any type of automatic action to stop or prevent the fire, there is no automatic contact with any of the concerned entities such as civil defense. The system lacks the communication with nearby buildings.

2.2.4 Efficient Smart Emergency Response System for Fire-Hazards Using IoT

Internet of Things standardized structure is used in [6] to design real time emergency response system for fire hazards. The system uses sensors to detect smoke, different flammable gases and fire then it alerts the fire department and police by sending the hazard location to the cloud-service through which all are connected. The complete network uses a light weighted data oriented publish-subscribe message protocol Message Queuing Telemetry Transport(MQTT) services for fast and immediate communication.

This system has less benefit in the absence of Internet service or slow Internet connection and doesn't provide any way to inform the neighbouring buildings about the fire.

2.2.5 Early Forest Fire Detection & Monitoring System in Greece

In [7] the author has proposed a project used to assist in forest fire detection and fire spread prevention, by means of an early warning system which alerts local firefighting forces. It also records surveillance video prior to the fire, to help identify fire root causes, such as arson.

By using 360^0 rotatable cameras and thermal radiometry sensors, the system detects the abnormal temperature when there is a fire and notifies the fire station with location information. It also activates a water cannon system in addition to notifying the local pumping stations to assist fire brigades.

2.2.6 IOT Based Fire Department Alerting System

The author of [8] describes a project used to detect the fire, directly notify the fire department about the fire using IoT server.

The system uses different types of sensors to detect fire and alert fire department over IoT by activating the fire buzzer there. It sends information about the incident by using Wireless Fidelity (Wi-Fi) connection to access IoT server and transmit data over the Internet so that the fire department team can use this information to take the suitable action.

This system has less benefit in the absence of Internet service or slow Internet connection.

2.2.7 IoT Based Fire Detection and Controlling System

The author of [9] proposed a system used to early detect fire accidents, communicate with respective authorities and store the data that is related to the fire accident. The system uses smoke and Down Hill Control (DHC) sensors to detect fire. Whenever the temperature exceeds the limit, the system communicates with respective authorities. Then it activates fire sprinklers and keep them in position till temperature is reduced below a specific value. Fire accident related data is stored in a remote server for future use.

In this system, heat sensor damage due to the fire may cause the sprinkler never turns-off.

2.2.8 Fire Rover System

The narrator in [10] describes a fire suppression system that is used to protect people and customer facilities. This system uses FLIR (company that specialized in thermal cameras) thermal cameras to detect the fire and sends an alarm to the monitoring station. This camera is attached with a mobile remote-controlled unit that is controlled by people in monitoring station to spray foam and suppress the fire.

This system is mainly designed only for the outdoor use and it is cost-ineffective due to the cost of thermal cameras.

2.2.9 Home Security Alarm System

The basic idea of the proposed system mentioned in [11] is to protect properties from different threats such as fire and thieves. It also controls doors remotely and even monitor kids' entrance. All this is done with the help of 50 different sensors. The system has stand-alone power and uses two different communication protocols Public Switched Telephone Network (PSTN) and GSM.

This system doesn't have direct communication with the fire station and less effective in the absence of Internet service or slow Internet connection.

2.2.10 Huawei Smart Smoke Detection

In [12] Huawei and china-Unicom have invented jointly a new Hothink pilot smoke detector which is free of disadvantages of the old smoke detectors, like frequently batteries replacements, installation difficulty and high cost. Huawei's detectors are wireless devices, which detects and automatically informs the owner of the location and the fire station using Text-to-speech system which leads to minimize losses. This system uses only smoke sensors which may lead to a false alarm.

2.2.11 IoT Based Fire Alarm and Monitoring System

The proposed system in [13] uses sensors to detect the fire and sends information to the central processing computer which starts the alarm, the sprinkler and disconnects the power. The proposed idea is to have a central processor connected to set of sensors in different zones and actuators. If the sensor values exceed the threshold, a signal will be sent to the central processor which controls number of relays. These relays are responsible for starting buzzer alarm, water sprinkler and disconnecting main power. In this system there is no communication either with the owner or fire station in case of fire.

