Fire Detection and Alarm System using Wireless Sensor Network (WSN) via LoRa Gateway with Flame Recognition

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***Abstract*--- One of the major problems that firefighters face are false alarm and poor navigation. It is very inefficient and time consuming. In order to address these problems, this paper proposes a smart fire detection and alarm system composed of sensor modules and interface module which detects fire incidents. The sensor module is composed of a microcontroller, smoke sensor, temperature sensors and LoRa transceiver, and the interface module which includes the Raspberry Pi, LoRa gateway and camera. The LoRaWAN serves as the link communication between the two modules. Once the sensor module is triggered with smoke and high temperature, the interface module will control the camera to face towards the activated sensor module and capture a video clip of the scene and recognize the smoke in the image. Mobile application and website are developed for the viewing of pictures and videos of the fire incident.**

***Keywords*--- Wireless Sensor Network, LoRaWAN, Fire Alarm System, GSM-Based, Smoke Detector, Temperature Sensor**

I. INTRODUCTION

Many lives and properties are lost every year because of inevitable fire incidents, usually caused by incaution fire build up which could have been prevented. These incidents show how a fire alarm system is necessary in protecting lives, properties, and structures. With the rapid evolution of technology, various automated fire alarm systems are now available and the components necessary to develop the system are more affordable.

Wireless Sensor Network (WSN) is a collection of autonomous sensor nodes deployed for real time monitoring of different parameters in the human unattended environment such as deep forest, over the top of trees, underground etc. WSN have been deployed in many applications such as smart home, healthcare, and agriculture. [1] To provide safety and prevention of fire incidents, a WSN that monitors all the essential parameters is designed and developed. The system proposed in this paper is composed of sensor and interface modules which detects, analyze, and capture image and video of the fire incident. All images, videos, and data gathered are accessible through mobile app and website.

A. Background Study and Overview

Nowadays, using Wireless Sensor Network (WSN) is a reliable solution for ecological variations. One of the valuable researches of WSN is for fire detection. The present study aims to illustrate that a device for detecting the presence of a fire and for tracking its space and time evolution can be designed from a Wireless Sensor Network. [2] This study is comparative to our study by analyzing and monitoring fire using Wireless Sensor Network and using RF transceiver to transmit and receive information differs with the sensors that used in both studies. This provides a report on process and procedures of using WSN and how the RF transceiver function.

Ahmed Imteaj et al. propounded [3] which is an IOT (Internet of Things) based fire alarm system for factories using Raspberry Pi 3 which controls multiple Arduinos integrated with couple of sensors (temperature, gas, smoke, flame sensor) and a camera assembled with a 360° relay motor that enables it to capture the image in any angle where fire is detected. The system will be placed systematically on vulnerable places of fire in the factory and intelligent algorithm determines when to start the alarm. The system also provides information of the incident and its location to a nearby fire brigade using GPS and GSM module.

In the work presented in [4], the system showed how a fire alarm system works for early detection of fire in the environment. The design used sensor node in wireless based

sensor network. With WSN, the data gathered is processed with the use of two algorithms in detecting fire. The detected information is sent to a computer system and is reported to the authorities through Internet.

In contrast to the previous studies stated, the proposed system will be using wireless sensor network with LoRa transceiver. When a sensor detects smoke in the environment, the area of which sensor is triggered will be captured. The system aims to cover a wide range of surrounding by networking multiple sensors and to monitor it through mobile app and website.

II. System Architecture

Figure 1 shows the system architecture. Once the sensor module is triggered with smoke and high temperature, the interface module will control the camera to face towards the activated sensor module and capture a video clip of the scene and recognize the smoke in the image. Mobile application and website are developed for the viewing of pictures and videos of the fire incident.

