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Research Article

Experimental Evaluation of Lightning and Weather Alert Methods in Rural India using LoRa and IoT Technology with Nanosensors

Ome Nerella,[1] **Syed Musthak Ahmed,**[1] **and Praveen Balakrishnan**[2]

[1]*School of Engineering, SR University, Warangal, Telangana, India*
[2]*Faculty of Material Science and Engineering, Jimma Institute of Technology, Jimma University, Jimma, Ethiopia*

Correspondence should be addressed to Praveen Balakrishnan; praveen.balakrishnan@ju.edu.et

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Every year, ~2,000 people are killed by lightning in India, with rural areas accounting for 94% of all lightning deaths. In rural locations, a weather and lightning alert system is crucial for alerting and raising awareness about severe weather and lightning. Only a few states in India have expensive lightning alert systems that send out alerts via SMS and mobile apps. Due to a lack of information about weather alert apps, poor network facility, low literacy, and less usage of smartphones, existing alert mechanisms is not reaching all rural populations. As a result, there is a need to build a low-cost lightning alert system in rural areas that alerts and creates awareness in advance about lightning to rural residents using a variety of alerting methods, such as announcements, sirens, WhatsApp, voice call alerts, and email, in addition to existing alert methods to overcome limitations of existing systems. In order to achieve this, we have developed an IoT- and long range (LoRa)-based weather stations, gateways, and announcement systems using ESP32, nanosensors (DHT11, BMP180, rain sensor, and LDR), lightning detector (AS3935), lightning emulator, Arduino Nano, SD card module, and speakers. This prototype is tested in real time by creating lightning radiation using an emulator shield and by monitoring environmental parameters. It sends an alert to authorized persons/village government officials/ rural communities through WhatsApp, email, and voice call about abnormal weather situations with the help of cloud platforms. It also alerts and creates safety awareness to rural people in advance about lightning/critical weather condition through announcement system using loudspeakers. In the future, the proposed system will be trained using artificial intelligence to predict the lightning and other hazardous weather situations in advance and alert rural residents about critical weather conditions in early.

1. Introduction

An occurrence in nature, lightning is both a stunning and hazardous phenomenon. Along with the release of large amounts of energy in the form of heat and thunder, it entails an electrical discharge in the atmosphere. This endangers living things as well as electronic, electrical, and communication infrastructure. Over the past three centuries, researchers have studied lightning protection systems in an effort to lessen the damage. For field laborers, however, protection systems fall short. Lightning is a random phenomenon that happens in nature, making it challenging to anticipate. This requires the establishment of a lightning alert system using monitoring of atmospheric variables [1]. Another area that needs more research is lightning-related economic damage, which costs billions of rupees each year to repair in the public, industrial, and agricultural sectors. To deal with the country's current worrisome lightning situation, the present funding allotment and mitigating efforts in India must be ramped up with location preventive actions including technological solutions and awareness campaigns [2]. In India, lightning claims the lives of about 2,000 people each year in addition to causing extensive property damage. According to the National Crime Records Bureau's, most recent report on unintentional deaths and suicides in India, lightning caused the majority (38%) of deaths due to natural causes in 2020 [3], which is shown in Figure 1.

According to research by the Lightning Resilient India Campaign, lightning might have been the cause of up to 1,697 fatalities in the years 2020–2021 [4]. Figure 2 shows the statistical representation of lightning deaths in India during 2010–2020 (NCRB Report & Annual Lightning Reports).

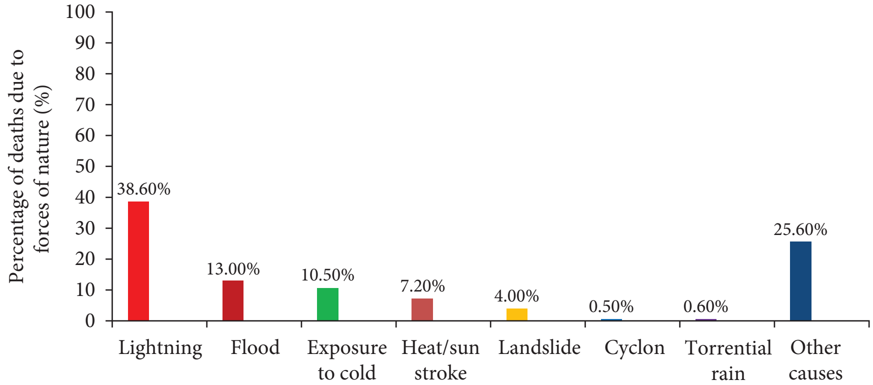

Figure 1: Deaths due to natural calamities.

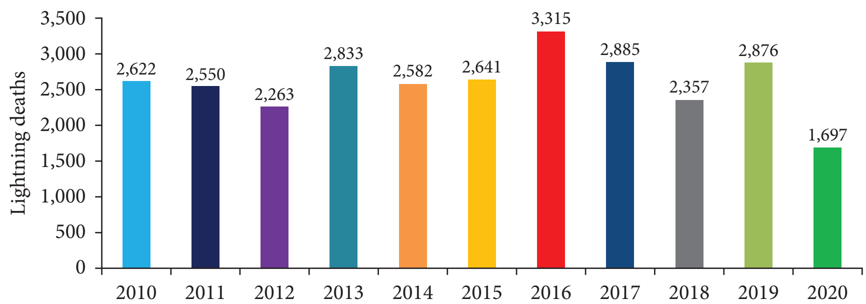

Figure 2: Lightning deaths in India during 2010–2020.

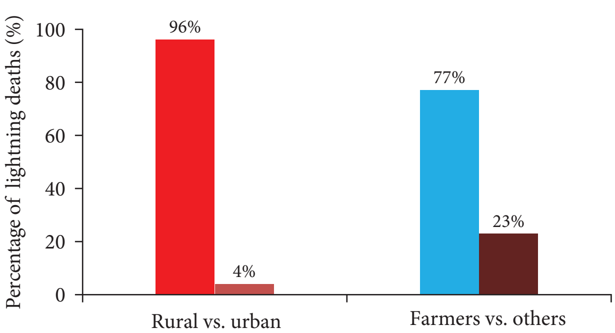

Figure 3: Percentage of lightning deaths in various sectors.

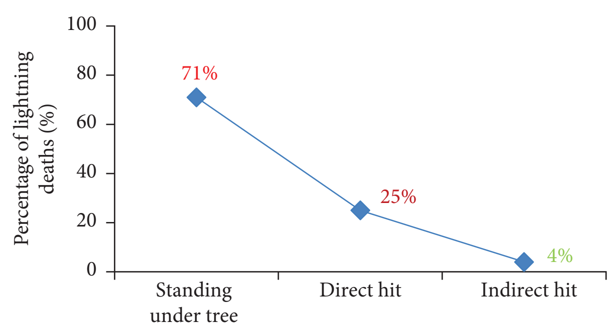

Figure 4: Lightning deaths due to primary causes.

According to Vaisala [5], Annual Lightning Report-In India, lightning poses a serious risk to both human life and property. The Himalayan Hills to the north and the Indian Ocean surrounding it in the tropics give ideal geographical circumstances for thunderstorm formation. Thunderstorm activity is heightened by the summer monsoon. The most at-risk areas of the nation are highlighted by high-quality information derived from GLD360 lightning data, which is being used to increase awareness of lightning, increasing awareness of lightning to protect people and property. IITM-Pune and MoES created the Damini Lightning applications in 2020. The software keeps track of any lightning activity that occurs specifically in India and notifies the user through GPS whenever lightning occurs within a 20 or 40 km radius of them. According to India, Annual Lightning Report 2020–2021, rural populations and farmers are more affected by lightning compared to urban and others, which are statistically shown in Figure 3.

The lightning annual report also says that the main causes of lightning deaths are due to standing under tree, direct hit, and indirect hit. The percentage of lightning deaths due to primary causes is shown in Figure 4. Tribal people that live in close proximity to nature are more susceptible to lightning strikes since they occur more frequently in open spaces, rainforests, and bodies of water. Their homes have thatched or katcha roofs, making them vulnerable to lightning strikes.

People are still impacted by the lightning issue and have been powerless to solve it. Although many studies have been done to lessen the effects of lightning, the physics behind it is still not fully understood. Several countries have established lightning awareness cells and lightning research centers, which are engaged in research and awareness raising [6]. In India, only a few states like Andhra Pradesh, Assam, Bihar, Karnataka, Odisha, and West Bengal have expensive lightning alert systems. These states are MoU with Earth Network for weather and lightning data. Lightning losses are attributable to a lack of understanding or a communication gap that does not enable last-mile connectivity. According to the survey, tribal members and farmers involved in the field are most at risk of being struck by lightning in rural areas. The majority of recorded lightning-related deaths involved people who were standing beneath large trees. So, there is a need to develop a low-cost lightning/weather alert system in rural areas to alert and creates awareness in advance about lightning/thunder storm through multiple alerting methods. The suggested system will eventually be trained to spot lightning and dangerous weather conditions in advance using AI and to warn rural people of these conditions.

2. Literature Review

Anuragini and Prabhavathi [7] developed a lightning alert system using Raspberry pi, which alerts people about lightning and critical weather conditions through SMS and it can also act as server for providing real-time weather and lightning data. Gilbert et al. [8] built a lightning strike monitoring and recording system. They put two lightning sensors in the same position to test the prototype's operation and found that when lightning strikes are tiny, the device's accuracy is higher than when the distance is large. Kodali and Mandal [9] designed a system based on the Internet of Things concept that uses a NodeMCU and several sensors to monitor weather conditions and send out weather notifications via email, SMS, and Twitter. Murdyantoro et al. [10] created a prototype of a long range (LoRa)-based weather station using the LoRa shield, Gateway, numerous weather sensors, and the ThingSpeak platform. They discovered that sensor readings varied depending on the type and amount of accuracy of the sensor.

