Efficient Smart Emergency Response System for Fire Hazards using IoT

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***Abstract*—The Internet of Things pertains to connecting currently unconnected things and people. It is the new era in transforming the existed systems to amend the cost effective quality of services for the society. To support Smart city vision, Urban IoT design plans exploit added value services for citizens as well as administration of the city with the most advanced communication technologies. To make emergency response real time, IoT enhances the way first responders and provides emergency managers with the necessary up-to-date information and communication to make use of those assets. IoT mitigates many of the challenges to emergency response including present problems, like a weak communication network and information lag. In this paper, it is proposed that an emergency response system for fire hazards is designed by using IoT standardized structure. To implement this proposed scheme a low-cost Expressive wi-fi module ESP-32, Flame detection sensor, Smoke detection sensor (MQ-5), Flammable gas detection sensor and one GPS module are used. The sensors detects the hazard and alerts the local emergency rescue organizations like fire departments and police by sending the hazard location to the cloud-service through which all are connected. The overall network utilizes a light weighted data oriented publish-subscribe message protocol MQTT services for fast and reliable communication. Thus, an intelligent integrated system is designed with the help of IoT.**

Keywords—Internet of Things (IoT); Aurduino IDE; GPS

I. INTRODUCTION

The proposed system is capable of detecting smoke, different flammable gases and fire. This system is capable of providing hazard location coordinates to the nearby fire department. This fire hazard sensing system with systematic IoT framework emphasises an application innovation to the public safety and livelihood service sector [12], [13].

The overall billing of the proposed system is given in Table I.

TABLE I. BILLING OF THE OVERALL SYSTEM

Component	Quantity	Cost
ESP32 microcontroller	1	$8.55
MQ-2 sensor	1	$6.90
MQ-5 sensor	1	$7.90
Flame sensor	1	$4.19
GPS Module	1	$6.19

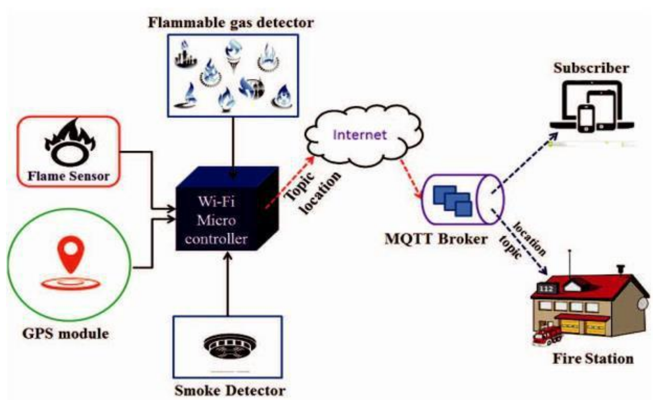

Fig. 1. Block diagram.

The fire hazard sensing system with IoT standardized design methods is shown in Fig. 1. The smoke detection sensor MQ-2 is used to detect the smoke, the Flame detection sensor is used to sense the flame, the flammable gas sensor MQ-5 is used to detect the gases like LPG/LNG and the GPS module is to obtain device location. These sensors along with Wi-Fi micro-controller are connected to a MQTT broker via Internet through which it communicates hazard status to the nearest fire-fighting organizations [14].

1) Internet of Things: The Internet of Things (IoT) is an umbrella of smart electronic devices like sensors and intelligent software applications to build an effective data exchange system.

In IoT the devices can communicate with each other and independently configure themselves in a network of multiple Internet connected devices. To unleash smart cities development agenda, many existing systems with the specific application domain serve a greater good in urban areas adopting this modern IoT technology [3]. After adopting this emerging technology, machine to machine communication transforms the existing human-h111uman or human-machine forms of communication [6]. IoT possess high resource sharing capabilities, high degree of intelligence, high scalability and other main characteristics. Internet of Things in the fire-fighting safety management field has more importance [2] in providing secured lifestyle in smart cities. This work gives the idea that designing an emergency response system for taking precautionary measures and rescue operations for fire hazards.

