GSM-Based Fire Detection and Alarm System Using Wireless Sensor Network (WSN) via LoRaWAN

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***Abstract*--- Many lives and properties are lost every year because of inevitable fire incidents. Firefighters must arrive in the incident within 5 to 7 minutes but due to late notification it is not often met. To address this problem, the proponents developed the smart fire detection and alarm system that is updated to the latest technology of the present. The system will alert the firefighters through calls/SMS and uses wireless sensor network for longer coverage. For long range connection, the system used Long Range Wide Area Network (LoRaWAN). The device's features include smoke and temperature detection.**

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

I. INTRODUCTION

Fire is considered as one of the top threats to physical safety. It spreads really fast depending on the material of the house and it gets bigger exponentially. It can take a life and destroy properties in just mere minutes therefore firefighters must respond as quickly as possible. The firefighter must arrive in the incident 7 minutes or less. The problem is that the notification system is a little behind with the latest technologies today. This project will improve the notification and fire alert system through SMS/Calls whenever the sensors detects the parameters of a fire.

A. Background studies and overview

For the various type physical data monitoring, wireless sensor network (WSN) is effective technique because of its cost, flexibility, and safety. For making the system stable, the solving the electric and electronic problems, e.g., power problems and communication problems and others in WSN are demanded. Furthermore, the collection and analysis of data in real-time can be implemented to guarantee the data precision. [1]

In [2], a cost-effective and power-efficient solution to this problem comes with the concept of the Internet of Things coming into play. This project implements a system which is efficient and effective with the help of proper communication protocols and inexpensive devices to realize the solution. A network of node have low-cost smoke and temperature sensors attached to them and are placed at strategic points in the establishment where the system is to be implemented. These nodes now constantly monitor for any fire breaking out and send the information to a Raspberry Pi which acts as a central hub. In the event of a fire the Raspberry Pi will get the information about the incident and the location from the corresponding sensor node, and sends this information via email to the concerned people. This way, we can know when and where a fire has broken.

Several smart fire alarm systems were proposed. For example, "Nest Project" is a smart fire alarm device, it could function as a single stand-alone device which smoke and carbon monoxide detectors. Nest produces an alarm sounds and sends a notification to the users when fire is detected. It could also communicate with other "Nest Project" smoke detectors – if they were available. In addition to that, users are alerted when the power of the device is low. Using the "Nest project" application, users can control Nest detector remotely. Users can also view recent safety activities from their device. However, the drawbacks of "Nest Project" are the need of Wi-Fi connectivity within the home and that it can only communicate with android or iOS phones. [3]

II. SYSTEM ARCHITECTURE

Figure 1 shows the block diagram of the fire alarm system. The upper box is the sensor module and the lower box is the interface module. When both the temperature sensor and smoke detector activates, the data collected will be sent to the microcontroller to make the data transmittable by the LoRa transceiver. The LoRa transceiver will pass it to another LoRa transceiver then the raspberry pi will control the movement of the camera and the dongle to call and text the fire authorities. The wireless sensor network is compose of many sensor modules (maximum of 10) and only one interface module.

