5th International Conference on Engineering Technology and its Applications 2022- (5thIICETA2022)

Fire Spread Monitoring System of A Forest Based On Interpolation and Cloud Computing

1st Hayder Fadhil Abdulsada
Babylon Technical Institute
Al-Furat Al-Awsat Technical University
51015 Babylon, Iraq
inj.had1@atu.edu.iq

2nd Mohammed G. Al-Hamiri
Computer Center
University of Babylon
Babylon, Iraq
m.ghadhban@uobabylon.edu.iq

3rd Laith A. Abdul-Rahaim
Electrical Engineering Department
University of Babylon
Babylon, Iraq
drlaithanzy@uobabylon.edu.iq

4th Heba Abdul-Jaleel Al-Asady
Department of Computer Technical Engineering, College of Technical Engineering
The Islamic University
Najaf, Iraq
en.he22@gmail.com

2022 5th International Conference on Engineering Technology and its Applications (IICETA) | 978-1-6654-7215-9/22/$31.00 ©2022 IEEE | DOI: 10.1109/IICETA54559.2022.9888683

***Abstract*— In the developed world, it is necessary to save the natural environments. A lot of incidents of human-made and natural catastrophes were occurring around the world. Forest fires are one of these environment disasters. The goal of this research is to construct and develop a cloud system which can detect the exact location of a forest fire and the spreading speed and direction of the fire. The location and direction of fire can be directly monitored on Google Maps application. An interpolation algorithm has been suggested to determine the time required for the fire an known point location on the forest. This will give the possibility to intervene and prevent the spreading of the fire significantly. The system utilizes Node Micro Controller Unit, Infrared flame detection sensors modules, Global Positioning System module with each sensor to provide the exact location for each to reach fire detected sensor. The proposed system gave accurate results and a high response speed, where the forest supervisor could monitor the fire continuously through a webpage which is connected to Google Maps. The interpolation algorithm was a suitable to determine the time for the fire to reach a certain point or a specific sensor at the forest.**

***Keywords*— Node MCU, Cloud Computing, Fire Spread Monitoring, Google Maps, Interpolation.**

I. Introduction

The forest is a vast area where plants and animals spread in it. The forest occupies an area of about 4-billion hectares, or about 30% of the world's total area. Forests are an immense help to the economy of a nation. There are typically different types of trees and animals in the forest. However humans get benefit greatly from the forest. Certain medicinal supplies, household needs and demands [1].

Forests can have an immense environmental influence that stops the earth from overheating. The forest removes emissions generated by people to a good manner. Therefore the fire in the forest can cause a large impact in our world. Forest fires in several places are unnoticed and grow very rapidly, causing serious damage to millions of acres and destroying several people's lives annually. Such forest fires will lead to a major environmental catastrophe. The casualties in the forest fire are large, impacting both animals and plants. In recent years, forest fire has increased in the world. This fire in the forest is attributed to nature or human.

One of the sources of natural wildfires is lightning. This is when dry wood, such as leaves, is burnt in the forest. human-made fires are very similar to smoking and caused by any various activities. It has suffered more damage in recent years from forest fires. The Tajin report from the National Interagency Center views that there are more than 65,575 animals were killed by wildfires in 2016. The loss rose to nearly 71,499 in 2017, and over 10 million acres were destroyed in the fire. The loss has decreased to 55,911 animals after taking an information strategy and nearly 8.6 million acres of wildlife have been burnt, which is smaller in comparison to 2017. And we discovered from this that the risk in the forest is higher and that urgent measures must be taken to mitigate forest fires. The government and even the forest management section must take practicable steps to mitigate the flames. Some of the steps depended by the government prevent people from accessing the forests regions before forest officers' agreement. In forest regions, in any wildlife sanctuaries and even in local forest regions, the use of fire-causing objects is restricted.