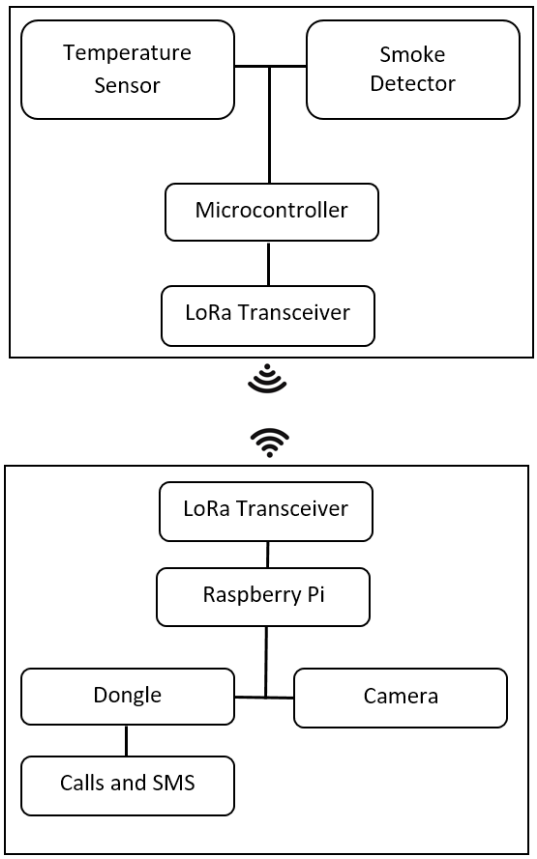

Fig. 1 Block diagram of the fire alarm system

III. Methodology

A. *Hardware*

The proposed fire alarm system is composed of sensor modules and interface module which detects fire incidents. The sensor module is composed of a microcontroller, smoke sensor, temperature sensors and LoRa transceiver, and the interface module includes the Raspberry Pi, LoRa gateway and camera. Raspberry Pi has good technical specifications and performs well on data processing. To reduce the tasks of the Raspberry Pi, the Arduino Uno was used to process the analog signal from sensor. The LoRaWAN serves as the link communication between the two modules and the surveillance cam is responsible for capturing the image or video of the incident.

B. *Software*

Several programming languages and other online applications are integrated to successfully develop the proposed system.

Python is a programming language and it present a high dynamic semantics. It is use for the rapid development of the application because of its high-level integrated data structures and the use of existing components in scripting or glue language as a link. Python includes packages and modules which promote advancement of the program and enable to have a backup of the code. [5] The Raspberry Pi is installed with Python Programming Language to process the image captured by using a surveillance camera and to call the authorities to alert about the fire incident.

Structure Query Language is used to manage database. It can perform update and retrieve data from the database. It is the standard language for relational database management according to ANSI (American National Standards Institute). [6] The captured images, videos and incident updates will be saved in the database using SQL.

MIT App Inventor lets you develop applications for Android phones using a web browser and either a connected phone or emulator. The App Inventor servers store your work and help you keep track of your projects. [7] The MIT App inventor is used to create an APK to access the images saved on cloud storage if there is a fire.

C. *Database and website*

Figure 2 shows the database which stores the data gathered by the system. The website shown in figure 3 is made using PHP and accessible through the URL: 192.168.43.225/index.php. The calibration of camera angles are done through 192.168.43.225/values.php.

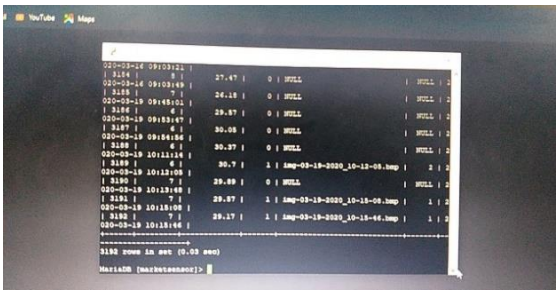

Fig. 2 Data stored on the server

Fig. 4 Website

D. *Mobile Application*

Mobile application are also developed for the viewing of pictures and videos of the fire incident. Information regarding temperature and smoke detection are also presented. The application are developed using MIT app inventor.