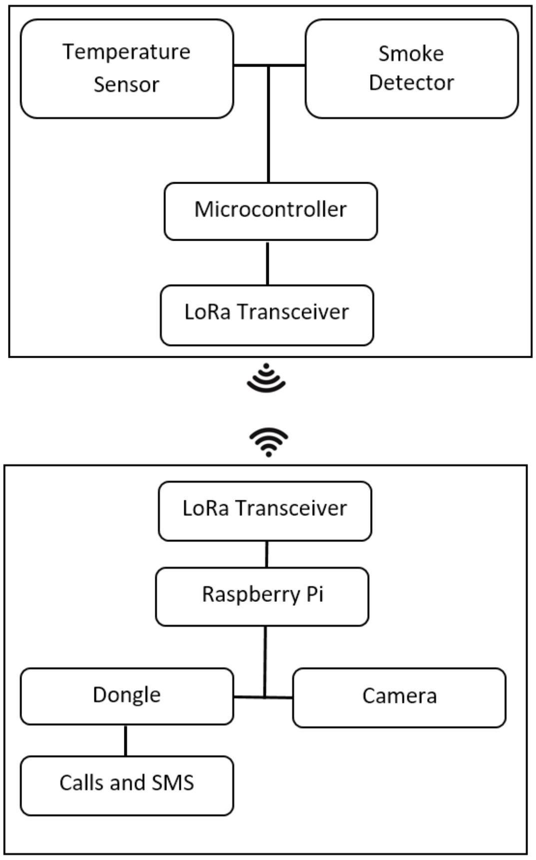

Fig. 1 Block Diagram of the System

III. METHODOLOGY

A. Hardware

The system has 2 modules, the interface module and sensor module. The interface module is composed of a raspberry pi, LoRa gateway, and a high quality IP camera while the sensor module is composed of commercial smoke detector, temperature sensor, microcontroller, and a LoRa transceiver. 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 an interpreted, object-oriented, high-level programming language with dynamic semantics. Its high-level built in data structures, combined with dynamic typing and dynamic binding, make it very attractive for Rapid Application Development, as well as for use as a scripting or glue language to connect existing components together. Python's simple, easy to learn syntax emphasizes readability and therefore reduces the cost of program maintenance. [4] 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.

SQL is used to communicate with a database. According to ANSI (American National Standards Institute), it is the standard language for relational database management systems. SQL statements are used to perform tasks such as update data on a database, or retrieve data from a database. [5] The captured images, videos and incident updates will be saved in the database using SQL.

C. Server/Database

Figure 2 shows the database of the system that users can access through the URL: Firealarmserver.ddns.net under User ID: 0000111. The webpage is made using Dreamweaver, a Java based programming language linked to a server hosted by Freehostia.com.

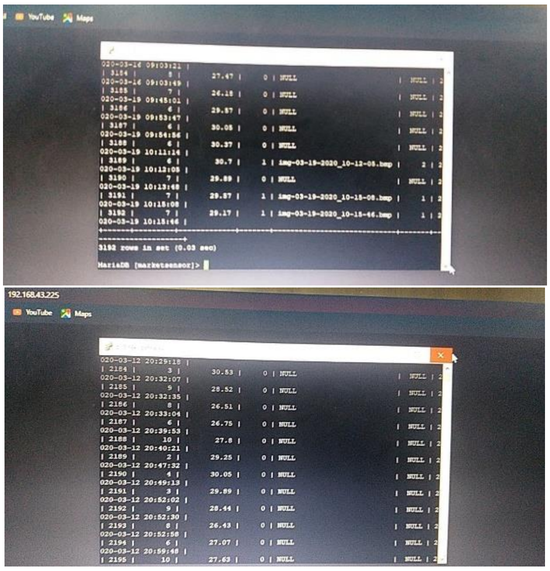
Fig 2. Data stored on the server

D. Calls and SMS

The raspberry pi is programmed to make a phone call and send an SMS to the fire authority when all the parameters are met. Figure 3 shows that the dongle will call the authority to alert them if there is a fire. Figure 4 shows a series of SMS that shows updates of sensors data.