2) Smart City Vision in INDIA: The evolution from the emerging technologies has lead Government of India to launch Smart city Mission on 25th June 2015 to improve the quality of life the citizens with smart solutions. These smart solutions are to improve the services for livability of the entire city. Under the smart cities development plan around 60 cities are chosen and US $21756.717 million is the total investment to implement smart solutions. In the whole investment US $15786.554 million is for revamping area based projects, remaining US $5970.163 million for smart city initiative investments [4]. The key importance has given to some of the core infrastructure elements like efficient public transport and urban mobility, digitalization and robust IT connectivity, affordable housing, sustainable environment and same importance has been given to safety and security of citizens [9]. In implementing the smart solutions and building life safety in urban landscape IoT has its own importance. IoT incorporates transparent, seamless heterogeneous end systems. In regarding fire safety and management, to safeguard the city's assets like local departments information systems, transportation systems, schools, libraries, hospitals, power plants and other community services Internet of Things (IoT) provides proper solutions in a secure fashion. The real time monitoring systems with IoT design structure with sensors integrated collects the leveraged data from the devices. The data from the devices processed and analyzed to take necessary precautionary actions [11].

The rest of the paper is organized as follows: Section II deals about experimental setup and working; Section III deals about required hardware aspects; Section IV deals about required software aspects; Section V deals about experimental results followed by Section VI as Conclusion.

II. Experimental Set Up and Working

The circuit connections for the proposed system are shown in Fig. 2. The Wi-Fi micro-controller board (ESP-32) is powered up by using USB cable. Different sensors for different measurements are used and interfaced to the micro-controller board using connecting wires.

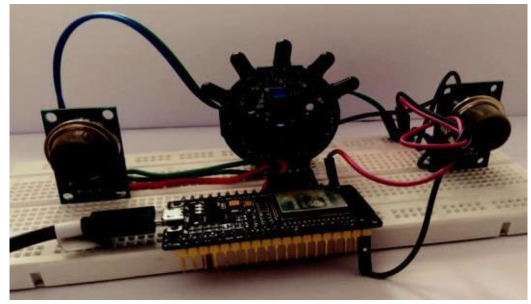

Fig. 2. The overall circuit connections of the System.

Flame sensor have 5 output pins which are connected to analog read general purpose I/O interface pins (GPIO pins) 36, 39, 34, 35 and 32 respectively. The MQ-2 gas sensor, MQ-5 gas sensor are connected to GPIO 25, GPIO 26 pins of the board respectively. And GPS module has both transmitter and receiver pins which are connected to GPIO17, GPIO18 pins of ESP-32 board respectively. After that, the logic is structured as required to operate the whole system as desired. For the desired system programming part is done in Arduino IDE. In the part of initialization pin configurations for respective connections are necessary.

III. Hardware Aspects

A. ESP32

ESP32 is the most advanced Espressif Wi-Fimicro-controller board. It is integrated with built in antenna switches, power amplifier and RF balun. Its compact design includes Flash memory and it has ESP32SoC and PCB antenna for better RF performance. ESP32 is well known for its hybrid functionality which consists of Bluetooth and Wi-Fi is shown in Fig. 3. It supports WPA/WPA and WEP for security aspects. For industrial environments it can give more reliability because it can adopt to environmental changes.

1) Its operating temperature range is -40 $^{\circ}C$ to +120 $^{\circ}C$. It can be interfaced with other devices using I2C/UART or SPI/SIDO interfaces. It has some built in sensors like Hall sensor, Ultra low noise analog amplifier and touch interface. As compared to other Espressif models its performance is better. It's receiver sensitivity up to -98dBm and transmits power range up to 19.20dBm. ESP32 is mainly designed for Low power applications like IoT based electronic industrial appliances [1].

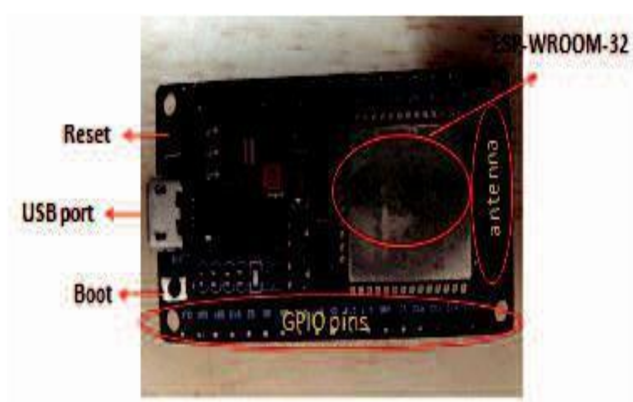

Fig. 3. ESP32.