In order to implement the Internet of Nanoscale Things (IoNT), Zahir Ahmed et al. [11] presented a novel communication model in which physical objects are integrated with nanotechnology. Wide range of engineering operations can greatly benefit from embedded nanosensors [12]. The network features are effective in nanoscale sensing and communication capability via WSN. Due its dependable and frequent changing capabilities, Kumar et al. [13] recommended using Zno-based storage in nanosensing units.

The authors created a LoRa-based wind monitoring system employing an anemometer, BME280, LoRa modules, and a gateway. The average latency for delivering LoRa node data to the Firebase database in this prototype is 0.25 s [14]. Based on the Markov chain Monte Carlo approach, the authors have suggested an alarming system for lightning storm weather situations. It is set up at the Birla Institute of Technology, Mesra, which is located in the Indian city of Ranchi [15]. Leal et al. [16] described upgrading a low-cost Lightning Detection and Waveform Storage System utilizing two preamplifiers, a novel processing method, and configurable analog filters. The enhancement of the useful dynamic range and the capacity to identify lightning across many frequency bands are the two key enhancements made in this module.

The death rate from lightning is reportedly four times higher in South Africa than it is globally. Rural areas remain at risk and carry on without receiving any lightning warnings despite major advancements in lightning monitoring and detection on a national level. A community-based alert system was built by Mahomed et al. [17] to identify and communicate lightning risks and alerts in Swayimane, KwaZulu-Natal, South Africa. This system consists of an electrical field meter and a lightning flash sensor, and it sends out email and SMS notifications as well as loud and visible alarms locally to notify people of impending danger. Earth Networks contribute to national, state, and municipal efforts to minimize lightning deaths, injuries, and damage throughout India by deploying and operating national total lightning detection networks and supporting stakeholders with much-needed data and analytics. Geospatial, SMS, and IoT-based lightning alert systems are presently existing to alert people about lightning/critical weather conditions. These alert methods are not reaching the rural people due to lack of the literature and poor network facilities. Nerella and Ahmed [18] proposed a low cost an AIoT-based lightning alert system to alert rural people in advance about lightning based on weather prediction to reduce lightning disaster.

Intriguing answers to problems in embedded and IoT applications are provided by LoRa, a low-data-rate, long-range wireless technology. It used little electricity and allowed data to be obtained from various sensors at remote locations [19]. Nerella and Ahmed [20] developed a weather monitoring and lightning alert system based on LoRa and IoT technology. This system overcome the limitations of IoT-based lightning alert system by using LoRa communication. Weather sensors, lightning detector, ESP32, LoRa module, gateway, and ThingSpeak platform are the components to make the system is IoT enabled. Dharani et al. [21] developed a system with the goal of rescuing and defending fishermen from calamities and border crossing. This prototype is built using GPS tracker, lightning detector, GSM module, MCU, LEDs, and buzzers, it alerts the coast guard and fishermen about severe weather conditions and border crossing through SMS and sirens.

Forewarning the public about impending natural disasters and lowering the number of fatalities and property losses, real-time weather and lightning forecasting is essential. A lightning detection and alert system were developed by Kanchi et al. [22] that leverages cloud computing to notify users via mobile apps. This alarm system was developed using an open-source cloud platform, a lightning detector, and a microcontroller. They created a system that can gather information on storms and lightning strikes up to 40 km away from the deployment site. An IoT-based real-time climate tracking system was created by Sharma and Prakash [23]. It is composed of many meteorological sensors and NodeMCU and system act as an embedded web server that delivered webpages in response to user requests. Without relying on any software or websites, anyone may check the current weather from anywhere using a web server.

Table 1: Comparison between existing lightning alert systems and proposed lightning alert system.

Parameter	Existing systems	Proposed systems
Alert methods	SMS and mobile apps	Announcement, siren, WhatsApp, VOIP, email, SMS, and mobile apps
Technology used	Cellular mobile network and IoT	LoRa and IoT
Implementation	Difficulty	Simple
Network facility	Mandatory	Optional
Development cost	Expensive	Low cost
Alert coverage to	Less people	More people
Source of lightning data	Earth network data and radar/satellite	Realtime weather data with prediction

In order to design a preventive action to safeguard electricity equipment from serious damage, a lightning tracking system is used to monitor, gather, and assess lightning occurrences. For the electrical energy supply to be dependable and long-lasting, an efficient lightning detection system is necessary. Sidik et al. [24] provided an overview of the operation of the pertinent sensors, the numerous approaches to transmission of data, storing, and processing, in addition to the various approaches to lightning strike prediction. Two of nature's most potent events are thunderstorms and lightning. The ability of emergency personnel to pinpoint the precise site of a disaster is essential for them to perform better by offering thorough coverage of the affected area. The IoT devices have lightning detection capabilities and are synchronized with the other devices in the sensor network. They are all a component of a network that use the trilateration technique to find various events inside a massive data ecosystem [25].

The problems with erratic renewable energy and reliance on the utility grid are lessened by neighborhood-level energy exchanges among interoperable smart microgrid (ISMs). Finally, a description of the cutting-edge wireless technology known as LoRa is presented, and a contemporary architecture using LoRa to create an ISM communication network is suggested [26]. Wireless nanosensors have revolutionized traditional methods for addressing a wide range of issues, particularly in the fields of medical, smart environments, farming, and food standards [27]. The several kinds of heat nanosensors, their production processes, and their implementations in diverse industries are all described by Behera et al. [28]. Various nanomaterials and structure analysis were also studied [29, 30].

According to Ghosh et al. [31], lightning strikes are influenced by a variety of environmental parameters. In their work, they predicted the lightning strike depending on some of the most important parameters, such as air pressure, electric field intensity, and electric field grade. Sarala et al. [32] designed a system that sends SMS notifications and website alerts to users in advance in case lightning strikes. By taking into account, the climate data in addition to the thunder data offered by the previous app, they expanded their work beyond the Vajrapaat mobile application. Various materials, nanoparticles, and structural analysis were studied [33–36].

3. Existing Lightning/Weather Alert Systems

There are three fundamental techniques for predicting lightning and warning people: SMS, IoT, and geospatial-based systems. These expensive lightning warning systems are installed in a few states, and with the help of the Earth Network Data and State Disaster Management Authority and alerts are sent via SMS, mobile apps, and television channels. Rural residents are still hard to reach despite these efforts to warn them due to inadequate network infrastructure, illiteracy, and ignorance of lightning-related mobile apps. The proposed system is one more way to get around these constraints. A comparison between the proposed and existing alert systems is described in Table 1.

4. Proposed System Design

Here, various alerting methods are introduced to alert the rural people about the weather and lightning. They are announcement, siren, voice call, Bluetooth, WhatsApp, email, SMS, mobile Apps, etc. IoT- and LoRa-based weather and lightning alert system is shown in Figure 5. ESP32, various nanosensors, LoRa module, Lightning Detector-AS3935, speakers, gateway module, cloud platforms, smartphone, and client systems are the basic building blocks of lightning alert system. Basically, a nanosensor is very sensitive device which is shielded precisely within the detectors. In this work, various nanosensors are used to monitor the weather parameters.

4.1. IoT-Based Lightning/Weather Alert Ecosystem. IoT-based lightning/weather alert ecosystem in rural areas is shown in Figure 6. Weather stations, gateway, wireless-based announcement system, cloud platforms, mobile users, authorized persons, and rural people are in the part of this ecosystem. Here, gateway module receives data from various weather stations and processes the received data. If weather conditions are abnormal, it sends lightning alerts and lightning safety awareness information to government officials/rural communities/nobile users/rural people through various alert methods using various cloud platforms, IoT, and LoRa technology for reducing lightning disaster.

4.2. Design Description of Weather Station. ESP32- and LoRa-based weather station is shown in Figure 7. ESP32 acting as a main processing unit in weather station and

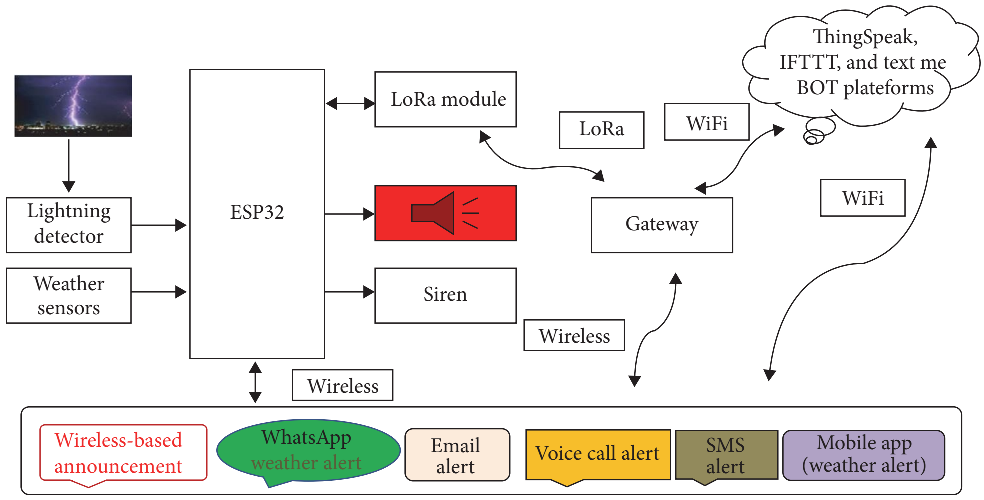

FIGURE 5: IoT- and LoRa-based weather and lightning alert system.

