Early Forest Fire Prediction System Using Wireless Sensor Network

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***Abstract*—Wireless sensor network (WSN), is a collection of sensors that is used for monitoring the activities in a given environment. They are used in the forests for fire detection where a large number of sensor nodes are placed to detect the fire in its early stages. Forest fires are the main reason which affect the wildlife and many living creatures. The project performs a comparative analysis between the traditional system and the new system developed used to predict forest fires early using the Wireless sensor network for detecting forest fires with the goal of monitoring the scale and intensity of the wildfire ignited at forests. The solution involves deploying the fire sensing sensors across the forest area, calculating Fire Whether Index (FWI) of the regions, establishing data communications between the sensors using the protocol to create dynamic routing paths across the Wireless Sensor Network [7]. These paths are developed based on several factors such as fire, energy, weather index and security. Tracing the multi dynamic route is established using star topology where the red alert zones send the alert message to all the nearby base stations. Using Net Logo simulator this project analyses the performance of the traditional systems and new systems based on network power, fire detection efficacy and the overall power consumed by the fires alerting systems.**

***Index Terms*—Wireless sensor network, Star Topology, Fire Whether Index, data communication, Net Logo**

I. Introduction

In the current generation, forest fires are one of the very serious hazards faced by the humans and the environment. Forest fires have a very destructive impact on the environment, wildlife and the biodiversity by affecting the quality of air, it also has severe impacts on the life cycle and health of human beings which includes various respiratory problems. The destruction caused spreads over area causing the destruction of large infrastructure as well as destructing the economies. It also affects the aquatic organisms due to soil erosion and contamination of water bodies. It is high time to develop an effective and reliable system is developed which can automatically detect the forest fires at the earliest and can prevent the happening of forest fires.

Wireless sensor networks are used to monitor a specific environment remotely or at a distance. WSN's have a large wide application in many scenarios such as monitoring climate changes, monitoring environment and habitats. Keeping the consequences and effects of forest fires, this project shows the implementation a model based on Wireless sensor networks, WSN's, based on the technique for monitoring and predicting forest fires [17]. In an effort to lessen the harmful effects of these calamities, a unique strategy for early forest fire detection by utilizing the capabilities of WSN's is proposed. This paper provides a thorough insights of the design, implementation, and performance assessment of a WSN-based forest fire prediction system. The suggested method helps to preserve natural ecosystems and save people and property by improving the speed and accuracy of fire detection as well as facilitating quick decision-making and efficient firefighting tactics.

The sensor nodes are deployed across the entire region of the forest, together forming the Wireless Sensor Network. The nodes are connected to one another, allowing the real-time and transmission of data between the sensor nodes by tracing the muti-dynamic route between the base stations and the red zone areas. In forested areas, the WSN promptly warns users and will speed up monitoring and detection [18]. The fire weather index (FWI) will determine how the sensors function based on the weather conditions at that region. WSN will assess the performance and efficacy, assess the forest fire occurrences continuously and aid in developing a system which predicts the forest fire occurrences at the earliest possible to prevent further damage by taking timely actions.

This research primarily focuses on the following objectives:

- Evaluate the Effectiveness: Performing the experimental analysis of factors such as the system effectiveness based on network power analysis, fire detection efficiency, data packet analysis and fire whether index analysis.
- Enhance the performance: Demonstrate the proposed solution and show the enhancement in the solution proposed for early detection of forest fires occurrence compared to the traditional solutions.
- Constantly track forest fires: The proposed solution constantly tracks the weather conditions and various parameters and monitors the occurrence of forest fires.
- Improving forest fire detection systems: The solution implemented will be able to identify and detect the occurrence of forest fires beforehand quickly and efficiently. The above objectives are carried out using network tools and their implementation is mentioned in the methodology section.

II. Literature Survey

This section will be including all the details regarding the literature survey conducted on the use of wireless sensor

networks for predicting the forest fires at the earliest.

B. Liu et al. [1] In this study, two-step technique has been introduced estimation of position in WSN. Determined starting places in the first phase unidentified nodes, where nodes that anchor announce their locations and one-hop distances. By exchanging values with the neighbors, based on accuracy of nearby data on weights for position and distance the second phase improves. By the recommended scheme position mistakes are slightly reduced, particularly in the second phase where it beats a referenced scheme. And also, this paper addresses situations where a node has two neighbors and finds a method for their positions. The technique shows for improving the finding of position in WSN. Accuracy might be improved in the first step.

Mohamed Hefeeda et al. [2] presented a design of wireless sensor networks for the early detection of forest fires by analyzing Fire Weather Index System (FWI). There is a pictorial representation of the model design behind FWI system along with the two main components used in designing this system. The forest fire detection problem can be solved as a k-coverage which used the simple k-coverage algorithm. Simulations show that the k- coverage algorithm maintains reliable coverage and prolongs network life time.