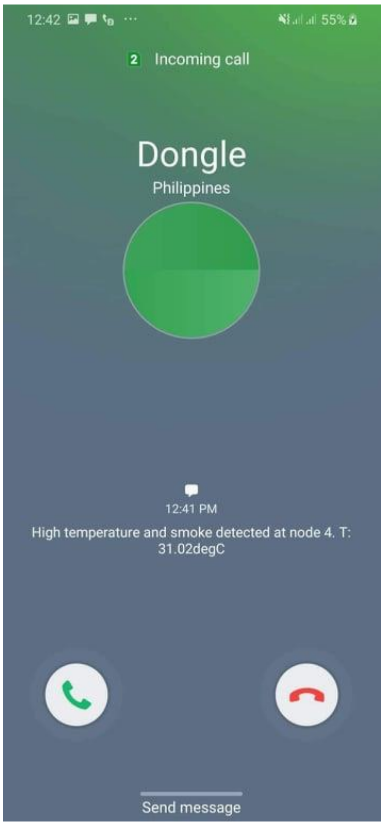

Fig 3. Alerting the authority through call

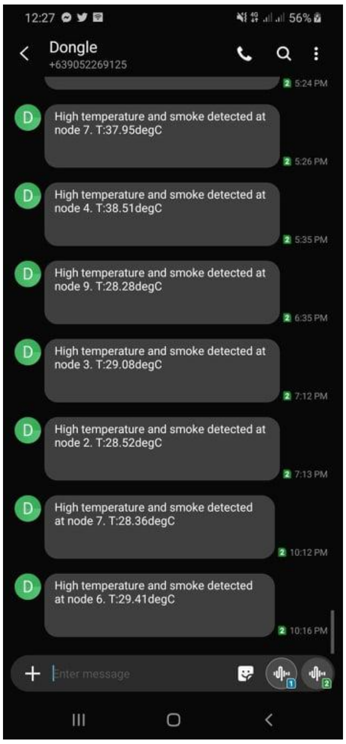

Fig 4. Sending an SMS with updates

IV. SYSTEM DESIGN

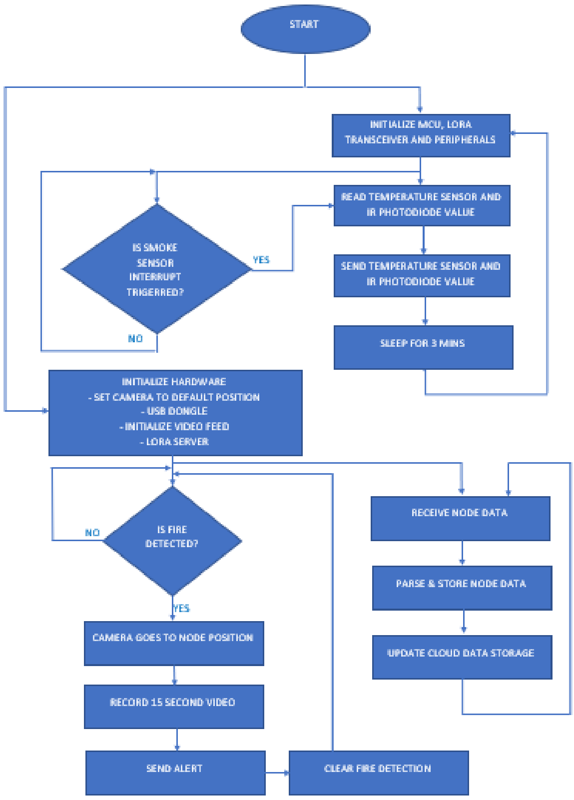

Fig 5. Flow Chart of the System

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 rotate towards the location of the sensor that is activated 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 capture image through camera. The Hardware requirements are Sensors, Camera, Raspberry Pi, Microcontroller, GSM module, RF Transceiver and Stepper-motor. 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 RF Transceiver. The Raspberry-Pi will control the camera and will face the alarmed sensor for the camera to capture image and record a video. When the image verification is processed, the GSM module will be used to notify the assigned officers of a fire incident via Call and SMS.

V. Results 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
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

In table 1, the data from the temperature sensor has been compared to an actual digital thermometer to test the accuracy. The calculated average percent error is 1.0545% hence the data coming from the temperature sensor is accurate and 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 interface module, composed of Raspberry-pi was developed. The interface 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.

The project was implemented successfully. However, the following recommendations were made for the improvement of the project: (a) use IP temperature sensor for the sensor node for faster acquisition of temperature; (b) integrate GPS on sensor modules to directly guide the camera on the right direction

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