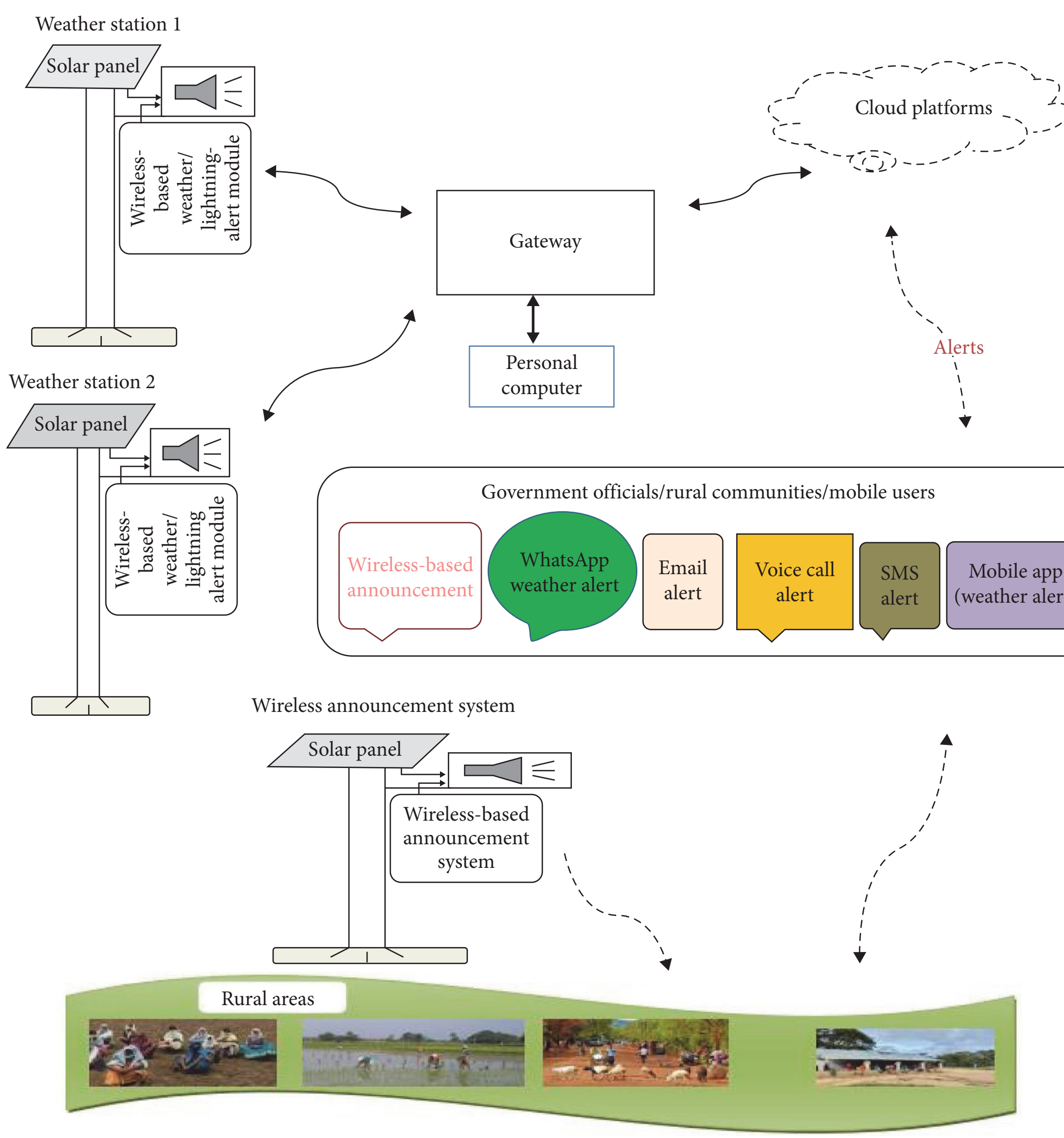

FIGURE 6: IoT-based lightning/weather alert ecosystem in rural areas.

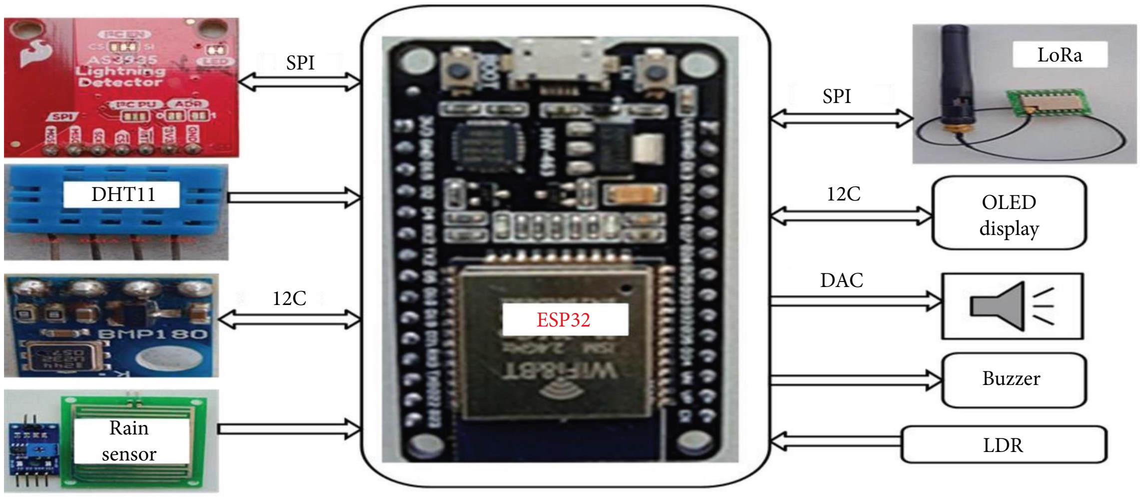

FIGURE 7: ESP32- and LoRa-based weather station.

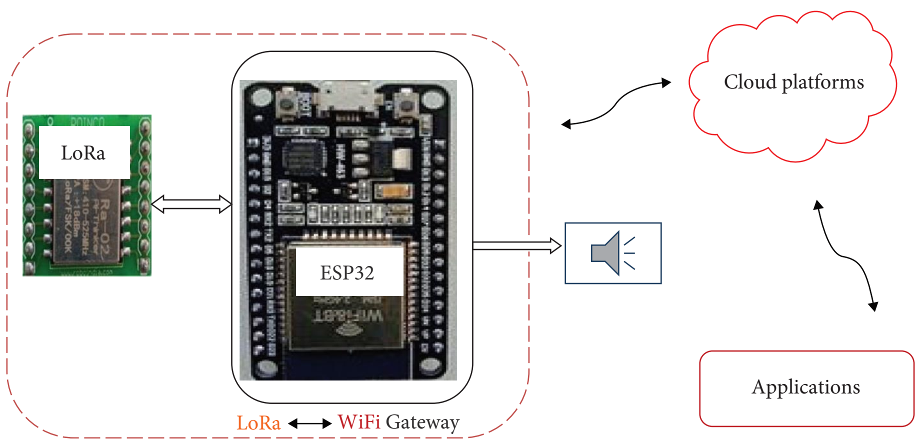

FIGURE 8: Gateway module.

gateway. Lightning detector, OLED display, LoRa module, and various nanosensors (DHT11, BMP180, rain sensor, and LDR) are the on-board peripherals in the weather station module.

4.3. Design Description of Gateway. LoRa module with ESP32 acts as a gateway. The picture of the gateway module is shown in Figure 8. Gateway module receives data packet from various weather stations and decode the packet for individual sensor readings. Here, gateway module acts as interface between LoRa to WiFi and vice versa.

4.4. Design Description of Weather Announcement/Alert Module. Prototype of wireless-based weather announcement module is shown in Figure 9. Arduino nano, LoRa-based gateway module, SD card module, speakers, and buzzer are the building blocks of announcement module. The gateway module receives weather information from weather station and sends the real-time weather sensors data to the announcement module. Announcement module processes the received data frame, announce the live weather/lightning information with the help of the speakers and it also creates the awareness to rural people about lightning/critical weather conditions in advance.

4.5. Nanodevices and Materials Used. In this prototype, various weather sensors, lightning emulator, lightning detector, ESP32, LoRa modules, Arduino Nano and SD card module is used to monitor environmental parameters and to implement various lightning/weather alert methods.

DHT11: It is utilized to guage the local humidity and temperature.

BMP180: The atmospheric pressure is measured using BMP180.

LDR: It is used to measure the light intensity levels at the deployed area.

Rain detection sensor: It is used to measure amount of rainfall as well as to detect rain.

Lightning emulator: To provide a signal that imitates lightning strikes, a lightning emulator shield is used to implement various lightning-based applications, which is shown in Figure 10. It is possible to set up the emulator

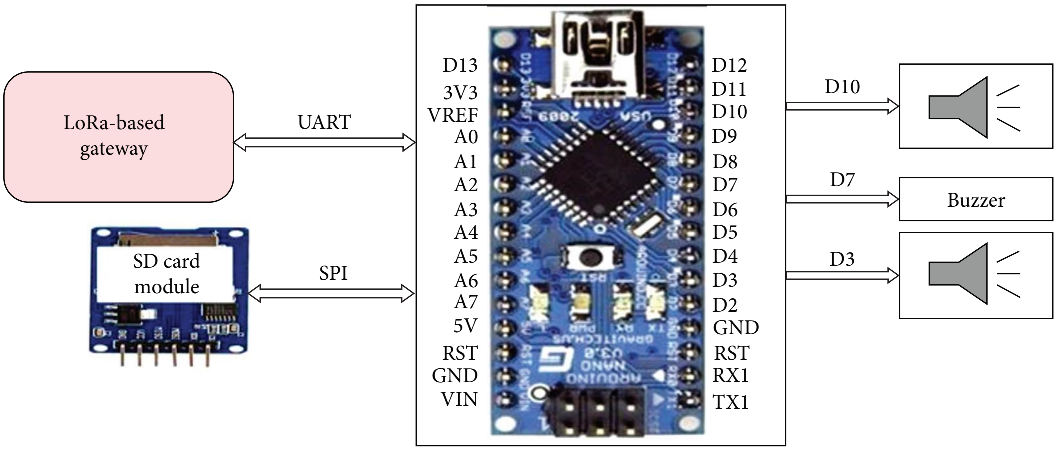

Figure 9: Weather announcement module.