2.2.12 IoT Smoke Alarm with Arduino, ESP8266 and Gas Sensor

The proposed system in [14] uses only smoke detectors such as MQ-2 to detect the smoke and activates a buzzer and a red light for local alert. The system sends the values of the detectors to a web server and it will display warnings in a web page by using ESP8266 module.
The smoke value only will be sent by the module. The esp8266 module requires an external Logic Level Converter.

2.2.13 IoT-Based Intelligent Modelling of Smart Home Environment for Fire Prevention and Safety

The system described in [15] uses multiple sensors of different types. If a single sensor alone detects the fire, processing unit will send a message to the owner to inform him. In case of no response from the owner the fire alarm will start. In case of 2 sensors or more, detects the fire or smoke, automatically the fire alarm will start and the data will be uploaded to server and cloud to inform the neighbors and the responsible departments. For communication they used ZigBee protocol.

This system is less effective in the absence of Internet service or slow Internet connection.

2.3 Limitation/Drawbacks of the Stated Similar Systems

After looking at many different examples and studies, we found that most of the systems lack automated fire notification alert to the fire fighting department; or the department is un-aware of any of these implemented systems. Most of the systems discussed did not use notification to neighbours about the fire. Another limitation is that most of the system relied only on cloud or SMS but not both which can sometimes lead to system failure. After carefully considering all what was studied, we have proposed a system that covers most of these missing features and takes an effective action in most of the cases.

3. SYSTEM ANALYSIS AND DESIGN

This section explains about the design of our proposed system which is automated fault tolerant fire detection and warning communicator system. Our proposed system has three subsystems namely: Fire Detection and Communication System (FDCS) which is the main system, fire station system and owner's smart device application system. First subsystem which is FDCS detects the fire and gas leakage, then sends the alarm signal and location of fire through IoT cloud and SMS to the fire station and another SMS alarm to the premise's owner. Usage of both IoT cloud and SMS alarm signals makes the system fault tolerant, that is, if one type of communication fails another type will work. The second subsystem is fire station system which receives the alarm signal and activates the fire station buzzer. It sends an acknowledgement SMS initiated by firemen to the FDCS. This subsystem also informs the neighbouring buildings near the location of fire through voice calls. The last subsystem is the owner's smart device application system that receives the SMS alarm signal from FDCS and sends an acknowledgement SMS initiated by the owner to confirm that the alarm signal has been received.