TABLE II. ESP32 FEATURES

Specifications	Features
Micro-controller CPU	Xtensa Dual-core 32-bitLX6 600 DMIPS
Wi-Fi 802.11 b/g/n	WiFi MAC, WiFi base-band
Frequency	2.4Ghz
Network Protocols	IPv6,IPv4,TCP/UDP, HTTP/FTP,iWLAN,MACProtocal
GPIOs	36
ADC	12-bit
ROM memory	448 KB
Instruction RAM	520 KB
Operating current	80mA
Operating voltage	3.3v

TABLE III. DIFFERENT TYPES OF WI-FI MICRO-CONTROLLER BOARDS

Board type	Special features	Cost
ESP32 NANO IOT development board	4MB Flash, 3.3V 0.5A Regulator , Xtensa Dual-Core 32-bit LX6 microprocessors, 32 gpio pins, Hall sensor, 10x capacitive touch interface, SD card interface sup- port	$8.36
WEMOS ESP32	32 gpio pins, USB to UART Chip CP2102, 16mb flash mem- ory, One Tensilica LX6 micro- controller	$9.8
NoduinoQuan- tum	SPI Flash 16MB, 16 GPIO pins,5V-12V Power supply,FreeRTOS	$25.90
Fipy	8mb flash memory, 8x12 bit ADCs, Tensilica LX6 micro- controller with dual processor, 22 GPIO pins, U.FL LoRa/Sigfox antenna connector, WiFi, BLE, cellular LTE-CAT M1/NB1, LoRa, and Sigfox Micropython enabled	$55.90

Table II is taken with reference to the documentation [1] the other ESP-32 On board wi-Fi micro-controller boards available along with their own specifications are listed in Table III.

2) Flame sensor: The flame sensor consists of emitter, detector with an associative circuitry. The emitter consists of an Infrared Light emitting Diode and the detector consists of an Infrared Photo diode which senses the Infrared light which is having same wavelength as that of emitted wave wavelength by IR LED. The basic principle that involved in working of the sensor is photon energy strikes out the electrons so that circuit resistance will change accordingly. Whenever Photo diode senses the IR light, the Resistance and corresponding Output voltage will be changed in proportion to the received IR light magnitude. Because of this flame detection sensor can often responds very quickly and give accurate measurement. This sensor is designed such that it ignores constant background IR radiation because it present in all environments. Instead it is designed to sense sudden changes in the IR radiation. So that it avoids false detection.

Fig. 4. Flame sensor.

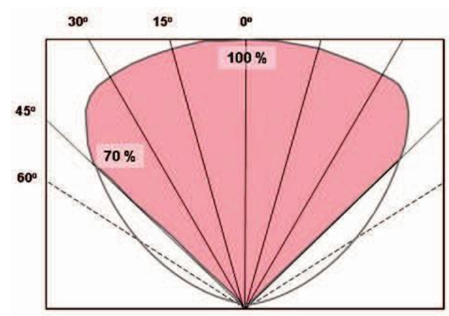

Fig. 5. View of the flame sensor.

The flame sensor needs to be aligned precisely in a Particular position to take care that it should not sense potential background radiation sources is shown in Fig. 4 and 5. The flame sensor detects flames in 3-D view and this cone of vision is not necessarily round. For the cone of vision vertical and the horizontal angles are often different. This sensor has advantage for projection thatit has a high sensitivity on edges of its angle of vision. Flame sensor detection range is depends on mounting.

Location, so when making projection it is important to know what it sees. The flame detector is mounted in a height as twice the height of highest object in the view. While projecting the sensor it is preferred that it should be accessible to maintenance and repairs.

By mounting a second flame sensor in the opposite of the first sensor the shadow effect can be reduced. In general several flame sensors can be mounted such that sensors look each other but not to the walls so that blind spots can be avoided as shown in Fig. 6 [19].

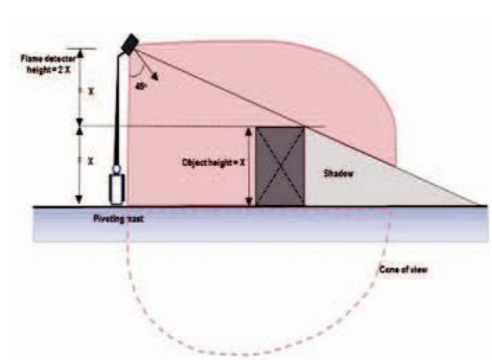

Fig. 6. Alignment of the flame sensor.