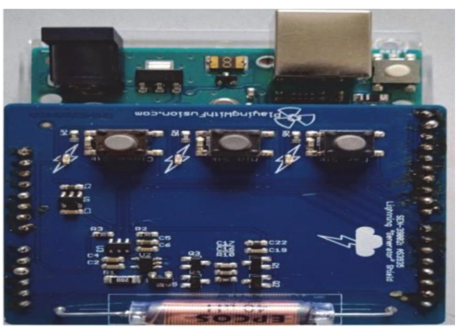

Figure 10: Lightning emulator shield.

to imitate near, mid-range, as well as far hits. Between the lightning simulator and lightning detector antenna, the maximum distance can be up to 14 cm practically. Lightning emulator can communicate with MCU using SPI/I2C protocol.

AS3935 lightning detector: The lightning detector module is shown in Figure 11. It detects radio frequency signal that generated by lightning. Based on SPI/I2C protocol, detector can communicate with MCU to analyze the lightning signal. The AS3935 is a completely integrated, programmable lightning detection chip that measures the distance to the storm's center as well as the existence and proximity of potentially dangerous lightning activity in the area. Within a 40 km radius, a lightning sensor detects cloud-to-ground and intra-cloud activity and warns the user.

ESP32: ESP32 is an IoT development board with built in WiFi and Bluetooth.

LoRa module: It is used to enable long range wireless communication.

Arduino Nano: Arduino Nano is a microcontroller-based board having an on-chip ADC functionality.

5. Methodology

(i) Work on various modules like lightning detector, weather sensors (DHT sensor, pressure sensor, anemometer sensor, rain sensors, etc.), LoRa module, GPS module, ESP32, and lightning emulator.

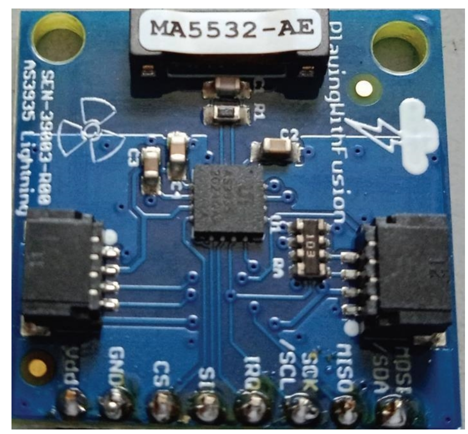

Figure 11: Lightning detector.

(ii) Implementation of IoT-based weather monitoring and lightning alert system in rural areas using LoRa technology.

(iii) Design and development of weather stations, gateways, and announcement systems to alert the rural people through various alert methods.

(iv) Study of various existing machine learning algorithms on weather and lightning forecasting and look into implementation of proposed system.

5.1. Workflow. Implementation of lightning/weather alert system is a step-by-step process, which is explained below:

S-1: System starts and initializes the necessary modules for processing the sensor readings.

S-2: Lightning emulator is installed to generate lightning into the module.

S-3: ESP32 module processes the weather and lightning data, then it sends sensor data to gateway using LoRa.

S-4: If weather and lightning readings are abnormal, then weather stations create awareness and alert the rural

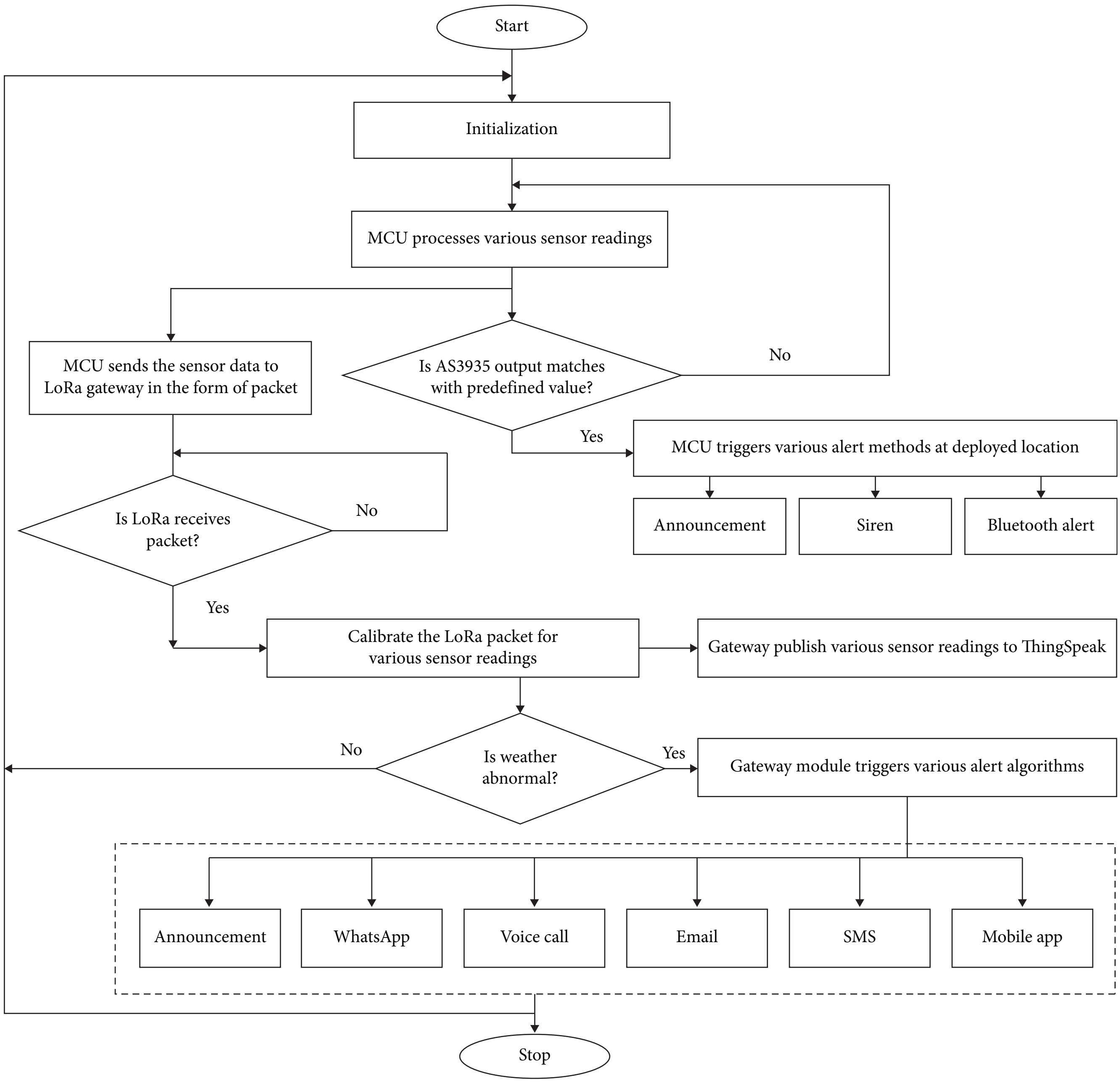

Figure 12: Flowchart of weather and lightning alert system.

people about lightning and critical weather conditions through announcements and sirens.

S-5: Gateway modules receive data packet from various weather stations and process the packet for individual sensor readings.

S-6: Gateway starts searching for available networks and connects to known network with help of SSID and password.

S-7: Once the gateway is connected to the Internet, then it sends sensor data to cloud platforms.

S-8: If weather/lightning readings are abnormal, then gateway module communicates with announcement system and cloud platforms to alert the rural people/village government officials/rural communities/WhatsApp users through announcement, siren, WhatsApp, email, voice call, SMS, and mobile apps.

S-9: Repeat from S-1.

5.2. Flow Graph Depicting the Complete Operation. Flowchart of implementation of lightning/weather alert methods in rural areas is shown in Figure 12. The operation of weather/lightning alert system is configured into three parts.

(a) Weather stations
(b) Gateways
(c) Weather announcement system

S-1: Include the LoRa, SPI, Sparkfun AS3935, DHT, BMP085 and Talkie libraries.
S-2: Initialization.
S-3: Read the DHT sensor & calibrate the Humidity and Temperature values by calling **dht.readTemperature()** and **dht. readHumidity().**
S-4: Read the Pressure sensor by calling **bmp.readPressure().**
S-5: Read the LDR sensor by calling **analogRead(34).**
S-6: Read the Rain sensor by calling **digitalRead(27).**
S-7: If lightning interrupt is generated, then read the **Interrupt register** of the lightning detector and store the result in variable **"I"**
If (I = = 0X01) Interrupt is due to **Noise.**
If (I = = 0X04) Interrupt is due to **Disturber.**
If (I = = 0X08) Interrupt is due to **Lightning** then estimate lightning distance by reading **REG0x07** register.
S-8: Frame the all the sensor readings in the form of packet like "**ST32H86P987R0LTL15E**" and **transfer** the packet to Gateways through LoRa.
S-9: Repeat from S-3.

Algorithm 1: LoRa-based weather station.

S-1: Include the LoRa and SPI libraries.
S-2: Initialize the Serial, SPI, and LoRa communications.
S-3: Check for LoRa packet is arriving from weather station or not. If a packet is available, then gateway receives the entire packet and stores in the array **"C"** and ESP32 process the array for individual sensor readings.
S-4: If sensor readings are abnormal then gateway sends this information to announcement module through serial pins.
S-5: Repeat from S-3.