Yeon-sup Lim et al. [3] explored the use of wireless sensor technology in the field of forest fire alarming system in a framework used to detect forest fires is proposed based on WSN's. The framework detects the forest fire and also provides with some rescue solutions. The framework requirements, components and deployment method are discussed in detail. Modified SurgeTelos routing protocol is used to implement the framework. the results shows that the suggested approach is an efficient way to manage the forest fires.

Huanqi Tao et al. [5] studied about the environmental impacts of forest fires and proposed a forest monitoring system that is makes use of the ZigBee wireless sensor networks. The network topology supported by this wireless sensor network are discussed and the hardware components along with the network protocols used to implement the proposed system are elaborated. This system acts as an enhanced forest fire detection system using WSN's helping to detect forest fires in an efficient and faster way.

J. Zhang et al. [6] In this paper a detail explanation has been done like traditional techniques and disadvantages for detecting forest fires is included, along with a wireless sensor network solution based on clusters enabling real-time detection. Topics like Ad hoc networks, sensor node hardware, forecasting models for forest fires, and UHF wireless signal propagation properties have been covered over here. This study also discusses the advancements of using WSN's for the purpose of forest fire detection. There is a detail analysis of using WSN for forest fire detection regarding advantages and challenges and also shown or focused to improve the effectiveness of both response and prevention.

Y. Zhu et al. [9] Here they have explained the crucial topic of forest fire monitoring, where they also focused on the significance of prompt identification and prevention. To create a forest fire monitoring system, it has been suggested to use GPRS and wireless sensor networks (WSN). And also explains about sensor nodes, central nodes, transmission network, monitoring system what are its significance like transmission of data with the help of nodes and monitoring to provide real time data The system keeps an eye on variables including temperature, humidity, and smoke content and notifies control centre of any abnormalities. It tells which components are included in hardware design like sensor boards, signal conditioning circuits, data processing modules, wireless communication components, GPRS modules, and power modules. The Z-Stack 2007 protocol stack from TI serves as the foundation for the software, which has an efficient modular architecture. For the prevention and early detection of forest fires, the combination of WSN and GPRS presents a viable approach.

G. Demin et al. [10] This paper addressing on different elements such as meteorological conditions, environmental elements, and human activity and the occurrence of forest fires. WSN to predict forest fires, With the help local weather, environment, and human behaviour. In this study, they make use of wireless sensor networks to collect the data (weather information) from sensors(nodes) continuously for 24-hours which will ultimately tell the risk of forest fire and help forest guards in reducing fire hazards by recognizing days that are high-risk. The is main challenge is Because Forest fires may have catastrophic effects on the environment and the economy, prevention and forecasting are essential, Fuzzy reasoning in conjunction with WSN's provides a better solution to this problem.

M. Owayjan et al.[11] similar to the traditional techniques, to detect early forest fire proposed a solution for it which involve deploying standalone boxes with various sensors in forest area where it continuously collect the data related to atmosphere like temperature, humidity and gases, and the communication is done via mesh network and for the communication purpose they have used different hardware components like transmitter and receiver units, the data collected is timely analyzed to transmit alerts when changes are detected related to any forest fire risk. Zigbee has been used for simulation of data.

Hemant Ghayvat et al. [12] explored the importance of WSN's and the WSN protocols in the implementation of automated home appliances. A new protocol is developed to achieve the goal of building smart homes named Ergo (wellness sensors networks), the protocol used to implement the smart system is Wellness protocol. The working of this protocol along with its hardware setup and implementation is shown. Results show that this protocol is better compared to ZigBee protocol compared based on data storage, and dealing with large amount of data.

Daojing He et al. [13] reviewed the drawbacks and the security vulnerabilities faced by the use of currently existing protocols for the wireless sensor networks based on the data discovery and the dissemination. The protocol named Di Drip is proposed which is the very first secured protocol in this area. This protocol has higher security and addresses many of the vulnerabilities faced previously. An experimental

implementation of Di Drip protocol along with its security analysis is conducted and the results are analyzed.

Jorge Granda Cantuna et al. [14] surveyed regarding the early forest fires occurrence at the Guanguiltagua Park, Quito, and developed a design for WSN's prototype which detects forest fires at this place automatically based on some gases present in environment. To implement the prototype various hardware requirements, communication protocols, software and the topology, used are explained in detail. The network configurations along with the way to implement the model is explained. The system helped to bring forest fires at this place in control, alongside it is an efficient method as it has smaller components with the use of Micro Electro Mechanical System (MEMS).