The Forest management section carries out surveillance steps through the use of cameras in the forest regions. The government and forest management sections take measures to prevent enormous damage to the forest from the natural disaster by providing some emergency supplies to mitigate the fire, such as a fire extinguisher, and some guards are assigned in the forest region to provide timely forest fire information so that timely appropriate steps can be made [1][2].

The presence of cloud computing introduces a revolution in smart technologies. Forest fire detection based on cloud computing seems as an important option for sustainable management of natural climates, involving remotely monitoring and early detecting of fires.

Many sensors can be used for forest fire detection such as temperature, smoke, flame, humidity sensors which can gather a large amount of data about forest environmental status. These sensors are connected to hardware controller like Arduino and Raspberry Pi and etc. to temporarily hold data. A wireless technique would be used for communication system between the terminal devices.

Authorized licensed use limited to: Queens University Belfast. Downloaded on November 15,2022 at 12:09:55 UTC from IEEE Xplore. Restrictions apply.

Node-MCU is an open source IOT module which provides a firmware that running on the ESP-8266 platform. The ESP8266 introduces completing and self-containing Wi-Fi network connection. This networking permits the ESP to either hosting the applications or to offloading whole Wi-Fi network functions from other processor. The efficient capability of the ESP8266 processor and storage enables it to be integrated with sensors and others application specific integrated circuits through its general-purpose Input/Outputs (GPIOs). ESP-8266 platform includes a small scale microcontroller with Wi-Fi. The user can run and program the ESP8266 by using the Arduino environment framework. It comprises of 17- GPIO, 128KB memory, 4MB for storage, and 3.3 input voltage. ESP8266 module is suitable for mobile and wearable devices and applications and Internet of Things (IOT) applications. It provides low power consumption with an integration of different proprietary techniques. The power saving mode works in three modes: active, sleep and deep-sleep mode. Fig.1 shows the ESP8266 module [1][2].

Fig. 1. The ESP-8266 board

GPS module is utilized for tracking and locating the exact location of the forest fire. It gives the longitude and latitude of the sensor location that detects the fire. It has the capability to locate the position at a high speed rate. The GPS module needs voltage of (3-5V) to operate and sends the information at 9600 bps. It also equipped with a support stored battery source that can be used to store the information when a problem occurred with main power [3].

A. Cloud Computing Model

Cloud computing represents a model for allowing Omnipresent, flexible, on-demand access to a participated pool of configurable computing resources such as networks, servers, storage, applications, and services. Cloud computing provides three main types of services to end clients which are Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS) as explained in Fig.1 below .. These services are also named as the service-platform-infrastructure (SPI) model of the cloud [4][5].

For IaaS services, the subscriber will get computing, storage, networks, and load balancing depending on the concept of pay-as-use where the IT user has the ability for deploying and running any software, which can contain operating systems and applications. The costumer is not capable of managing or controlling the underlying cloud infrastructure but he has controlling of the operating systems, the storage, and the shared applications. The IT architect has no fully control of selecting network components such as host firewalls. The services vendor owns all the computing resources and is responsible for managing and maintaining that resources. Amazon Web Service is an example of the common large IaaS provider. [4][5].

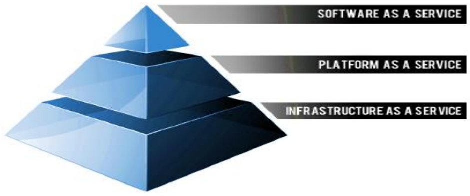

Fig. 2. Cloud computing Services.

The PaaS providers allow the developer to develop and deploy their applications directly on the same cloud infrastructure. They support programming languages, application frameworks and their libraries, databases, servers, networks, storage and other supporting tools. The developer is not capable of managing or controlling the cloud infrastructure and has only control over the application regarding the development and deployment. There are many cloud PaaS provider like Windows Azure, Google App Engine and Force.com Platform.