Algorithm 2: LoRa-based gateway at announcement module.

Since the Arduino IDE platform has the capabilities to support large libraries, a sizable community, and simple to integrate the board packages in it, we chose it to construct the lightning/weather alert system. Here, Arduino programming is used to implement the functionality of weather stations, gateways, and announcement system. An algorithm for a weather station is explained in Algorithm 1 and implementation of gateway functionalities are described in Algorithm 2 and 3. Algorithm to implement announcement system functionality is explained in Algorithm 4.

5.3. Workflow for Reaching Alerts to Rural People. Here, gateway module acts as a interface between LoRa to Wi-Fi and vice versa. It communicates with various cloud platforms such as ThingSpeak, IFTTT, Webhooks, and Text me BoT to send weather and lightning alerts through voice call, email, WhatsApp, SMS, and mobile apps. Figure 13 depicts the workflow to reach weather/lightning alerts to people.

S-1: Include the LoRa, SPI, ThingSpeak, WiFi, and HTTP client libraries.
S-2: Initialization.
S-3: Connect gateway module to known network using network SSID and password.
S-4: Check for LoRa packet is arriving from weather station or not. If packet is available, then gateway receives the entire packet and stores in the array **"C."**
S-5: Gateway processes the array **"C"** for individual sensor readings.
S-6: If sensor readings are abnormal
- It communicates with cloud platforms (ThingSpeak, IFTTT, and Text me BoT) to send alert message through mobile app, email,VoIP, Whats App, etc.
- It communicates with announcement module to alert rural people through announcement.

S-7: Repeat from S-4.

Algorithm 3: Gateway system to alert rural people through various methods.

S-1: Include the software serial, SD card and audio-related libraries.
S-2: Initialize the Serial, SD card, software serial and audio communications.
S-3: Check whether data frame is available on digital pins 7 and 8.
S-4: If data frame is arriving from gateway and if frame first character is **"S"** then MCU receives entire string and store results in the array **"C"** otherwise nothing.
S-5: MCU calibrate data packet for individual sensor readings.
S-6: If sensor readings are abnormal, MCU alert the people through announcement using speakers.
S-7: If C [14] = = "L" then MCU calibrate estimated lightning strike distance and announcement module alerts and create safety awareness about lightning to rural people through speakers.
S-8: Repeat from S-4.

Algorithm 4: Weather announcement/alert module.

5.4. Gateway to Text me BoT Platform. Figure 14 depicts the gateway to Text me BoT platform. WhatsApp has become ingrained in our everyday routines. It could be amazing to receive any weather and lightning warning messages over WhatsApp right away.

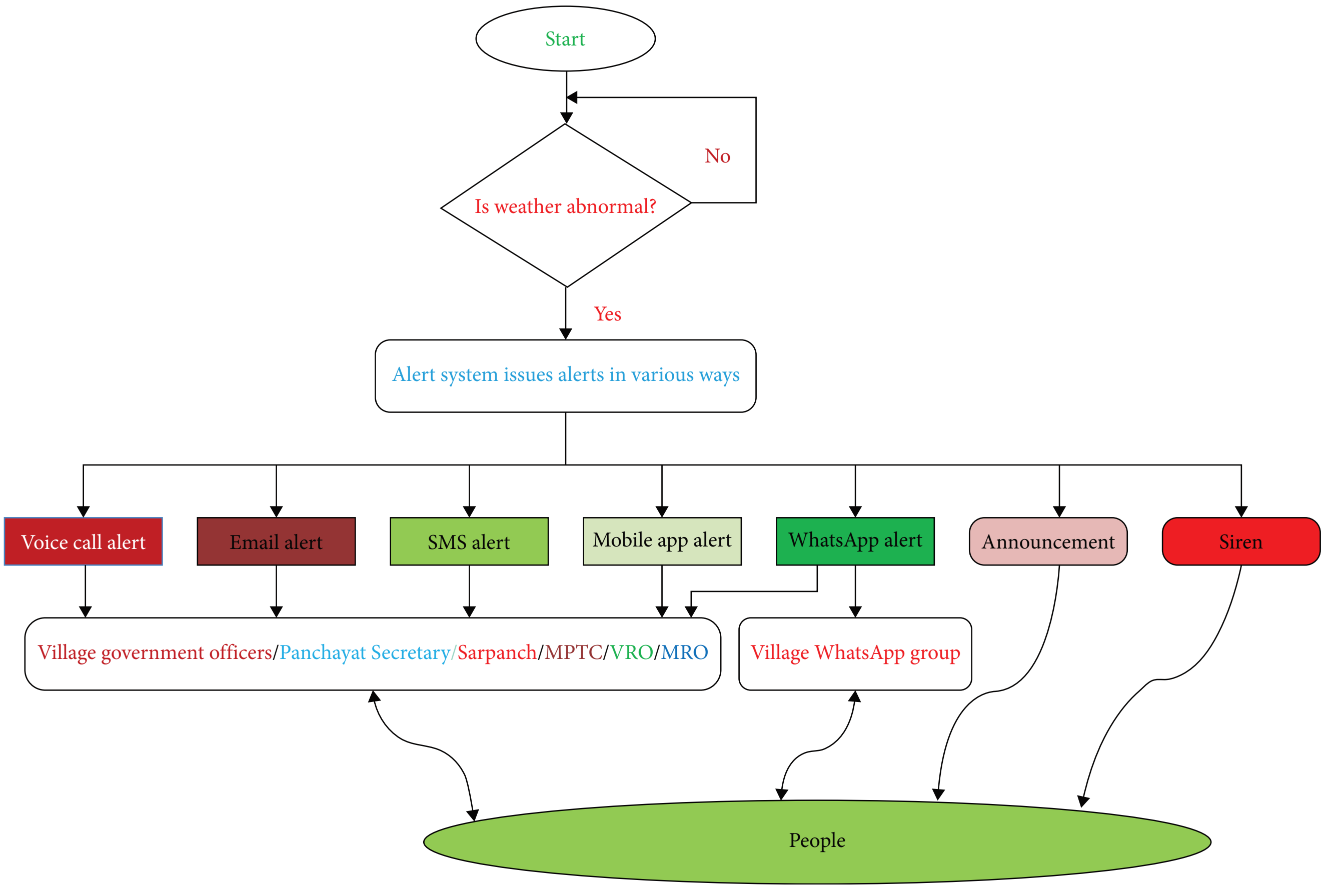

Figure 13: Workflow to reach alerts to people.

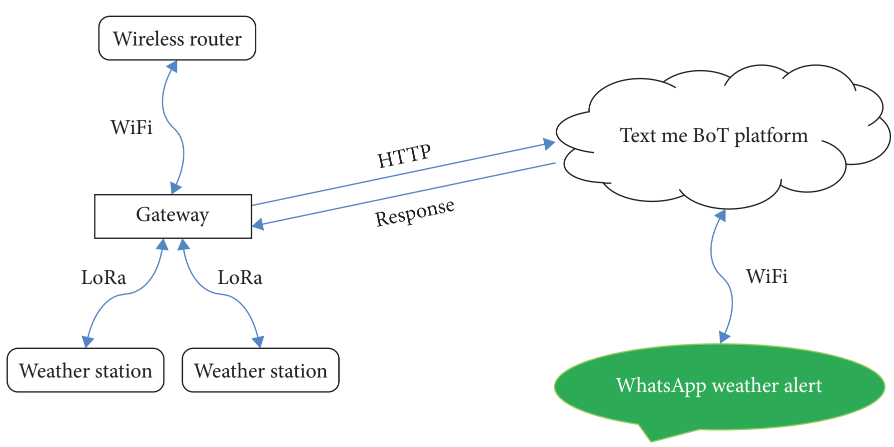

Figure 14: Gateway to text me BoT platform.

5.5. Gateway to IFTTT. Figure 15 shows the pictorial representation of gateway to IFTTT communication. Gateway module communicating with the IFTTT platform to alert the people about weather and lightning through email, SMS, and voice call with the help of HTTP and Webhooks service.

6. Results and Discussion

Prototype of complete setup of weather/lightning alert system is shown in Figure 16. Weather station, gateway, announcement system, and lightning emulator are incorporated in implementing various alert methods.

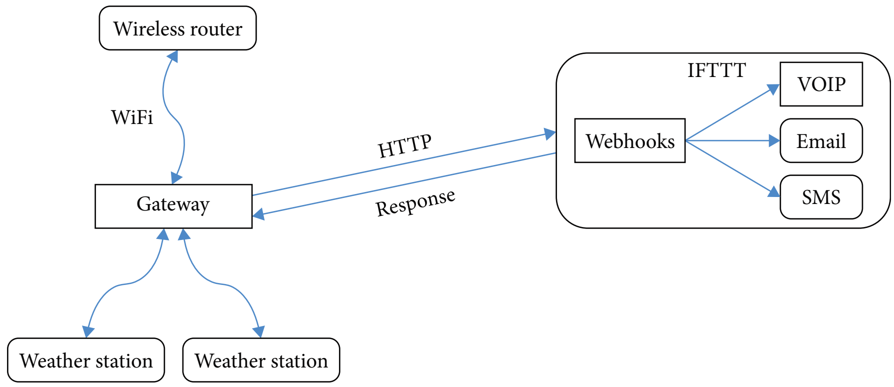

Figure 15: Block diagram of gateway to IFTTT platform.