Premsai Dasari et al. [17] studies the hazards caused by forest fires due to the increasing rate of forest fires. The detection of these fires can be done using a system which works automatically or human surveillance method. This paper proposes an automated fire alerting system which is helps to detect forest fires and using the smoke and the fire sensor. This system proposed can alert humans present at remote area using the Global System for mobile communication. This software simulation and the hardware implementation of the project is explained in detailed in this paper. The proposed system is of low cost and low maintenance which can use various sensors to detect the forest fires effectively.

III. Methodology

This methodology section discusses the structured approach and steps involved in the implementation of the forest fire prediction system using the WSN's.

- Analysis of System Architecture and Design
- Setting the environment
- Deployment of sensor node
- Fire Weather Index
- Data Communication protocol
- Tracing multi dynamic route
- Simulation
- Performance analysis

"Fig. 1." depicts the steps involved in the methodology is shown in.

The Methodology of the proposed solution requires wireless sensor network (WSN's), a data communication protocol and Net Logo simulator to analyse the performance of the forest fire prevention system. Initially all the sensor nodes should be made operational, and out of all the nodes, the nodes with higher FWI value will be identified as red zoned sensor node which will be connected to all other nodes in the network acting as the base stations to which the alerting message will be sent. The overall deployment of the proposed solution can be done by calculating the Fire Weather Index (FWI) of each node to identify the danger zones and send the fire alerting message to all the nearby stations by tracing the route from base station to the danger zones using the multi dynamic routing to take quick actions to prevent forest fires.

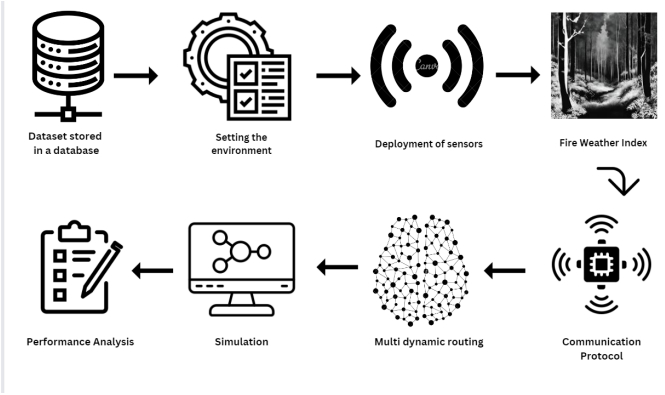

Fig. 1. Architectural flow of the project

IV. Implementation

A. Setting up Environment

It refers to the area for deploying the sensor network. Before deploying the sensor nodes in the forest region, its necessary to setup the area with appropriate requirements for deploying the sensor network. To visualize the forest situation in Net Logo, the model settings of the simulator are altered. In context of Net Logo, the environment setup is as follows:

- The origin is set at the centre.
- The forest area is spread across the region with dimensions of 41 x 41.
- To have a clear visualization of the forest area, the path size is set to 11, font size is set to 10 and the frame rate is set to 30.

"Fig. 2." represents the model settings to be maintained to set up the environment of Net Logo simulator to design a forest fire prevention system.

B. Deployment of sensors

Once the region is setup, the sensors are deployed at various regions of the forest [4]. All the sensors are connected to each other forming the Wireless sensor networks (WSN's) enabling the communication between various nodes. The sensors are deployed such that they are distributed over a vast area including all the regions of the forest.By continuously monitoring the information provided by the WSN's the approximate position where the forest fire may be ignited will be recognized and the alerting message will be sent to the base stations at the earliest.

C. Fire Weather Index

The Wireless Sensors Network (WSN) analyses the factors such as temperature, wind speed, and humidity at a particular region and calculates the FWI. The colours associated to the sensors depends on the FWI calculated at that region as shown in Table I. The higher the FWI , the more is the probability of occurrence of forest fire at that region [19]. As soon as a