For SaaS services, the customer can remotely access the software applications and directly employ the applications developed by the developers and that running on the cloud infrastructure resources. The SaaS services include servers, networking, storage, operating systems, and other application capabilities. The applications can be remotely accessed from several customer devices through a web browser or a user program interfacing. The client does not have the ability for managing or controlling the underlying cloud infrastructure. Salesforce.com is an example of Software as a Service which offers business services including customer relationship management (CMR) [4][5].

II. Related Work

In 2018, G. Neumann et al. have introduced the concept of realizing a low cost infrastructure for intelligent forest utilizing mobile objects and hubs for detecting fire. The researchers utilize WPAN, Bluetooth temperature and humidity sensors . The phone device receives information from sensors and processes it then sends it to the forest server. The server stores data and notifying entities about the events happened [6].

In 2018, Kalatzis N. et al. have proposed the reliance of Edge-Fog computing basis to the drones for forest fire detection based on a hierarchical design. This research introduced a three layers scheme to detect fire in a large forest region. A drones attached with Raspberry Pi board capture the necessary photo data which can be processed in a local or in the fog computing [7].

In 2019, Jayaram K et al. have suggested system for fire detecting in a forest and then notifying the officer of the forest about the fire. A microcontroller has been utilized for controlling of the system activities. Temperature and smoke sensors are connected to detect the forest fire. The system is also detecting the precise location of the fire and sends that location to the nearest forest officer. So that the system is a fully IoT based system where the system activities are always monitored and the monitoring specifics are stored in web pages that are showed by the officer. The specifics have been stored as a data and this data can be showed any time later [3].

In 2019, Divya A et al. have suggested a wireless sensor network (WSN) for early detection of forest fire. The system introduced uses temperature and smoke sensors and data

Authorized licensed use limited to: Queens University Belfast. Downloaded on November 15,2022 at 12:09:55 UTC from IEEE Xplore. Restrictions apply.

transmitting through a wireless channel. The microcontroller will collect data and then transmit them to a small satellite which sends them to ground station to be processed and analyzed [8].

In 2019, Antunes M et al. have developed a modular system with minimum cost. The system uses Master-Slave (MS) frame to permit adding additional slave nodes as required. The objective of slave nodes is to read and pre-process information from the flame sensors so that they provide temperature readings of the surroundings regions to the master node. The master node connects to the web and it receives and processes data coming from slave nodes. It is used for monitoring in real time and for transmitting alarm signals [9].

In 2019, Marcu A et al. have proposed a smart forest monitoring system depending on Raspberry Pi-3. Digital and analog sensors have been used to monitor temperature, gas amounts, humidity and etc. the researcher suggest an algorithm to analyze the background sounds. The user receives notifications about fire detection, pollution resources, or illegal elimination of forest. This research provides monitoring solution for forest fire based on IoT system [10].

In 2020, Srividhya S et al. have proposed IoT-Fog computing monitored system for forest fire management. The system provides balance load data computing and analyzing and distributes the operations across fog, aggregator and central cloud layer. Many wireless sensor nodes have been utilized for monitoring the forest region. These environmental sensors are temperature, humidity, wind and rainfall. The collected information from these sensors are always monitored by aggregator-nodes separately. Finally, Cloud layer assists to handle all fire associated notifications, and sends alert signal to the forest officer and users in the surrounding regions [11].

In 2020, Zope V et al. have utilized cloud storage, machine-learning, and IoT sensors configuration. The sensors which are used to predict the occurrence of wildfires are temperature, pressure, soil-moisture, humidity, and altitude sensors. Any unexpected changes in sensor reading indicate that forest fires. The supervisor can monitor the system and the changes in the reading values by using of an android application. The sensor outputs have been updated in the Google database every short time and these updated reading have been monitored in the android application. The application illustrates the expected intensity of forest fire. In case of high intensity of fire, the user will receive a notification on his phone [12].