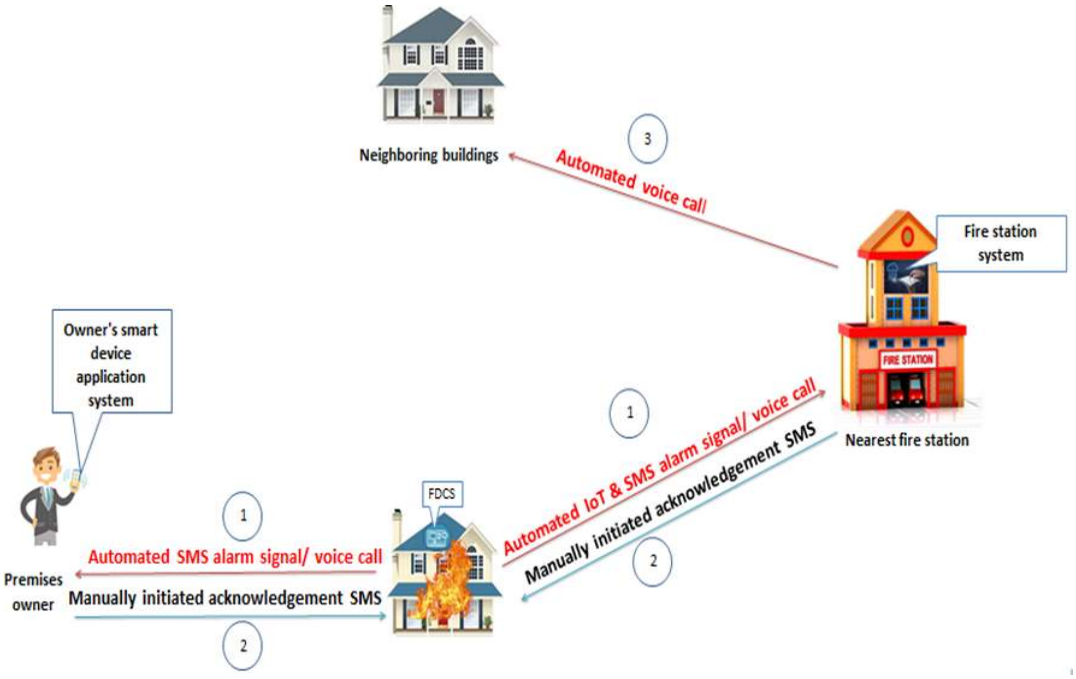

Figure 1.Automated fault tolerant fire detection and warning communicator system

3.1 First Subsystem: Fire Detection and Communication System:

3.1.1 Installation Place:

3.1.1.1 Installation of the FDCS in Different Types of Buildings:

Single-Story Buildings Like Houses:
The full system including sensors will be installed in the ceiling of the premises.

Multi-Storied Buildings:
One main system will be attached to the buildings' fire alarms control board. The sensors will be distributed in each floor of the building. They will be connected to the main system with wire or wirelessly according to the owner's choice.

Institutional Buildings:
There will be one main system attached to the automated fire alarm of the building and the sensors will be distributed in the other buildings according to the range of used sensors, but more than one main system can be used according to the area of the campus. The sensors will be connected to the main system wirily or wirelessly according to the owner's choice.

3.1.2 FDCS Functionalities:

1. It detects and senses the fire through multiple sensors.
2. In the case of fire or gas leakage, it directly communicates with the fire station by sending an alarm signal through IoT Internet cloud and SMS along with the location of fire.
3. Activating fire or gas leakage alarm in the premises.
4. The system also notifies the owner of the premises.
5. Ensures that alarm signal received by the fire station system and the owner using acknowledgement mechanism.

3.1.3 Components:

Gas/smoke, heat and flame sensors, Wi-Fi module, GSM module, fire buzzer alarm, gas leakage buzzer alarm and microcontroller.

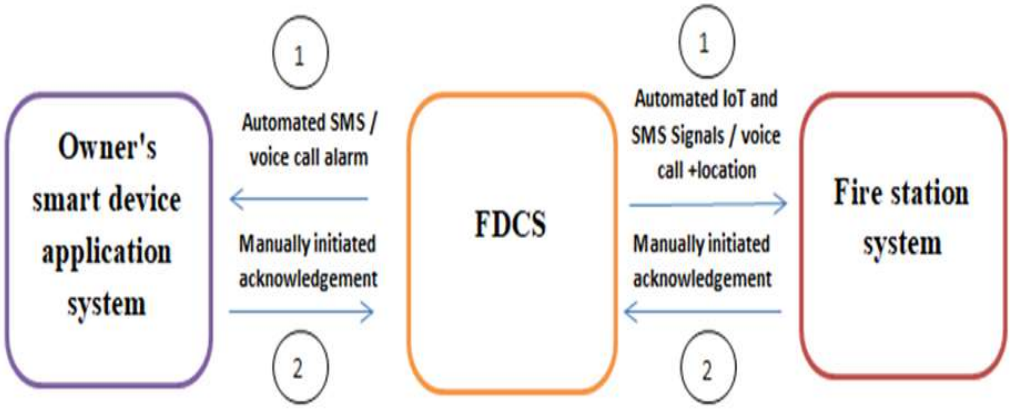

Figure 2. Sequence of operations in FDCS

3.1.4 Operation of Fire Detection and Communication System:

3.1.4.1 In the Case of Fire:

In the main system, when the flame sensor detects the fire or the sensors' data of smoke/gas sensor, carbon monoxide sensor and heat sensor reach beyond the normal limit, the main system will send an alarm signal along with the location of fire to the fire station system through the IoT Internet cloud using Wi-Fi module. At the same time, the system also sends the alarm signal using SMS through GSM to both owner and fire station systems. It will also activate a fire buzzer alarm in the premises. The system ensures the alarm signal has been received by the owner and the fire station by using acknowledgement mechanism. After sending the initial alarm signal, the system waits for acknowledgement SMS from the owner and the fire station. If there is no acknowledgement, the system will resend the alarm signal using SMS and also makes an automated voice call to both of them.

