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# Forest Fire Detection, Prediction and Monitoring

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**ABSTRACT:** This paper focuses on detection of Forestfire across a wide area using sensors and gather the data in real time and store it, all the sensors deployed are connected together using Zigbee and to conserve the energy of batteries LEACH protocol is used. WSN plays vital role in transferring the data from each node to the sink (data base). This data will be used to monitor the current conditions and also to feed the machine, which uses RNN-ML for the training of the machine and processes the data, and thus predicting the fire in a specific area based on its previous data and conditions.

**KEYWORDS:** LEACH protocol, WSN, Machine Learning, ML, Recurrent neural network (RNN), Forest Fire, Prediction, Fire Detection, Sensory Circuit.

## I. INTRODUCTION

An extensive tract of land that is heavily covered in trees and other vegetation is referred to as a "forest." Forest ecosystems are important for a multitude of reasons. Homes to millions of plants and animals are found in woods. They also supply a range of important resources, filter air and water, and help regulate the temperature. Notwithstanding their importance, forests are actually under constant threat from things like deforestation, wildfires, and damage. Many trees are destroyed to provide space for agriculture or to harvest important resources like minerals and lumber. Additionally, woods are seriously threatened by global warming. As Earth's climate changes, woods become more vulnerable to diseases, pests, and fires. Forests are actual homes for many different kinds of animals and plants, so they must be protected.

Forest fires may be very harmful to people, property, and natural resources, even though they naturally happen in a range of habitats. In wild places, lightning strikes or carelessness on the part of humans frequently starts these fires. When the right circumstances are present, dry vegetation can feed a wildfire to spread swiftly and widely across wide regions. A fire prevention policy and disaster response program are essential for protecting homes and communities from the threat of wildfires.

Detecting and predicting wildfires is challenging due to their unpredictable nature and quick spread. Early-warning systems can be developed with high accuracy using IoT and AI technologies. We believe that using important sensors to measure temperature, humidity, and wind speed, as well as detect smoke and fire, is a relevant approach to this task. The data from these metrics can be saved and utilized to create ML models that predict the chance of a fire starting. Analysing data from prior fires allows us to create models that anticipate the progression of a fire under different conditions. Creating fire databases can help firefighters and emergency personnel effectively manage wildfires. Additionally, it can help identify high-risk locations for wildfires and execute preventative actions. We conducted a literature study to explore the potential of IoT and deep learning for wildfire detection and prediction. The Internet of Things is fast growing in popularity. Many companies are creating devices that utilize IoT technologies. IoT has numerous potential applications. IoT's most common uses are home automation, health care, and city administration. IoT pulls inspiration from WSN and the internet, but with major improvements. The Internet of Things (IoT) connects physical devices, automobiles, home appliances, and other objects to the internet and permits them to communicate with one another using electronics, software, and sensors. Compared to WSN, IoT is utilized for both monitoring and control.

## II. LITERATURE REVIEW

A number of remedies have been proposed and executed for this issue. Video surveillance is the most often used system in field work. Video cameras detect smoke only during the daytime. At night, fire-sensitive cameras use IR thermal imaging to measure heat flux and backscatter laser light to identify smoke particles. The fire alert system has

limits due to environmental factors such as dust, mist, and shadows. A wireless sensor network-based system for forest fire surveillance was proposed. Wireless sensor networks collect humidity data, which is analysed by an application. This methodology results in some information loss during communication. Forest fires can be detected using temperature sensors and GPS modems. Temperature sensor data was sent to the base station using both primary and main antennas. Too many antennas and sensors made continuous power supply difficult. Climate change may additionally affect the system, in addition to the limitations mentioned above. A group of academics proposed an ad hoc network with cluster topology to anticipate forest fires and recognize prone locations. It was discovered that WSNs offer more benefits. A study by a few institutes used sensors to collect meteorological data. This data was utilized to predict and avert forest fires.

Wireless Sensor Networks (WSNs) are made up of sensor nodes that communicate with one another, sensors that measure physical quantities, and a system base station that collects, processes, and connects to the wide area network. Microprocessors are built into modern wireless sensor nodes for local data processing, networking, and control. WSNs have enabled a wide range of advanced monitoring and control applications in the environment, biomedicine, and other fields. Sensors in such networks have their own dynamics, which are often nonlinear, and modelling such a network is not always easy. Because Recurrent Neural Networks (RNNs) are made up of interconnected dynamic nodes, we investigate their parallels with WSNs and use such similarities in WSN modelling. This dissertation discusses modelling WSNs with a modified dynamic RNN.