In 2020, Lakkar P et al. have introduced an integrated IoT for detecting and monitoring forest fire. The system comprises uniform monitoring of the forest region with the assistance of cloud computing and analysis of the real reason of the fire. The proposed system utilizes newest Microcontroller, Wi-Fi board for transmission and exact sensors to detect fire. The system also gives a fast response therefore the fire can be detected and controlled at the earliest step [1].

In 2020, Deepthi S et al. have suggested a combined technique for detecting and managing of forest fire. The system comprises humidity and flame sensors to detect the variation in the humidity and temperature and utilizing Node-MCU microcontroller which includes Wi-Fi module. The controller sends the sensors data to the cloud database and these data are compared with a threshold level to decide if there forest fire or not [13].

In 2022, Ananthi J et al. introduce a study to create a forest fire prognostication tool. the system presents a deep learning for forest fire prognostication and detection system. This technique detects the forest fire based on a group of sensors connected with the system and they are considered as an input to the learning system. For monitoring system, a digital camera with a high resolution was used. smoke, humidity and temperature sensors have been utilized for fire and smoke detection which are connected to the microcontroller Node-MCU that manage the system [14].

In 2022, Latha M et al. have introduce a designing of internet of things system that is self-maintaining and used for forest fire detecting and predicting. the designed system transmits the fire location to forest officer through GSM. the system uses the Arduino as a main Microcontroller with set of sensors for fire detection [15].

As compared with previous studied, our proposed system can detect fire location, monitor fires in the forest, measure the speed of fire spreading accurately through the proposed interpolation algorithm, and also know the direction of fire spread through Google Maps.

III. The Proposed System

The research aims to design an integrated monitoring system to detect forest fires and give the exact location of the fire on Google Maps, as well as to know the speed and direction of the fire spread. The system consists of a central controller represented by the Node MCU-ESP8266 module and a group of sensors distributed randomly in the forest and each sensor attached to a GPS module. In the event of a fire, sensor status and GPS reading are collected by the ESP controller and then sent via Wi-Fi to the cloud, so that this data is stored in the cloud MySQL database. Fig.3 below shows the general block diagram of the overall system.

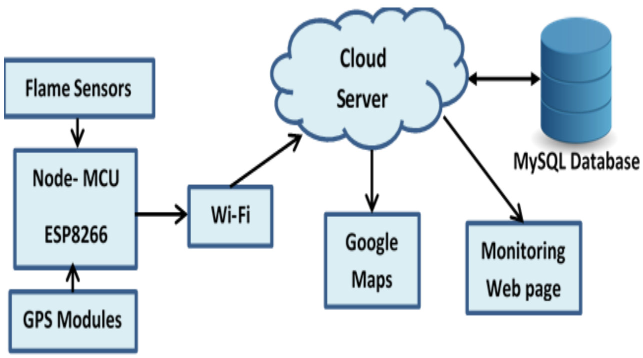

Fig. 3. Block diagram of fire spread monitoring system

The implemented design of the fire spread monitoring system was declared in Fig.4 below. It displays the connection of ESP-8266 with the sensors and GPS module. Since the overall system is implemented in the forest, so it is difficult to connect a transmission wire to the forest for electrical supplying. Therefore an external solar power supply was used to fed the ESP-8266 Microcontroller, the sensors and the GPS module. At day time, the system is powered directly from the solar cell and at night time, it is powered from the stored power in the batteries. The devices needs only less power supply.

Authorized licensed use limited to: Queens University Belfast. Downloaded on November 15,2022 at 12:09:55 UTC from IEEE Xplore. Restrictions apply.

Firstly the ESP module software checks if its correctly connected to the server cloud database through Wi-Fi, and then checks that the location of the all sensors are correctly fetched to the ESP module through the ESP module Wi-Fi. The serial monitor of the Arduino software environment will displays that as shown in Fig.5 below.