3) MQ-Gas sensors: In designing of these two sensors, SnO2 is used as gas sensing layer, Au, Pt are used as electrodes, Ni-Cr alloy is used as heater coil, SUS36 100-mesh (Stainless steel gauze) is used as anti-explosion network and Bakelite is used as resin base is shown in Table IV. In the clean air, the sensitivity material SnO2 of MQ-gas sensor initially has lower conductivity. If the sensor detects the target gas, the sensing material conductivity raises along with the concentration of the gas is shown in Fig. 7 and 8. The variation in conductivity in turn converted into variation in voltage over load resistance. The resistance of sensor can be measured from the below given formula:

Resistance of sensor Rs:

$$R_S = (V_C / V_{RL} - 1) R_L \quad (1)$$

where, RL is adjustable.

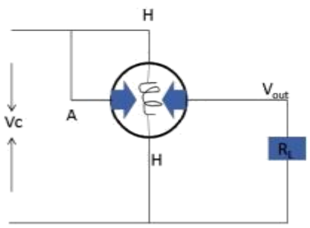

Fig. 7. Internal circuitry of MQ-gas sensor.

Fig. 8. MQ-gas sensors.

TABLE IV. MQ-GAS SENSORS FEATURES

S.NO	Specifications	MQ-5	MQ-2
1	Sensing resistance	10KΩ-60KΩ	2KΩ-20KΩ
2	Range	200-1000 ppm	300-1000 ppm
3	Gases to be de- tected	LNG, LPG Nat- ural gas, propane iso- butane	Smoke
4	Applications	portable gas de- tector, industrial combustible gas detector, Domes- tic gas leakage detector	Smoke detectors, fire alarms
5	Temp condition Humidity condition	$18^{\circ}C$ to $20^{\circ}C$ 60% to 70%	$18^{\circ}C$ to $20^{\circ}C$ 60% to 70%
6	Power consump tion-	$\leq 800mW$	$\leq 900mW$

4) GPS Module: GPS receivers uses constellation of ground stations and satellites to track position on the earth. At any time above 12,000 miles over the object location there are 12 satellites orbiting and transmitting information back to the earth RF range 1.1GHz. GPS receiver uses that information and math to provide its orbital position [17]. It uses NMEA data format to display in sentences and sent out using serial Tx pin. Satellite position, weather, signal to noise ratio and obstructions such as mountains and buildings are primary variables that effects GPS accuracy is shown in Fig. 9. A GPS receiver must be able to get a lock on 4 satellites to be able to solve for a position.

Features:

1) 66 acquisition/22 tracking-channel receiver
2) WAAS/GAGAN/MSAS/EGNOS support
3) NMEA protocols (speed: 9600bps)
4) Ultra high sensitivity: -165dBm
5) Temperature range: -40 C to 85 C
6) RoHS compliant (Lead-free)
7) Form factor 20.5mm x12.8mm x 7.8mm
8) Embedded patch antenna 12*12*4 mm
9) One serial port

Applications:

1) Location Based Service
2) Portable Navigation Device
3) GPS mouse and Bluetooth GPS receiver
4) Vehicle navigation system
5) Timing application

Fig. 9. GPS Module.

IV. Software Aspects

A. *Aurduino IDE*

Arduino IDE software is used to write programs, and programs can be uploaded directly to the board. It is available for many operating systems like Windows, Linux, Mac OS X, Portable IDE (Linux & Windows). It is an open source platform for electronics design, and very easy to use for both hardware and software. Arduino ide comes with few advantages like fast prototyping and also helps the students who don't have any prior knowledge in electronics and software programming. It provides flexible, simple and clear programming environment for beginners [5].

1) Adafruit.io: Adafruit IO is a cloud-service that makes sensed data useful. It is well known for ease of use, and allows simple data connections with little programming. The client libraries that wrap MQTT APIs and available to receive and send data with Adafruit IO. It can be built on Node.js and Ruby on Rails. Adafruit MQTT Client Library, PubSubClient MQTT Library are very popular MQTT client libraries used for Arduino IDE to access Adafruit IO [15]. The main Idea that data can be sent or receive by defining feed. The datacan be published or subscribed to the feed. The MQTT client is connected to Adafruit Io with port number 1883, Adafruit account username and Adafruit IO key. The important features of MQTT are the ability to specify a QoS and impose a rate limit to prevent excessive load.

B. *MQTT*

Message Queue Telemetry Transport (MQTT) is extremely light weight, simple and publish/subscribe messag-ing protocol is shown in Fig. 11. This is specifically designed for low-bandwidth, high latency networks which are unreliable and constrained devices. It satisfies the design principles like minimum net-work bandwidth and meets the device resource requirements and allows simple way of telemetry transport. MQTT assures fast delivery and ensures reliability is shown in Fig. 10. These principles makes this protocol ideal for the emerging technologies like Internet of Things and M2M technologies with multiple connected devices where bandwidth and battery power are concerned [18]. A paradigm shift steering away from request-response protocols to the leading publish-subscribe protocols because it is needed for easy implementation of human web and communication among machines at a large scale [7], [8].