3.1.4.2 In Case of Gas Leakage:

If the gas/smoke sensor detects the gas level beyond the limit, the main system will send a different type of alarm signal through IoT Internet cloud and SMS along with the location of the premises to the fire station but with a kind of alarm, different from fire alarm, that indicates there is only gas leakage which may cause fire. In addition, it also sends an SMS alarm to the owner that there is a gas leakage and activates gas leakage buzzer alarm in the premises. The acknowledgement mechanism also used here to confirm that the alarm signal has been received. This will prevent from the fire that may come out.

3.2. Second Subsystem: Fire Station System

3.2.1 Installation Place: Fire station control room.

3.2.2 The Fire Station System Functionalities:

1. Receiving the IoT and SMS alarm signals along with the location of fire from the FDCS and activating buzzer alarm in the fire station.
2. Displaying the location of fire in the control room screen in the fire station.
3. Waiting for the firemen to press the acknowledgement button in the fire station application to send an acknowledgement SMS to the FDCS.
4. Informing the neighbors who are close to the location of fire.
5. There will be a database in the fire station, which will contain the details of the residence and their neighbors.
6. The database will be used by our system to notify the neighbors of the fire location

3.2.3 Components: Smart display device, mobile device application and the database.

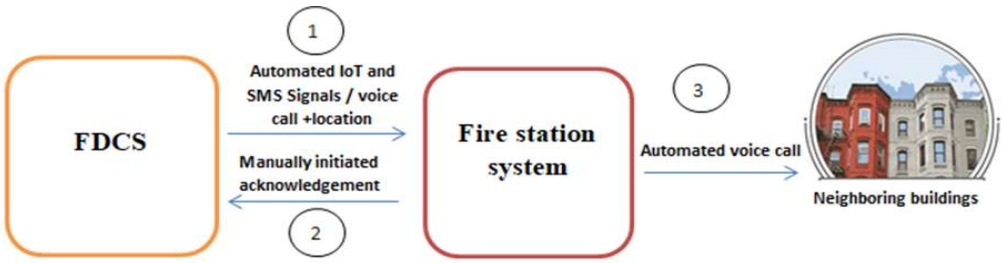

Figure 3. Sequence of operations in fire station system

3.2.4. Operation of Fire Station System:

When the fire station system receives fire alert notification along with the premises location through IoT Internet cloud and SMS, it will activate fire station buzzer alarm and display the location of the premises in the control room screen. It will use the received fire location to inform the neighbouring buildings by making use of the information that is stored in the fire station database. It informs the neighbours through a pre-recorded voice call. Then the system will wait for the firemen to press the acknowledgement button in the application to send an acknowledgement SMS to the FDCS.

3.3. Third subsystem: Owner's Smart Device Application System

3.3.1 Installation place:Owner's smart mobile device.

3.3.2 The Owner's Smart Device Application System Functionalities:

1. Receiving the SMS alarm signal and activating a sound and vibration alarms in the owner's smart device.
2. Waiting for the owner to press the acknowledgement button in his mobile application to send the acknowledgement SMS to the FDCS.