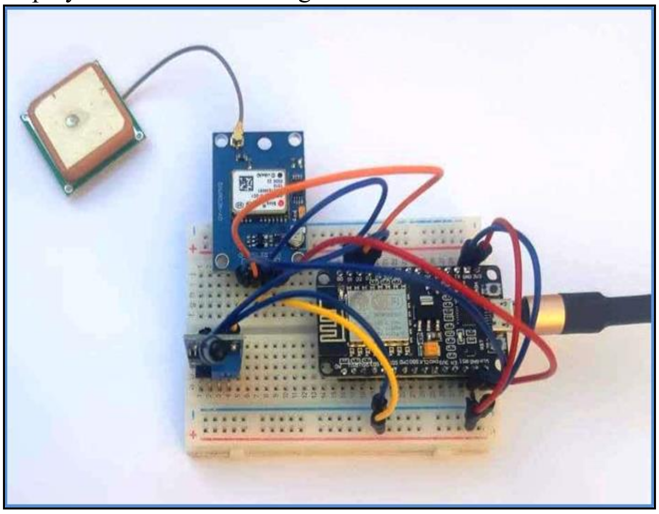

Fig. 4. The implemented fire spread monitoring system

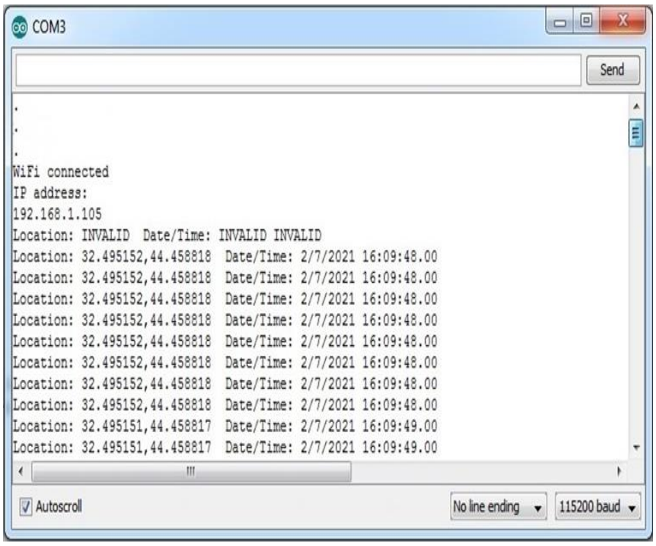

Fig. 5. Arduino serial monitor

When the flame sensor detects the presence of a fire, then the sensor reading and the time of fire occurrence are recorded and sent to the cloud database. Also, the location of the fire is determined by the GPS module and also sent to the data base as longitude and latitude readings.

When the fire reaches the second sensor, the fire time and location are also measured at the second sensor, and also sends to the MySQL database. Based on these readings, the elapsed time between the first and second sensor is calculated, and then the speed of the fire spreading is calculated. This mechanism is applied between each sensor and the one that follows it, and by it, the real location of the fire and the spreading speed at each direction are also known. Fig.6 below displays the MySQL data base that is built to save updated values of sensors status, the sensing time of the sensors and the location (longitude and latitude) of each sensor.

The web server that used to implement this work is run on APACHE module, programmed by PHP language. And the database that is interfaced with the web server is built through MySQL module. The infrastructure web server with the database is located in a work computer hard storage disk. The web server sends http request to the server database to fetch the sensors readings, the sensing time, and the GPS modules location in XML format including longitude and latitude of each sensor position. The server processes these data to determine the forest fire spreading speed and the direction of the fire and displays these results on the officer monitoring webpage. The server is also connected with the google maps to show the exact location and direction of forest fire.

A (getRhamb LineBearing) function was used to calculate the direction between the last two fire detecting sensors by knowing the latitude and longitude of the location of each sensor.

An index PHP simulation page was build that simulate the physical components and it is interfaced with Google maps to display the position and direction of the spreading fire as shown in Fig. 6 below.

