Managing Forest Fires

- **Abstract**

Forest fires have become a major threat around the world, causing many negative impacts on human habitats and forest ecosystems. Climatic changes and the greenhouse effect are some of the consequences of such destruction. Interestingly, a higher percentage of forest fires occur due to human activities. Therefore, to minimize the destruction caused by forest fires, there is a need to detect forest fires at their initial stage , This paper proposes a system and methodology that can be used to detect forest fires at the initial stage using a wireless sensor network taking advantage of prior knowledge of the average wind speed in the forest to minimize the number of sensor nodes ,

Furthermore we have developed a computer vision model as a backup (last defense line) to detect the fire in case of low wind speed or inability of the sensor nodes to detect the fire making use of satellite imagery of NASA datasets

we also have developed an optimization machine learning model (Gaussian Model) to detect the gasses propagation (smoke flow) with different wind speeds and directions to specify the optimum sensor nodes allocation and to specify the temperature and gasses threshold above which the sensor will send it’s reading.

Because of the primary power supply provided by rechargeable batteries with a secondary solar power supply, a solution is readily implementable as a standalone system for prolonged periods .

- **Introduction**

At earlier times, forest fires were detected using watchtowers, which were not efficient because they were based on human observations. In recent history and even the present day, several forest fire detection methods have been implemented, such as watchtowers, satellite image processing methods, optical sensors, and digital camera-based methods, although there are many drawbacks, such as inefficiency, power consumption, latency, accuracy and implementation costs. To address these drawbacks , a forest fire detection system using LoRaWAN is proposed in this paper. LoRaWAN stands for Long Range Wide Area Network, is a wireless communication technology designed for long-range, low-power communication between Internet of Things (IoT) devices and a central network. It is well-suited for applications that require data transmission over extended distances while conserving battery power , LoRaWAN is known for its exceptional range, covering several kilometers , LoRaWAN operates in a star-of-stars network topology. End devices, such as sensors or IoT nodes, communicate with centralized gateways. Gateways act as relays, receiving data from end devices and forwarding it to a central network server. This topology simplifies network management and scaling

- **How the System Works**

In the proposed detection system, wireless sensor nodes are deployed according to cellular architecture to cover the entire area with sensors to monitor temperature, smoke and carbon monoxide (CO) level using a microcontroller, transceiver module, and power components. The power supply to the sensor node is provided using batteries as the primary power supply, and solar panels are used as the secondary power supply , in our detection system we have optimized the power consumption while selecting the appropriate controller, transceiver module and network topology .

The sensor readings for each parameter are checked with a preset threshold ratio and a ratio that is calculated continuously in the node in real time, and only the ratios that exceed the preset ratio are sent from the sensor node to the base station for further analytical processing , that will reduce the network traffic within the cluster . The network utilized for this transmission is in the architecture of tree topology considering facts such as low power consumption, reduced latency, less complexity. Cluster heads are used in this network to gather data from several sensor nodes and pass them on to the base station or the gateway node. The gateway node is an interface that connects the network with the secondary analysis process.

As supplying power to a sensor node is a challenging task in forested areas, utilizing only battery options is difficult because they do not last long, and distributing power using a wire would require a higher cost to deploy in a large forest.

Therefore, many researchers have proposed solar-powered systems as secondary power sources along with rechargeable batteries as the main power source , while some researchers have proposed solar batteries because they last longer .

As a smaller number of nodes involved for transmission results in minimum energy consumption, concepts based on cluster heads have been used . We will divide our forest into regions (Clusters) these regions take the shape of a hexagon each cluster consists of number of sensor nodes and a cluster head which is responsible for sending the detected readings to the gateway or to another cluster , the area of each cluster and the number of sensors in each cluster depends on the type of the sensors and the average wind speed in that forest .

To minimize the loss of energy and data packages during transfer, a cluster-tree network topology structure was proposed .

Considering the sensing range of a node, fault tolerance, and energy consumption

As the network connectivity of service providers in forest areas is not robust, communication techniques that use dedicated network paths such as LoRa should be used

Because of the environmental parameter variations according to the place and time, we used a machine learning model (Gaussian model) that determines the lowest concentration of gasses at which the gas sensors can detect the fire . It also tell use how far should the allocation of sensors be from each others .

Our system starts when a sensor node detects anomaly which could be a high temperature or abnormal gas concentration

The LoRaWAN of the sensor node which detect that reading will send that detection to the cluster head of this sensor node if the sensor node is in the main cluster (cluster that contains the gateway) then the reading will be sent directly to the datacenter , otherwise it will be sent to a cluster that is nearer to main cluster. Then to the main cluster .

The main cluster is a cluster that contains sensor nodes and also provide a connection between the entire forest and our datacenter through the main cluster head , then it will have high traffic so we will use 2 wireless modules (ESP & LoRaWAN) the LoRaWAN module is for the local communication inside the cluster and the ESP module for the connectivity with the data center , We also will use a SIM card to provide internet connection to the ESP in the main cluster head .

once the reading is stored in our server , the application will immediately display the coordinates of the sensor node that detect the fire on a map to let the competent authorities make an appropriate movement

What if the internet connection in the main cluster head is lost , then the reading will not reach the server and the competent authorities won't know about the fire . We have solved this by providing a local storage in the main cluster head to store the readings in case of no internet connection , after the connection is restored the readings will be loaded to the server

If for any reason there is a failure in our system and the nearest sensor node to the fire haven't detect any thing , in that case the developed computer vision model will give us a detection of a fire based on the given images from the satellite , the images given from the satellite is updated every 5:30 minutes , that provide a second defense line to our main system

In our detection system we have keep in mind the reliability scalability and security, the reliability achieved by the computer vision model it works if our main system fails we will detect that failure in our main system based on a pre-set conditions depends on the environment being protected by our system .

the scalability achieved by dividing the entire forest into clusters that make the process of covering a wide area forests easier , finally the security is achieved by the use of the LoRaWAN as a wireless Module which is able to encrypt the wireless communication

- Resources
  - https://www.nature.com/articles/s41598-021-03882-9
  - (PDF) Turbulent Combustion and Thermal Radiation in a Massive Fire (researchgate.net)
  - Home - FireSmoke.ca