### III. PROPOSED METHODOLOGY

The fire alert system consists of three stages: sensing, routing, and communication. Two sensors are utilized to detect physical changes in the environment: smoke and fire. The MQ-2 smoke sensor is highly sensitive to propane, methane, LPG, smoke, alcohol, CO, and hydrogen. The MQ-2 gas sensor is constructed of aluminium oxide with a covering of tin dioxide (SnO<sub>2</sub>). SnO<sub>2</sub> is the most sensitive material to flammable gases. When combustible gases have been detected at the target location, the sensor's conductivity increases in proportion to the concentration of gases. The project involves a fire sensor, which is highly sensitive and responds to fires. The batteries used to power the entire operation are being managed and are being properly utilized using LEACH protocol, and further RNN and data sets for the prediction.

#### 3.1 LEACH Protocol:

The leach protocol is a MAC protocol that uses TDMA. This protocol's primary goal is to extend the life of wireless sensor networks by reducing the energy

The Leach protocol is divided into two stages;

1. The setup stage
2. Steady state

The leach procedure operates in many cycles each with two parts. The leach protocol is generally used to depict hierarchical routing protocols. It is self-organizing. The Leach protocol employee's round as units with each round consisting of a cluster setup stage and steady-state storage to save energy expenditures.

The phase of the leach procedure are as follow:

**Setup phase:** During the setup phase the purpose is to create cluster and choose a cluster leader for each cluster based on the sensor node with the highest energy

The setup process consists of three essential steps:

1. Cluster Head Advertisement
2. Cluster setup
3. Creation.

In the initial phase a cluster's head notifies the clusters node that they have received the advertisement packet have as a cluster's head based on the subsequent formula:

$$T(n) = \frac{P}{1 - P * (r \bmod P^1)}$$

T(n) = 0

Where, n is a random number between 0 and 1  
 P is the cluster-head probability and  
 G is the set of nodes that weren't cluster Heads  
 the previous rounds

Formula No. 1: Cluster head selection

**Steady phase:** During the stable phase, cluster nodes send data to the cluster head. The cluster sensor can only connect with the cluster head over a single hop transmission. A cluster head receives data and sends it to the base station via a static route established in the source code. After a specified amount of time, the network returns to the setup phase.

**Results of the LEACH Protocol for 80 nodes:** We have developed a python code for the clustering and selection of cluster head and the results of life time of sensor nodes and residual energy up to 200 rounds are being given here:

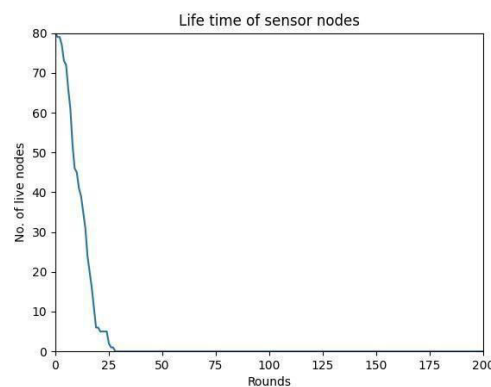


Fig 1: The life time of sensor nodes.

The suggested network model implements the LEACH algorithm for grouping and routing. We will simulate 80 nodes with equal initial energy. Nodes are thought to be immovable. We investigated single-hop communication between the cluster head and base station, as well as the sensing node and cluster head.

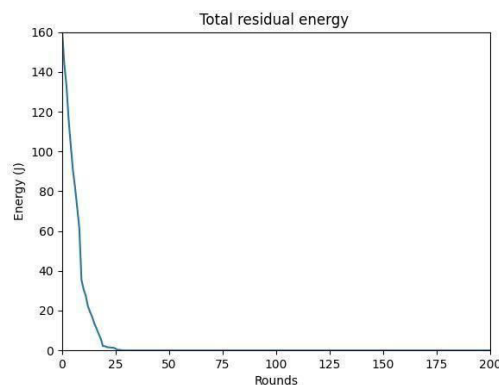


Fig 2: The Total Residual Energy.