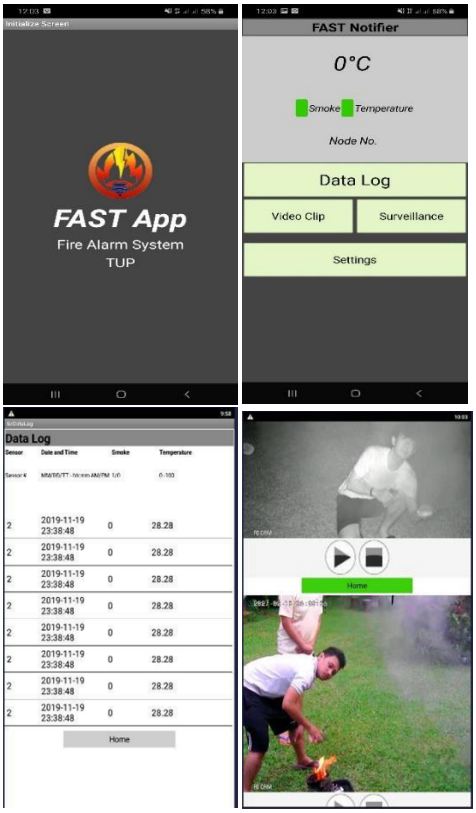

Fig. 3 Features of mobile application

IV. System Description

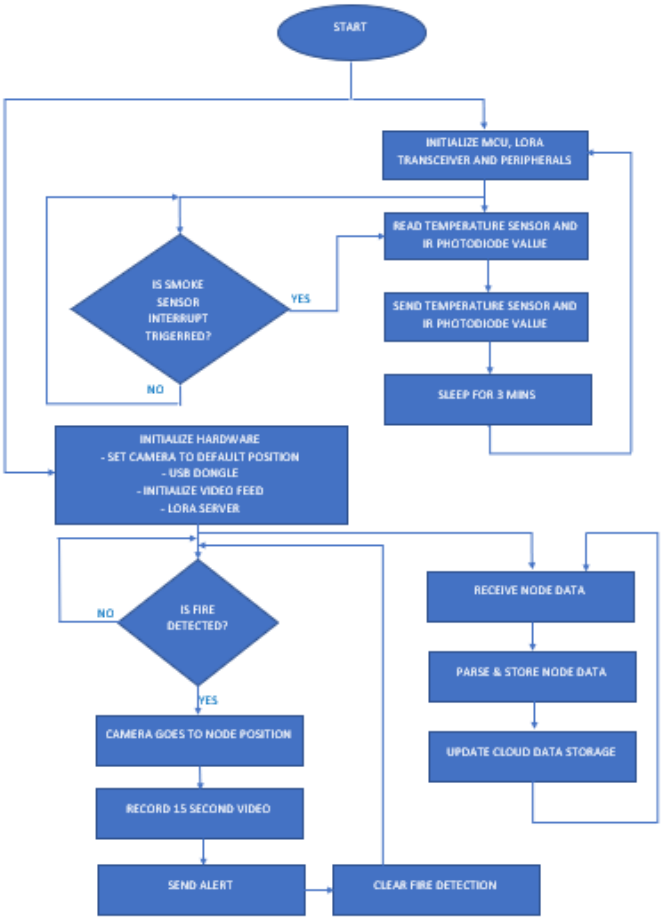

Fig. 5 System Flowchart

The illustration above shows the flow diagram of the system. The input consists of three variables namely smoke, temperature, and image. These will be detected using smoke sensor, thermal sensor, and surveillance camera, respectively. When the smoke is detected and the temperature will exceed a certain threshold, the camera will face where the sensors are located and will capture an image. The knowledge requirements in this study are the truth table of threshold of the sensors and the image verification and Automation of Wireless Sensor Network (WSN), and the calibration of camera angles. The Hardware requirements are Sensors, Camera, Raspberry Pi, Microcontroller, GSM module, and LoRa Transceiver. When there is a fire incident within the area, the nearest sensor will detect the fire then the sensor will give a data to the microcontroller which will translate to a raw data that will transmit to the Raspberry-Pi via LoRa Transceiver. The Raspberry-Pi will control the camera towards the alarmed sensor for the camera to capture image and record a video. The image and record logs will be sent through the mobile app to confirm if the fire incident is real or not. This data with the recorded video will also be sent to the working webpage.