3.3.3 Components: Standalone mobile application that can be activated by the system.

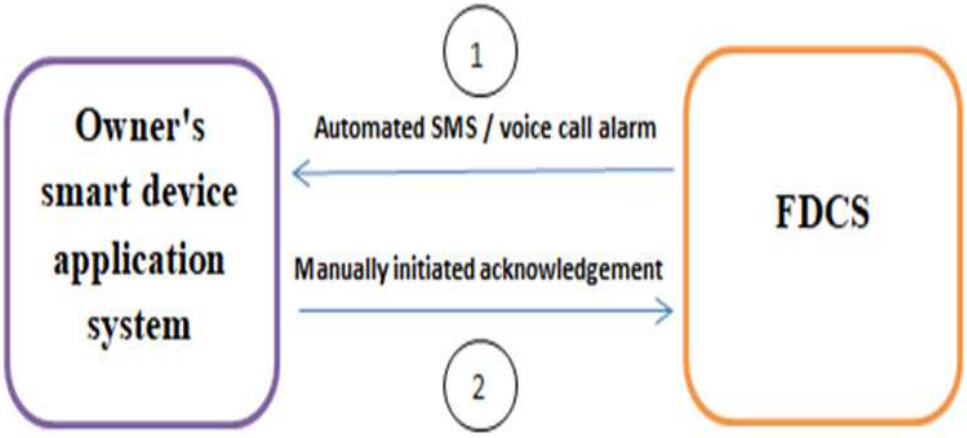

Figure 4. Sequence of operations in Owner's smart device application system

3.3.4. Operation of Owner's Smart Device Application System

When owner's smart device application system receives an SMS alarm from FDCS, it activates sound and vibration alarms in the owner's device, so that the owner will notice the alarm and press the acknowledgement button to send an acknowledgement SMS to the FDCS. In case if he didn't press the acknowledgement button he will receive same SMS signal along with a pre recorded voice call.