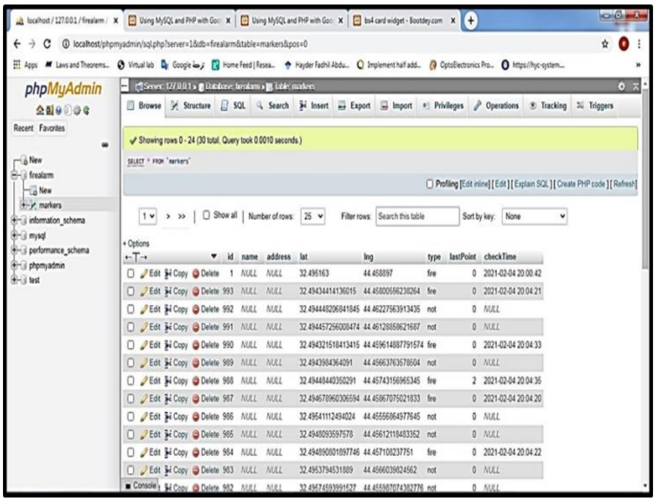

Fig. 6. MySQL database web page

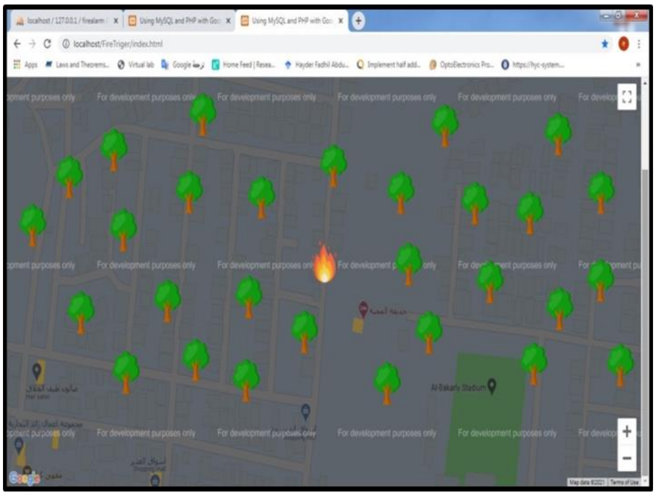

Fig.7. Simulation of physical fire detecting sensor displayed on google map

Fig.7 display that the forest fire has been occurred so the sensor state, sensing time and fire location will be saved in MySQL database. The fire will continue to spread, and then

Authorized licensed use limited to: Queens University Belfast. Downloaded on November 15,2022 at 12:09:55 UTC from IEEE Xplore. Restrictions apply.

the second sensor detects the fire, its data is sent to the database, and so on for the rest of the sensors as shown in Fig. 8 below

Fig. 8. Fire spread monitoring system on google map.

IV. Result And Discussion

The proposed system is designed to protect forests, detect the presence of fire, as well as know the speed and direction of fire. The system gave good results regarding the fire speed and directions, and the response speed was high. The forest administrator can use web pages linked to Google Maps through which they can monitor and track the fire if it occurs. Thus, the course of the fire can be predicted and precautionary measures can be taken to prevent the fire from spreading further and empty the areas that the fire is heading to.

Fig. 9 below shows a webpage that displays the path of the fire on Google Maps, as well as its speed and direction.

The figure shows that the direction angle between the last fire detected sensors are 59 and it's the same on google maps with speed of 14 Km/h. a live API was created to send information and reading every 5 seconds from the data base to the user interface webpage.

Fig. 9. Fire speed and direction on google map.

An interpolation algorithm has been proposed to determine the time that the fire needs to reach a certain point or a specific sensor before the fire reached it. The Spatial interpolation algorithms has been utilized to fill missed information or data in any time sequences. The prior way depends observations found at different positions in an area to infill the data at a position with missing data, while the current ways uses only information from the position itself for infilling data.

This algorithm is based on a previous values of sensing time of each sensor and their locations through which the fire passed. These values which represent sensing time and locations were saved in the server's MySQL database, and used to calculate the time required for the fire to reach a known location at a forest.