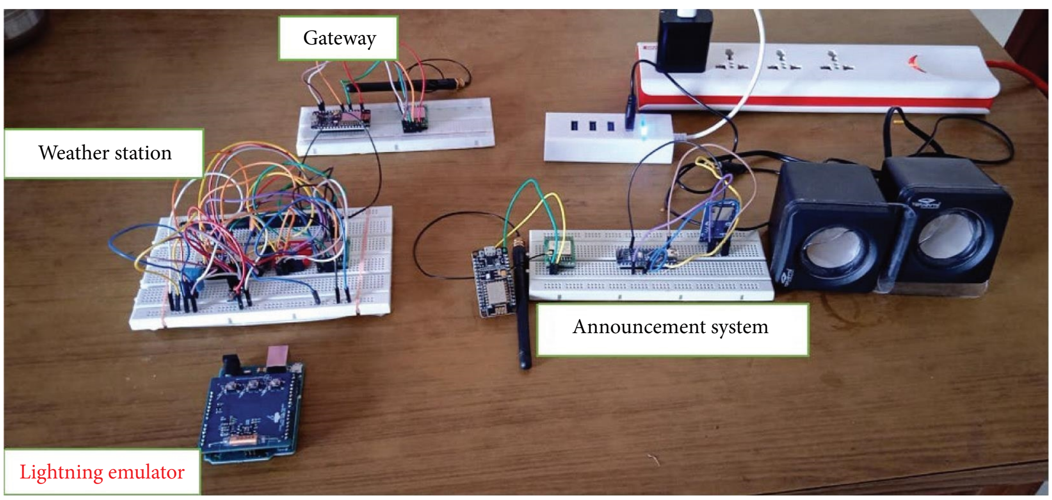

Figure 16: Complete setup of weather/lightning alert system.

The prototype of ESP32-based weather station is shown in Figure 17. Weather sensors, lightning detector, lightning emulator shield, and LoRa module are the basic building blocks in the weather station. It will monitor real-time weather parameters locally and sends the sensor readings to gateways in the form of packets using LoRa communication. Figure 18 shows the display of sensor readings recorded at the weather station.

6.1. Weather Station Output. Testing is carried out by creating an RF signal nearer to lightning detector using a lightning emulator shield. Depending on the lightning signal strength, the detector estimates the distance of a lightning strike, as shown in Figure 19. If weather conditions are abnormal, the weather station alerts the people through announcements and siren at the deployed location.

6.2. Weather Station Output during Lightning Creation. Figure 20 depicts the prototype of LoRa- and ESP32-based gateway. It receives LoRa packet from various weather stations and processes the received packet for individual sensor readings. The received packet and sensor readings at the gateway are displayed on serial monitor, as shown in Figure 21.

6.3. Gateway Output

6.3.1. Announcement Method. Prototype of wireless-based announcement module is shown in Figure 22. Announcement module receives the data frame from the gateway and it announces the live weather/lightning data and also plays the safety awareness about lightning/critical weather conditions on the speaker. Real-time weather and lightning data at the announcement system are shown in Figure 23.

6.4. Announcement System Output

6.4.1. Siren Method. This prototype of alert system issues siren during abnormal weather and lightning conditions.

6.4.2. Bluetooth-Based Alert Method. This method is the best choice to monitor the healthy status of the alert system (weather station and gateway) and to alert the mobile users

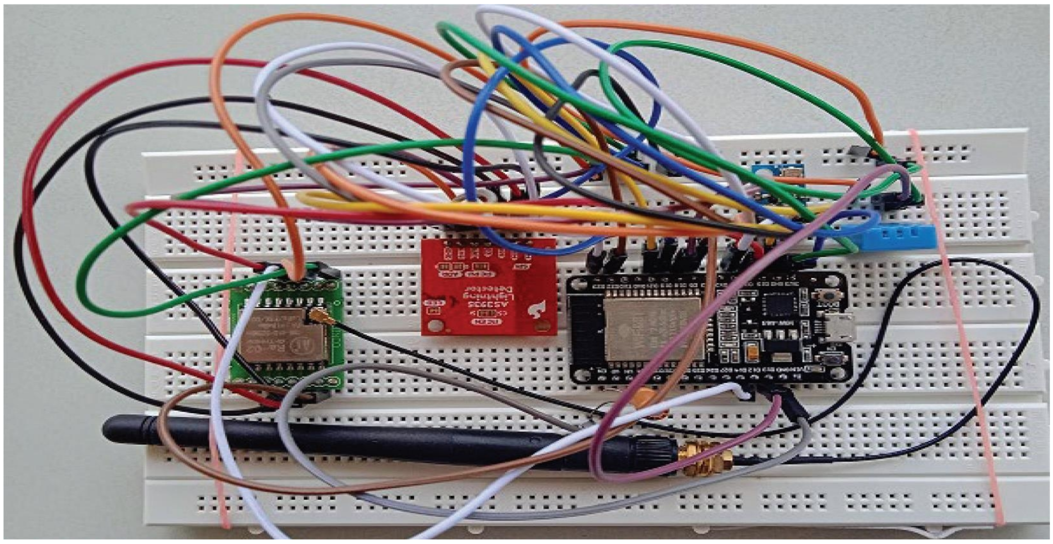

Figure 17: Prototype of ESP32-based weather station.

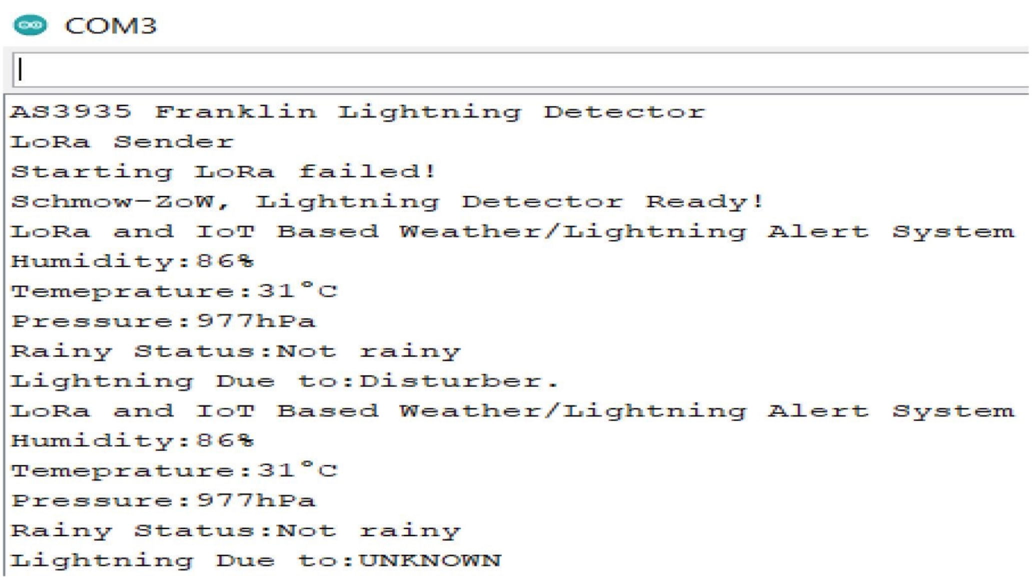

Figure 18: Sensor readings on PC at weather station.

about weather conditions if they are in nearer to deployed location. Figure 24 shows the real-time weather and lightning data on Bluetooth app.

6.4.3. WhatsApp Alert Method. Lightning alert system sends an alert message in addition to YouTube links for precaution during lightning/thunderstorm to village communities and Panchayat Secretary via WhatsApp with the help of the Text Me BoT platform. Figure 25 shows the weather and lightning readings on WhatsApp.

6.4.4. Voice Call Alert Method. Prototype of the lightning alert system makes a voice call to authorized government officials about weather and lightning using VOIP and IFTTT platform. IFTTT mobile app converts text message into audio output. Figure 26 depicts the weather and lightning alert text on VOIP applet.

6.4.5. Email Alert Method. Email is one of the official ways to send weather and lightning alert information to village government officials. Here, gateway module receives weather and lightning data from various weather stations. If weather conditions are abnormal, gateway sends an alert to the corresponding Village Panchayat Secretary through email using IFTTT platform. Email alert about the weather and lightning is shown in Figure 27. Then, Panchayat Secretary will alert and create awareness to the rural people about thunderstorm/lightning in various ways.

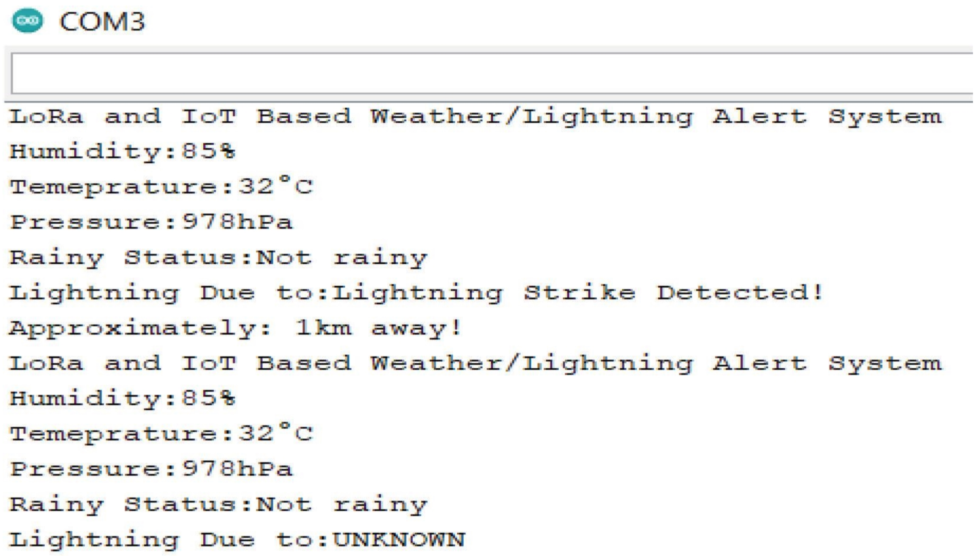

Figure 19: Estimated lightning strike distance on PC at weather station.