V. Result and Discussion

TABLE I
TEMPERATURE SENSOR DATA

TRIAL	MODULE	DIGITAL THERMOMETER	ERROR (%)
1	29.41	29.7	0.976
2	28.36	28.8	1.528
3	28.52	28.6	0.279
4	29.08	29.7	2.088
5	28.28	28.6	1.119
6	38.51	39.0	1.256
7	37.95	38.4	1.172
8	35.61	35.9	0.808
9	40.20	41.0	1.951
10	42.86	43.3	1.016
TRIAL	**MODULE**	**DIGITAL THERMOMETER**	**ERROR (%)**
11	37.71	37.9	0.501
12	35.53	35.9	1.031
13	38.91	39.1	0.486
14	33.11	33.5	1.164
15	31.74	32.0	0.813
16	31.98	32.3	0.991
17	32.07	32.4	1.019
18	33.19	33.6	1.220
19	32.47	32.5	0.092
20	31.98	32.3	0.991

The data gathered on comparing the temperature from multiple sensors and temperature from an actual digital room thermometer are shown in the table above. The average error calculated from this test is 1.0545%. Hence, the temperature data coming from the sensors are reliable.

TABLE II
TEST RESULT SUMMARY

Smoke	Temperature °C (Threshhold: 30°)	Smoke Image	Action Taken
Not Activated	29.69	Not processed	Number not alerted
Not Activated	33.98	Not processed	Number not alerted
Not Activated	34.57	Recognized	Number alerted
Activated	27.83	Not processed	Number not alerted
Activated	31.49	Unseen	Number alerted
Activated	31.73	Recognized	Number alerted

The table shows the summary of the test results obtained from the alert feature of the system. At first condition, the system was tested on a normal/usual environment without the presence of the three factors resulting to not alert the registered phone number. Next, there was a high rise in temperature and has reached the threshold limit, whereas smoke was both undetected by the sensor module and unseen from the camera leading also to not alert the registered phone number. Now for the third condition, there was a high rise in temperature and has reached the threshold limit, whereas smoke was still undetected by the sensor module, but smoke was clearly seen from the camera, alert has been sent. For the fourth condition, the temperature was normal, and smoke was detected from the sensor module, yet it was not seen by the camera as a result of no alert to the registered phone number. Further on the fifth condition, the system alerted the registered phone number caused by the reached in temperature threshold and presence of smoke, both detected by the sensor module even though smoke was not seen from the camera. Finally, the system was tested with all three factors present, resulting in alerting the registered phone number.

Conclusion

A wireless network of sensor modules was developed. The sensor modules were composed of smoke and temperature sensors that are interfaced to a programmed microcontroller. The microcontroller retrieves data from the sensor and send it through RF transceiver. The control module composed of Raspberry-pi was developed. The control module does the following : (a) identify the activated sensor module ; (b) control the movement of the surveillance camera towards the activated sensor ; (c) recognize the image of smoke and obtain video then return the camera back to its default position ; (d) send an alert via call and SMS; (e) live streaming of the camera footage; and (f) update the data on android app and web page. An android application that notifies the fire authorities was developed.

The project was implemented successfully. However, the following recommendations were made for the improvement of the project: (a) additional feature of the android app that may solve the traffic issues experienced by the firefighters;; (b) use IP temperature sensor for the sensor node for faster acquisition of temperature; (c) integrate GPS on sensor modules to directly guide the camera on the right direction; and (d) enhance the image processing of the system for more accurate recognition of smoke or fire in the image.

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