From Fig. 10, Let the location of the first fire detected sensor is (x_1,y_1) which is (12,23) and the location of the second fire detected sensor is (x_2,y_2) which is (36,40) as shown in Table I below. The fire is started at sensor one at time T_1 = 20:00:00 , and then arrive to the second sensor after 8 seconds at time T_2 = 20:00:08.

TABLE I. Calculation Of The Time Required For Fire To Reach A Specified Time

Sensor No. (i)	Fire location		Check Time (Ti) hr:min:sec	Fire Speed (km/hr)
	Xi	Yi		
1	12	23	20:00:00	-
2	36	40	20:00:08	13.234
3	60	57	20:00:17	13.234
4	503	520	20:02:09	13.234

Then the speed of fire spreading (S_1) between the two points is calculated to be 13.234 km/hr by using the formula:

$$S_1 = \frac{\sqrt{(y_2\text{-}y_1)^2+(x_2\text{-}x_1)^2}}{T_2\text{-}T_1} \quad (1)$$

In the same way, the speed of fire spreading (S_2) between the second sensor location (36,40), and third sensor location (60,57) is calculated to be 13.234 km/hr as follows:

$$S_2 = \frac{\sqrt{(y_3-y_2)^2+(x_3-x_2)^2}}{T_3-T_2} \quad (2)$$

And know calculate the average of fire spreading speed of S_{avg} .S_1 and S2 to be 13.234 km/hr as follows:

$$S_{avg.} = \frac{S_1+S_2}{2} \quad (3)$$

Then the time required for the fire to reach a specified point location (x_4,y_4) which is (503,520) at a forest is determined to be T_4 = 20:02:09 as follows:

$$T_4 = \frac{\sqrt{(y_4-y_3)^2+(x_4-x_3)^2}}{S_{avg.}} \quad (4)$$

That means that the fire need 2 minutes and 9 seconds to reach the point location (503,520) at the forest. At the same way, it is easily to determine the time required for the fire to reach any other sensing point at the forest.

Authorized licensed use limited to: Queens University Belfast. Downloaded on November 15,2022 at 12:09:55 UTC from IEEE Xplore. Restrictions apply.

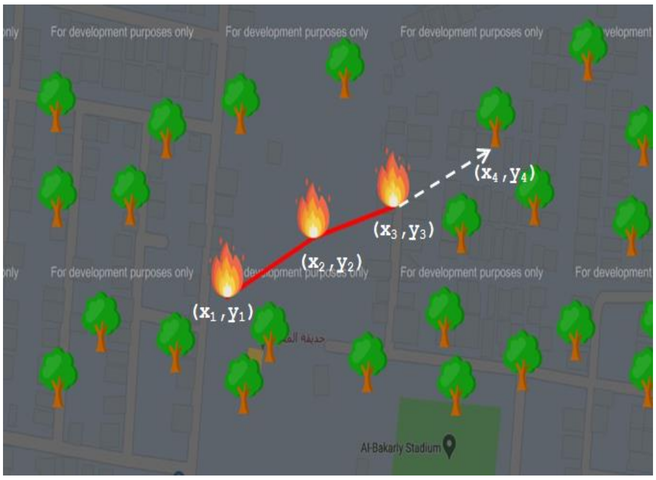

Fig. 10. Picture of sensors with their locations

Fig.10 above displays the sensing points with their locations. Here the point (x4,y4) is known point location and fire time arrival to it must be determined. This algorithm provided a great service so that by which it was possible to know the time needed for the fire to reach a specific place, and thus the follow-up team could take appropriate precautionary measures before the fire reached that place. It is also possible to evacuate the area before the fire reaches it, to preserve life and nature.