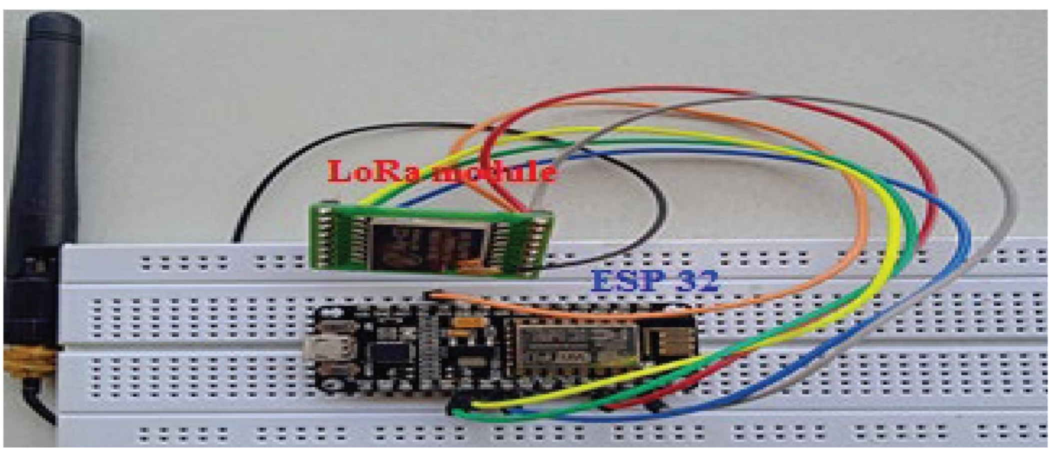

Figure 20: Prototype of LoRa- and ESP32-based gateway.

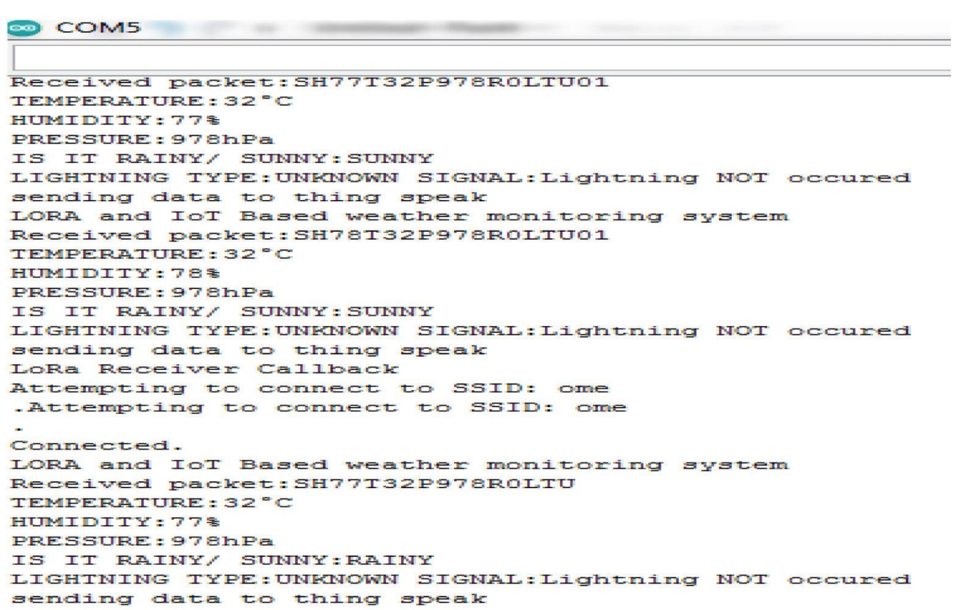

Figure 21: Real-time weather information on PC at the gateway.

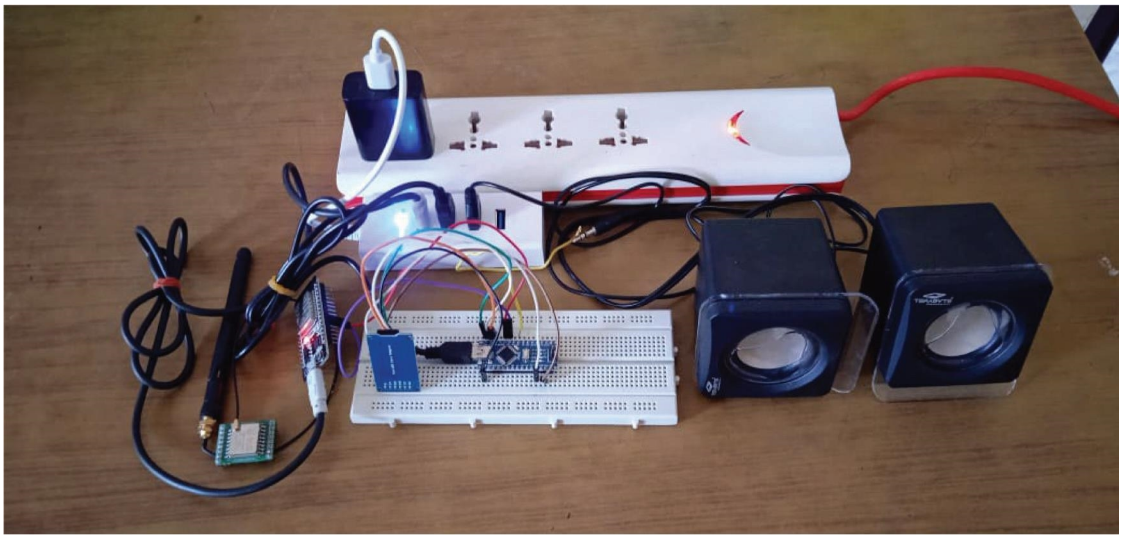

FIGURE 22: Prototype of wireless-based announcement system.

```
LoRa based Weather announcement and alert system
Data received from LoRa based Weather ststion is:T28H95P986R0LTL15
Sensor readings are
TEMPERATURE:28°C
HUMIDITY:95%
PRESSURE:986hPa
RAIN:0
RAIN ALERT
Playing Rain Alert Announcement
LIGHTNING TYPE:Lightning strike  occured
Lightning strike approximate  distance: 15KM
playing Lightning awarness announcement:
Data received from LoRa based Weather ststion is:T32H90P934R1LTNOO
Sensor readings are
TEMPERATURE:32°C
HUMIDITY:90%
PRESSURE:934hPa
RAIN:1
LIGHTNING TYPE:Noise
Data received from LoRa based Weather ststion is:T35H78P990R1LTDOO
Sensor readings are
TEMPERATURE:35°C
HUMIDITY:78%
PRESSURE:990hPa
RAIN:1
LIGHTNING TYPE:Distrubance
```

FIGURE 23: Real-time weather and lightning data at the announcement system.

6.4.6. SMS Alert Method. Prototype sends a trigger to webhooks service during critical weather situation. Based on received web request, IFTTT platform alerts the Village Government Officials (Village Panchayat Secretary, Sarpanch, MPTC, MRO, and others) about weather and lightning through SMS. Figures 28 and 29 show SMS alert text on IFTTT and mobile.

This prototype is tested successfully with an alert to the people about lightning and weather through various alert methods to reduce lightning disasters in addition to giving announcement on real-time weather using an announcement system at the deployed location. Table 2 describes the list of protocols, libraries, and technologies that are used in various alerting methods.

7. Conclusion and Future Scope

Existing lightning/weather alert methods are not reaching the end point of rural areas. Resulting in an increasing the lightning death cases in rural areas compared to urban. We have developed a prototype of lightning/weather alert system using IoT and LoRa technology to alert rural people through various alert methods. This prototype can monitor weather (temperature, humidity, pressure, rain intensity, light intensity, etc.) and lightning conditions locally at the deployed location and it transfers sensors data to gateways through LoRa communication. Gateway module process the LoRa packet, and push the real-time weather data to ThingSpeak platform for making system is IoT enabled. Here, Arduino

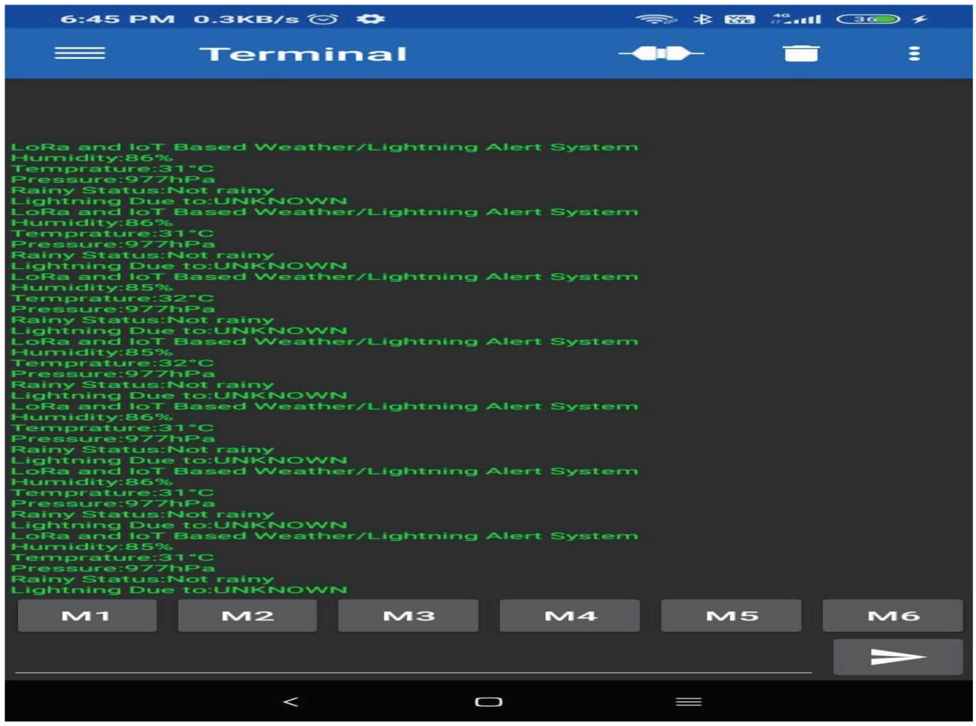

Figure 24: Weather and lightning data on Bluetooth app.