3.4 Flowcharts Illustrating Sequences of Tasks Done by Our System After Detecting Fire or Gas Leakage

3.4.1 Flowchart of FDCS

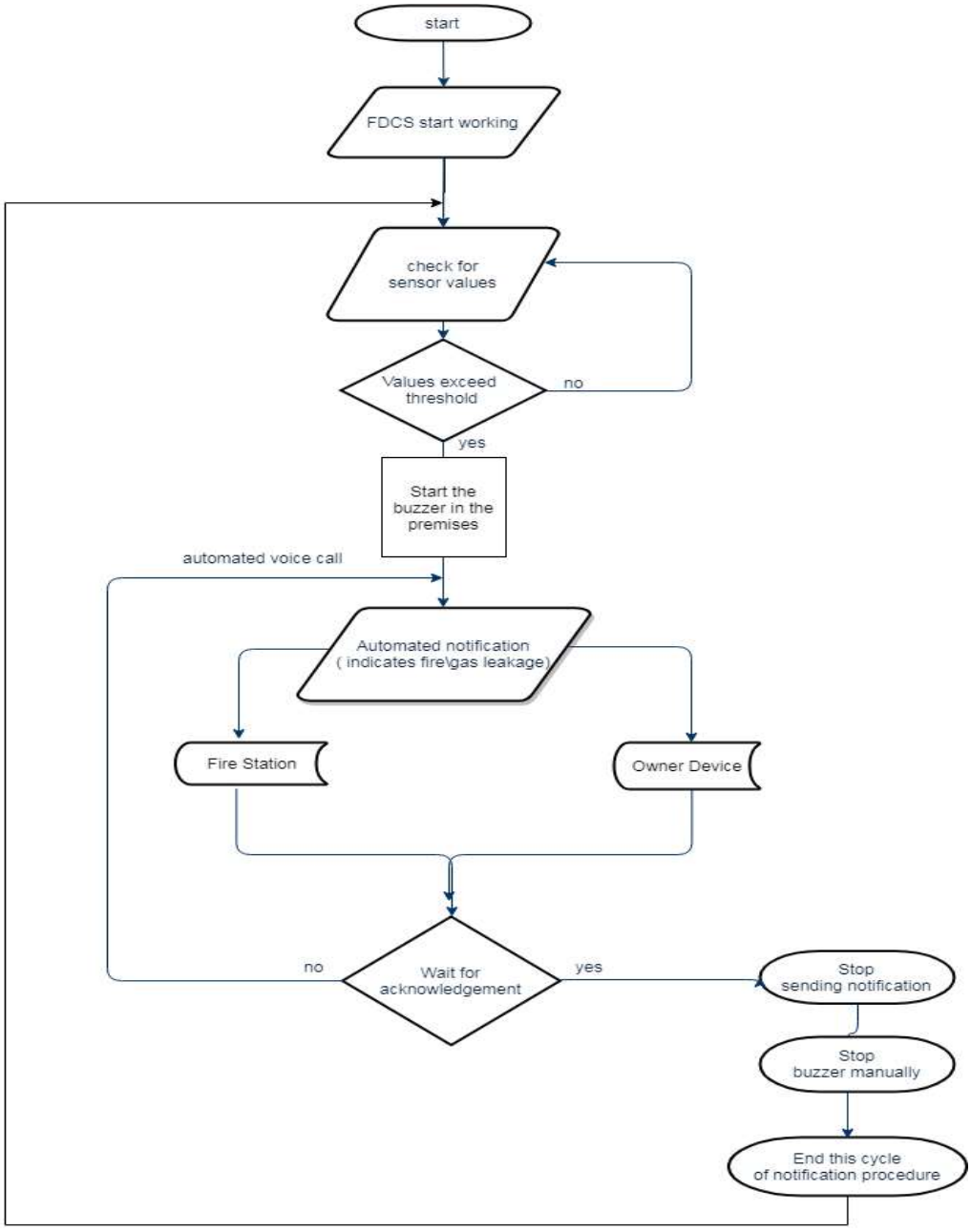

Figure 5. Sequence of tasks in FDCS

3.4.2 Flowchart of the Fire Station System

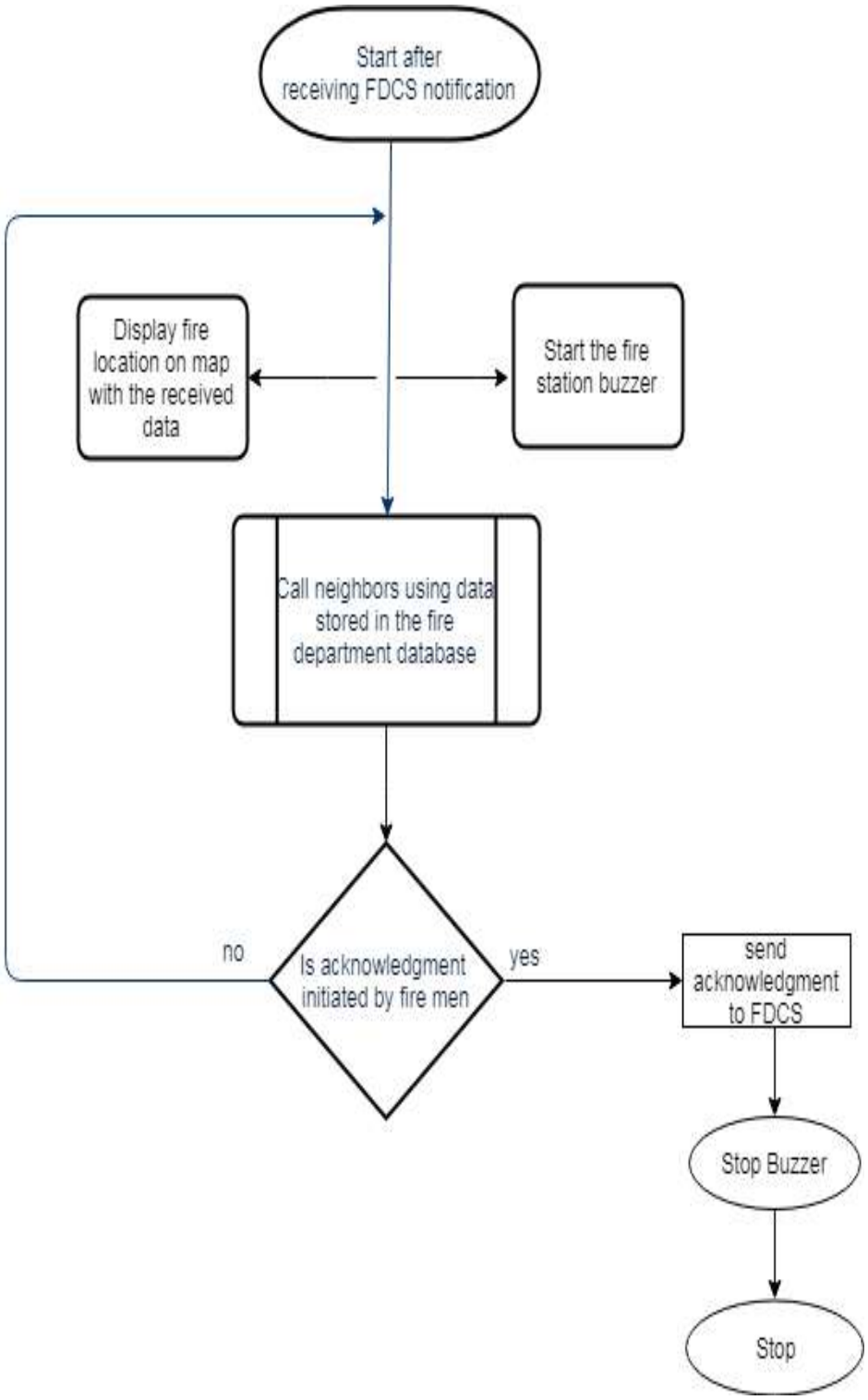

Figure 6. Sequence of tasks in fire station system

3.4.3 Flow Char of the Owner's Application System

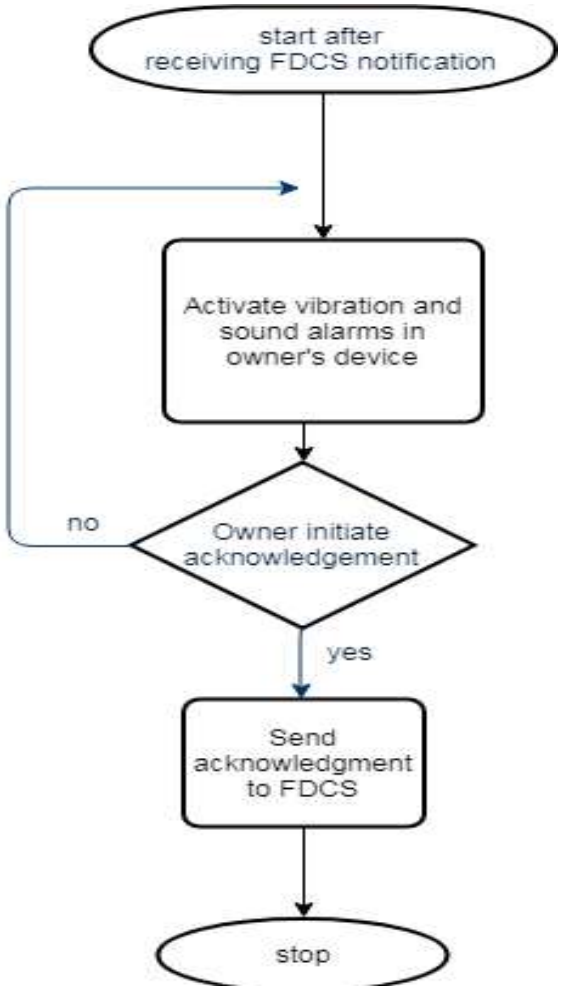

Figure 7. Sequence of tasks in the owner's application system

4. RESULT ANALYSIS

Our proposed system notifies the fire breakout to the fire station immediately after detecting the fire, using automated fire alert notification through IOT cloud and SMS directly. With the use of our system, the time taken from the time of fire break out, up to the time the fire department receive the notification is reduced significantly when compared to the conventional systems in which the human make call to the fire department after noticing the fire. In case of absence of human in the fire place, notification to fire department is delayed until someone pass by notices the fire and informs to fire department.

Let us consider the total time taken from the time of fire to the time the fire men reach the place is T. The time T includes two parts, which can be written as:

$$T = T_a + T_b \qquad \text{- Equation 1}$$

Where $T_a$is the time elapsed from the time of fire break out, up to the time of receiving the notification by the fire station.

$T_b$is the time elapsed from the time of receiving the notification by the fire station until the time to reach the fire place.

T_b will be relatively same in either case with or without using our system.

T_a will be reduced a lot (which includes only SMS reaching time) by using our system.

From this analysis, as the T_a is reduced by our system, the fire fighters can reach the fire place quickly and save more people and reduce the damage happened by fire. As our system notifies the neighbours also, the losses for the neighbours are reduced and it helps in saving neighbouring people lives.

5. CONCLUSION

In this project we proposed the Automated fault tolerant fire detection and warning communicator system, which is a fire detection system that mainly focuses on automated fire notification between the main system which is FDCS and the fire station along with the premises owner and premises neighbouring buildings in case of fire or gas leakage. The fast-automated fire alert notification between these units will help to save more people's lives and reduce physical losses that may be caused by the fire or the gas leakage.

The recommendation for future improvements of this project include, adding fail-safe sensors which has continuous self-check up feature, attaching sprinklers together with the system which takes automatic defense action in stopping the fire and improving the system to work in open areas like forests and farms.

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