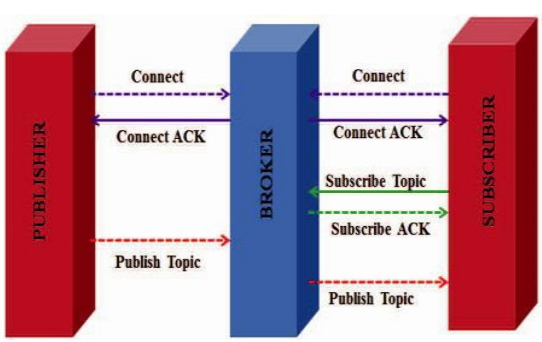

Fig. 10. MQTT publisher-broker-subscriber communication.

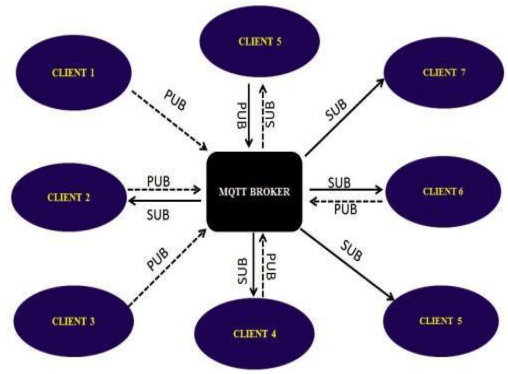

Fig. 11. Architecture for MQTT connection.

MQTT is standardized by OASIS. MQTT utilizes many features of the TCP transport. It requires minimal working TCP stack protocol overhead where small code foot print is used which is now available for even the smallest micro-controllers. MQTT fallows the brokered publish/subscribe pattern which decouples the clients. The publisher (client1) which sends particular information broker and the subscriber (client2) which receives that information from the broker doesn't know each other [16]. The broker does the decoupling, by filtering all incoming messages from publishers and it distributes them to the correct subscribers. Decoupling can be done in three ways like space decoupling in which publisher and subscriber dont know each other. In Time decoupling, publisher and subscriber need not be connected at the same interval. In synchronization decoupling, both are not halted during receiving and publishing [10]. In comparison with the other networking protocols like HTTP/S, MQTT is best suit for Internet of Things applications. The main differences and important features of MQTT over HTTP/S are listed in Table V.

TABLE V. DIFFERENCES BETWEEN MQTT AND HTTP/S

S. No	Feature	MQTT	HTTP/S
1	Architecture	Publish- Subscribe architecture	Request- Response Architecture
2	Design Methodology	Data oriented	Document Oriented
3	Data security	secure	Not secured
4	Upper layer protocol	TCP	UDP
5	Message Size	Small with 2Byte Header	Large ASCII for- mat
6	Data Distribution	One to Many	One to One

V. Experimental Results

The overall circuited system with different fire hazard detection sensors and Wi-Fi micro-controller is shown in Fig. 2 and results given in snapshots. After connecting each and every device in the desired manner and making sure that each and every component is connected in accordance with the other components. An external power supply is given to ESP32 board with USB for current to flow. The sensor detects the hazard if any smoke or any flammable gas or any flame in the surroundings. Here the GPS module gives the hazard location in Decimal Degree format. The sensed data and the location co-ordinates are published on to the Arduino.Io cloud service. The dashboard shown in Fig. 12 indicates NO hazard status. The dashboard shown in Fig. 13 is when hazard detected. The Location obtained by the Decimal Degree co-ordinates is shown in Fig. 14.

The system utilizes the light weighted protocol MQTT services to provide fast responses so as to provide emergency rescue operations immediately. The information along with hazard location in decimal degrees is published on to Adafruit.IO along with hazard status which is subscribed by social organizations.

Fig. 12. Dashboard status when NO hazard detected.

Fig. 13. Dashboard status when hazard detected.

Fig. 14. Location with the obtained DD co-ordinates.

VI. Conclusion

In this paper, it is mentioned that Internet of Things is an emerging technology which helps in providing smart solutions in Smart city development aspect. In providing a quality public safety and security services it is very important to adopt leveraged data driven emergency response systems with urban IoT design standards. A smart emergency response system for fire hazards is designed and implemented with required IoT standards which prioritize the immediate rescue operations by pushing relevant information to the public safety managements.

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