### 3.2 Wireless Sensor Network (WSN):

A wireless sensor network, or WSN, is a network of independently placed sensors that are used to measure and track various environmental and physical parameters, including sound, pressure, temperature, humidity, and others. To facilitate analysis and decision-making, these sensors wirelessly send their data to a central location. Several sensor

nodes, a sink (base station), and occasionally a gateway for communication with other networks make up a WSN. Every sensor node has a microprocessor, transceiver, power supply, and sensors. Zigbee and Bluetooth are two examples of protocols that the nodes use to interact wirelessly with one another. The sink receives the data that the sensor nodes have collected and combines and processes it. Ultimately, a central server or user interface receives the processed data in order to analyze and make decisions. Remote forest areas are monitored for temperature, humidity, and smoke levels using WSNs as part of forest fire detection and prevention programs. The network can identify unusual changes in these variables that can point to the possibility of a fire by placing sensor nodes across the forest. Early discovery enables quick action to be taken in order to contain the fire and reduce damage, such as notifying the appropriate authorities or deploying firefighting equipment.

**The following are some modifications and enhancements that can be applied to WSN- based forest fire detection and prevention projects:**

1. Improving sensor node dependability and efficiency to guarantee precise and prompt data collection. Applying data analysis technologies, such machine learning, to lower false alarm rates and increase the accuracy of fire detection.
2. To improve monitoring and surveillance capabilities, WSNs can be integrated with other technologies like satellite imaging or unmanned aerial vehicles (UAVs).
3. Coordinating coordinated firefighting activities and evacuation processes by working with local authorities and communities to develop efficient emergency response protocols based on real-time data from WSNs.

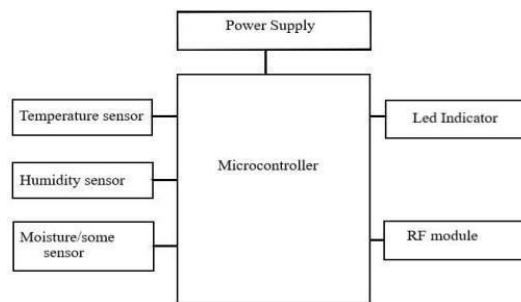


Fig 3: Block Diagram of Transmitting Node.

**3.3 Sensors used:**

1. PIC Microcontroller PIC16F72: PIC A microcontroller is the smallest microcontroller available and may be made to perform an enormous variety of functions, these microcontrollers also have other functions like LCD, ICSP, CCP, RAM, and SSP.
2. Fire and smoke sensor (MQ309A): MQ309A is a tin dioxide semiconductor gas sensor which has excellent performance in detecting both CO and Methane.
3. LED indicator: The receiver unit receives the transmitted data and it displays in LED board.
4. RF module: It is used in various areas like Remote lighting controls, long-range RFID, wireless alarm and security systems etc.
5. GSM: These modules comprise a GPRS modem or GSM module that is powered by a power supply circuit and computer communication interfaces (such as USB 2.0, RS- 232, and others).

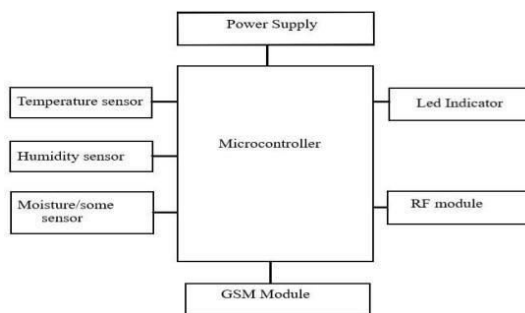


Fig 4: Block Diagram of Receiving Node.

### 3.4. Machine Learning (RNN):

Data mining comes out as a critical approach for making forecasts like those on forest fires. Access to authentic, error-free data is critical for successful predictions in data mining. When datasets contain a large number of unknowns, solutions for discarding or imputing these values become critical before modelling. The data mining process is divided into several stages, including data collection, purification, conversion, amalgamation, modelling, predictive examination, visualization, and distribution. The image depicts the stages of data mining in order.

Recurrent Neural Networks (RNNs) have showed potential for a variety of sequential data analysis applications, including time series forecasting and anomaly detection, both of which are relevant to forest fire detection. Here's how an RNN algorithm can be used to identify forest fires:

1. **Data Collection:** Collect historical data on factors that influence forest fires, such as temperature, humidity, wind speed, and vegetation density. This information can be gathered using weather stations, satellite imaging, and ground sensors.
2. **Data Preprocessing:** Clean and prepare the collected data. This includes dealing with missing values, standardizing the data, and maybe using feature engineering to extract essential features.
3. **Sequence Formation:** Arrange the data into sequences. Each sequence represents a temporal window of input features preceding a goal event, such as the appearance of a forest fire. For example, you could construct a series of temperature, humidity, and wind speed observations for the last few days.
4. **Model Architecture:** Create an RNN architecture that is suitable for sequence prediction applications. Long Short-Term Memory (LSTM) networks, also known as Gated Recurrent Units (GRUs), are frequently used for capturing long-term dependencies.
5. **Training:** Use the prepared sequences of input features and target labels to train the RNN model (for example, whether a forest fire occurred during a specific timeframe). During training, the model learns to estimate the likelihood of a forest fire based on the input sequence.
6. **Evaluation:** Test the trained model on a separate validation dataset to determine its ability to predict forest fires. Evaluation metrics include accuracy, precision, recall, and the F1-score.
7. **Deployment:** Once the model showed adequate performance, use it to identify forest fires in real time. The deployed model can continuously assess incoming data streams from weather stations, satellites, or sensors and send forth notifications when it forecasts a high risk of a forest fire occurring.
8. **Monitoring and fine-tuning:** Track the model's performance over time and fine-tune it on an ongoing basis with new data to adapt to changing environmental conditions and enhance detection accuracy.

Using the temporal dynamics collected by RNNs, this system may effectively recognize patterns indicative of impending forest fires, assisting in early warning and prevention efforts.

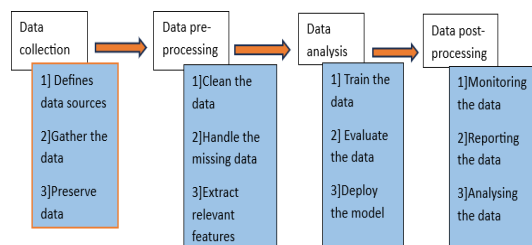


Fig 5: Block Diagram of RNN.

**Accuracy:** The accuracy metric is a mathematical formula that assesses the accuracy of machine learning predictions. The accuracy metric correlates anticipated values with actual values. The accuracy metric measures the performance of machine and deep learning models. The accuracy metric ranges from 0 to 1, with 1 representing the perfect score. The accuracy statistic compares a machine learning model's predictions and actual values. The accuracy metric measures the performance of machine learning models. The accuracy is calculated using the formula shown below:



$$\text{Accuracy} = \frac{\text{TP} + \text{TN}}{\text{TP} + \text{TN} + \text{FP} + \text{F}}$$

Formula No. 2: Accuracy of Machine

#### IV. RESULTS

The integrated results of both the WSN and ML are given below.

The results of our small simulation of two nodes of receiving and transmitting node carrying the information about the values of fire, smoke, humidity and moisture of their respective sensors are being transferred and evaluated in real time and the prediction in percentage is given:

| Temp | Humidity | Moisture | Smoke | Result |
|------|----------|----------|-------|--------|
| 25.5 | 62       | 28.3     | 0.1   | 0      |
| 32.6 | 57.9     | 39.3     | 0.1   | 0      |
| 54.3 | 28.3     | 41.1     | 0.7   | 1      |
| 99.2 | 1.9      | 45.7     | 0.6   | 1      |
| 60.6 | 14.2     | 46.3     | 0.8   | 1      |
| -2.2 | 45.8     | 4.2      | 0.7   | 0      |
| 111  | 0        | 4.9      | 0.5   | 1      |

The above table holds all the obtained values and the corresponding results.

All the values are in their measured units and may vary with the kind of sensors used.

The above table shows us the result in binary for its respective values, this may also change with what kind of ML model is being used.

#### V. CONCLUSION AND FUTURE WORK

A fire is easier to put out in the early stages than it is in the later ones. Therefore, the most crucial objective is the prompt and accurate detection and localization of the fire. The suggested fire alert system eliminates the requirement for human intervention to keep an eye on the forest area all the time. The ingrained sensors monitor and detect, and message alerts are used to notify the appropriate authorities. It provides authorities with immediate location information and aids in containing the fire before it reaches cultural heritage monuments.

The equipment in this fire alarm system is reliable as well as durable, and it uses little power, money, or maintenance. Future system upgrades will allow us to include a wind sensor, which will aid in determining the fire's direction and rate of spread. In addition, we can install an automated fire extinguisher system. An extinguisher is triggered as soon as a sensor senses fire. To pinpoint precisely where they are of fire or smoke, nodes might have a GPS module attached to them. IOT enables data transmission to cloud databases for storing and forecasting. Several other sensors can also be used in addition to these, depending on the needs of the user.

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