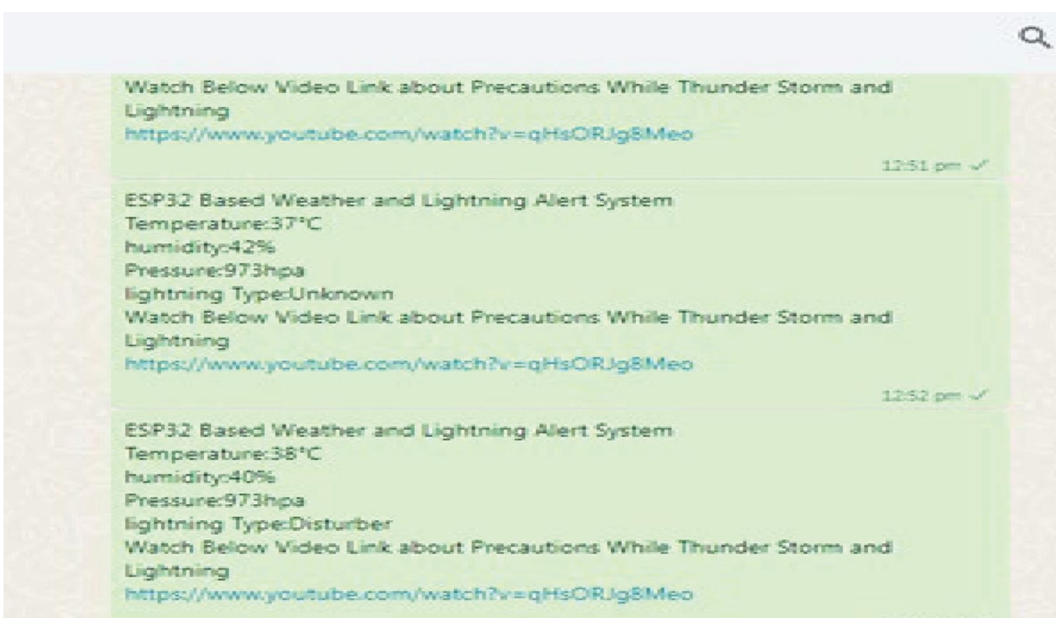

Figure 25: Weather alert message on WhatsApp.

programming is used to perform weather station, gateway, and announcement system functionalities. If weather/lightning conditions are abnormal, then gateway module communicates with announcement system, IFTTT platform, and Text me Bot platform to alert the Village Government Officials/rural communities/rural people through speakers, sirens, WhatsApp, voice call, email, SMS, etc. This prototype announces the real-time weather information in rural areas using speakers and it also creates the awareness to rural people in advance about lightning/thunderstorm through an announcement system using loudspeakers and SD card module.

By adding AI in to this prototype, the system is able to predict the lightning/weather conditions and alert the people in advance to reduce lightning/weather disaster.

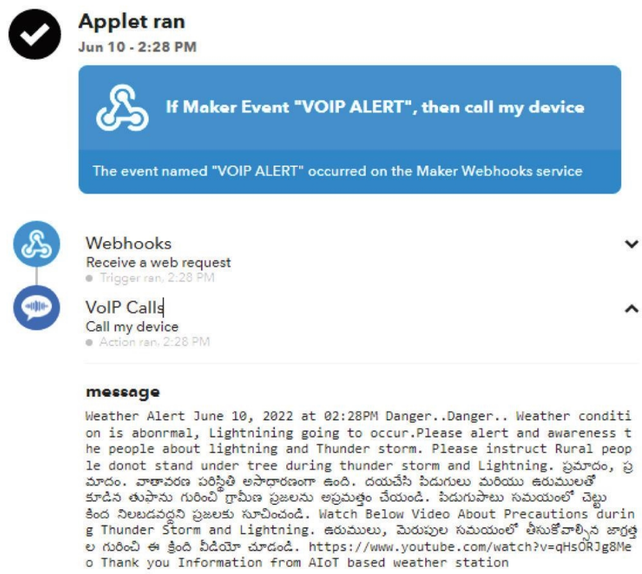

Figure 26: Weather/lightning alert message on VOIP applet.

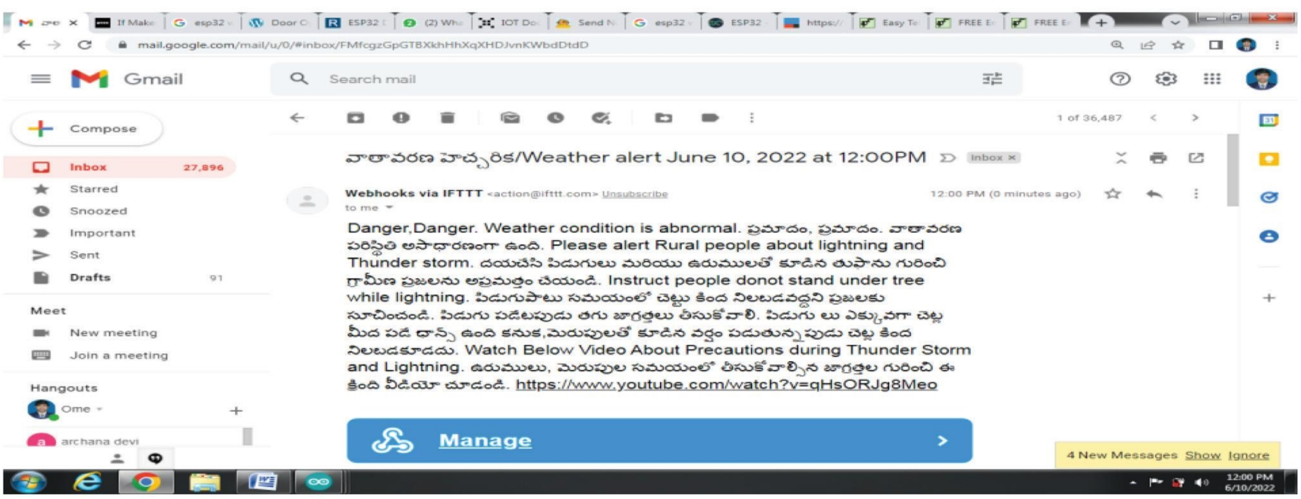

Figure 27: Email alert about weather and lightning.

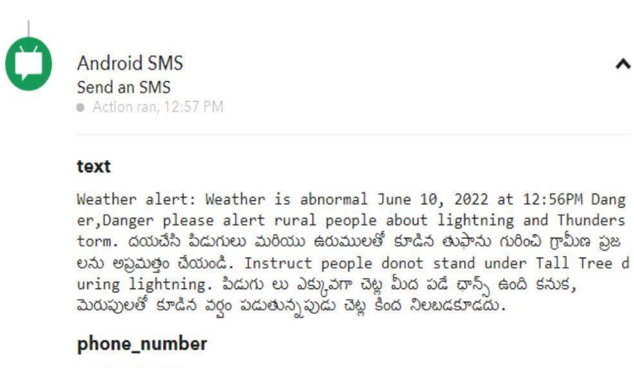

Figure 28: SMS alert message in IFTTT platform.

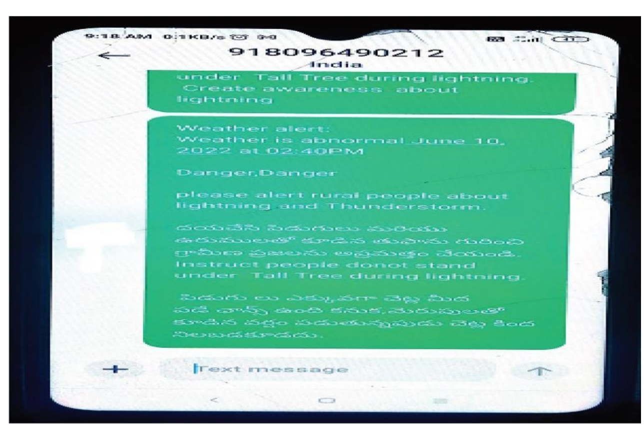

Figure 29: SMS alert message on mobile.

Table 2: Comparison of among various lightning/weather alert methods.

Alert method	Method/technology	Software package/service(s)	Remarks
Announcement	Linear predictive coding	Talkie library and TMRpcm library	Simple way to alert and create awareness about weather and lightning
Bluetooth	Bluetooth classic	Software serial library and Bluetooth mobile app	Good choice to monitor healthy status of alert system and alert in short distance communication
Email	HTTP and SMTP	Webhooks, IFTTT, and email	Email is the official way to sends the alert
VOIP	WiFi, HTTP, and IP	Webhooks, IFTTT, and VOIP	IFTTT app converts weather alert message into voice
WhatsApp	WiFi and HTTP	Text me BoT platform	Effective/fastest way of reaching alert message to people
Siren	Digital IO	DigitalWrite()	Issues weather and lightning alert by siren
SMS	WiFi and HTTP	Webhooks, IFTTT, and android SMS	Alert and awareness message to authorized persons in Telugu and English languages
Mobile app	WiFi	ThingSpeak, ThingView, and thingTweet	It represents the sensors readings in a graphical way and send alerts through Twitter

Data Availability

The data used to support this study are included within the article.

Ethical Approval

This article does not contain any studies with human or animal subjects.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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