V. Conclusion

There are many techniques used for monitoring fires in forests to reduce the damage caused by natural disasters or fires caused by humans. A monitoring system has been proposed to monitor fires in the forest, measure the speed of fire spreading accurately, and also know the direction of fire spread through Google Maps. flame sensors were used and deployed randomly in the forest, and each sensor was equipped with a GPS module, where data were collected from these devices by using ESP-8266 controller and sent via Wi-Fi to the server's MySQL database continuously. The data is processed and analyzed on the cloud server to calculate the fire speed and direction. The processing also includes determine the expected direction and speed of the fire. The proposed system gave accurate results and a high response speed, where the forest supervisor could monitor the fire continuously through a webpage which is connected to Google Maps. The interpolation algorithm was good to determine the time for the fire to reach a certain point or a specific sensor at the forest.

References

[1] L. Prateek, N. Meghana, "Forest Fire Detection, Prevention and Response System using IoT," *International Research Journal Of Engineering And Technology (IRJET)*, pp2133–2136, 2020.

[2] I. K. Osamah, M. A. Ghaidaa, A. Noor, "IOT fire detection system using sensor with Arduino. *Revista Aus*, pp74-78, 2019.

[3] K. Jayaram, K. Janani, R .Jeyaguru, R. Kumaresh, N. Muralidharan "Forest Fire Alerting System With GPS Co-ordinates Using IoT," *5th International Conference on Advanced Computing & Communication Systems (ICACCS)*, 2019, pp488-491.

[4] K. Chandrasekaran, *Essentials of Cloud Computing*, Taylor & Francis Group, LLC, 2017.

[5] B. Sandeep, *Cloud Computing*, Cambridge University Press, 2015

[6] B. N. Guilherme, P. A. Vitor, E. Markus, "Smart Forests: fire detection service," *IEEE Symposium on Computers and Communications (ISCC)*, 2018, pp 1276-1279.

[7] K . Nikos, A . Marios, D . Dimitris, P. Konstantinos, R. Ioanna, P. Symeon, "Edge Computing in IoT ecosystems for UAV-enabled Early Fire Detection," *IEEE International Conference on Smart Computing,* 2018, pp106-114.

[8] A. Divya, T. Kavithanjali, P. Dharshini, "Iot Enabled Forest Fire Detection And Early Warning System," *2019 proceeding of International Conference on Systems Computation Automation and Networking*, 2019.

[9] A. Miguel, M. F. Lu´ıs, V. Carlos, C. Paulo, T . An´ıbal, and D. Almeida, " Low-Cost System for Early Detection and Deployment of Countermeasures Against Wild Fires," *IEEE 5th World Forum on Internet of Things (WF-IoT)*, 2019, pp 418-423.

[10] M. Alina, S. George, O. Elena, M. Delia, D. Alexandru, M. Ioana, " IoT System for Forest Monitoring," *IEEE*, 2019, pp629-632.

[11] S. Srividhya, S. Sures, " IoT-Fog Enabled Framework for Forest Fire Management System," *IEEE* , 2020, pp 273-276.

[12] Z. Vidya, D. Tarun, M. Ashutosh, "IoT Sensor and Deep Neural Network based Wildfire Prediction System," *Proceedings of the International Conference on Intelligent Computing and Control Systems*, 2020, pp 208-208.

[13] S. Deepthi , G. K. Shushma, and K. B. Sahana, "IoT IOT Enabled Forest Fire Detection and Management," *International Journal of Engineering Research & Technology (IJERT)*, 2020, pp 196-199.

[14] J Ananthi , N Sengottaiyan , S Anbukaruppusamy , Kamal Upreti and Animesh Kumar Dubey, "Forest fire prediction using IoT and deep learning," *International Journal of Advanced Technology and Engineering Exploration*, 2022, Vol 9(87), pp 246-256.

[15] L Maheshwari , J Janet , S Jeevanandham , S Kausic , M Manish , "Forest Fire Alerting System with GPS Co-ordinates Using IoT," Journal of Physics: Conference Series, 2022, pp 1-6.

Authorized licensed use limited to: Queens University Belfast. Downloaded on November 15,2022 at 12:09:55 UTC from IEEE Xplore. Restrictions apply.