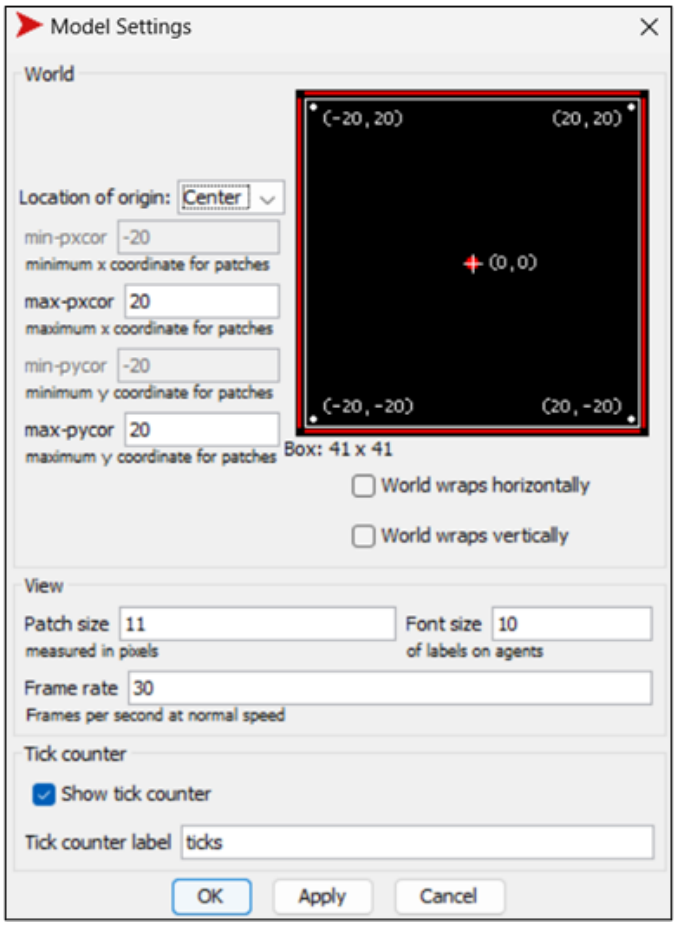

Fig. 2. Environment settings

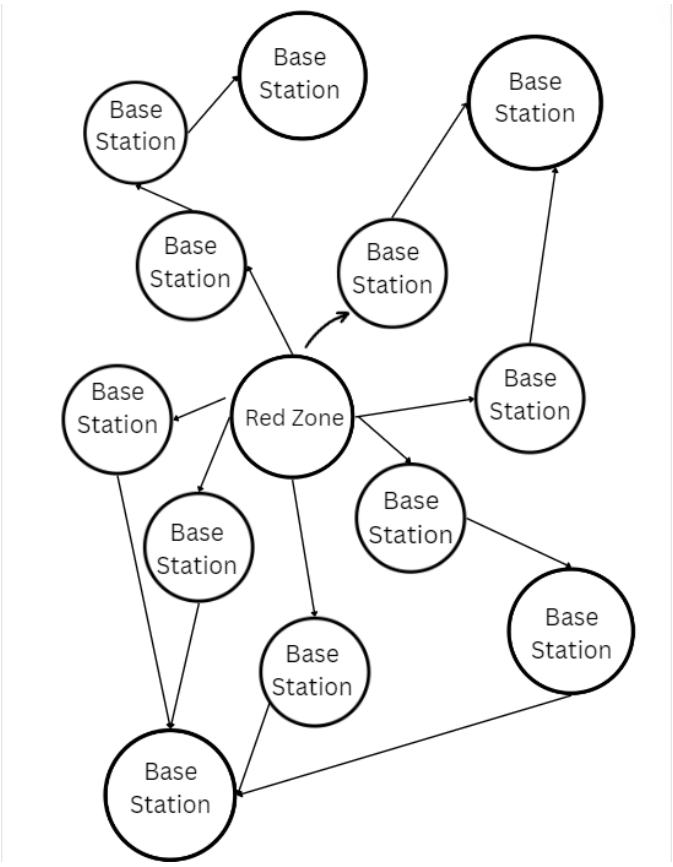

Fig. 3. Tracing multi dynamic route paths

TABLE I
FWI VALUES AND COLOUR CODES

Serial Number	FWI Range	Colour Code
1	FWI $>$ 30	Red
2	FWI $\geq$ 10 && FWI $\leq$ 30	Yellow
3	FWI $<$ 10	Green

higher FWI value or any possibility of forest fire occurrence at a particular location is observed, the sensor at that region sends an alarming message to all the other sensors in the network so that the emergency task force can take the appropriate actions promptly.

D. Data Communication Protocol

The data communication protocol is used to establish the communication among the sensor networks and the base stations in a sensor network connected. Parameters such as weight, security, priority play an important role in the communication between the sensor nodes deployed. A customized protocol is made use of which is based on standards of wireless application protocols [15]. This customized protocol emphasizes on tracing the most efficient and shortest path ensuring to send alert message to all the sensor nodes following a star topology in the deployed network [20]. Development of the protocol involves the Dijkstra's algorithm used to find the shortest distance. The weight for the formula is calculated based on the radius of the node and the energy that is remaining.

E. Multi dynamic Routing

The communication protocol will be helping to identify the dynamic route with the help of priorities such as energy and weight. This multi-dynamic routes are chosen based on these priorities. This route helps the red zone or the zones with high value of fire whether index to send the alerting message to the nearby base stations [16]. In "Fig. 3.", the tracing of multi dynamic route is depicted using the sensors. The messages sent from the red zoned node to all the other nodes in the network follows star topology.

F. Simulation

For simulating the proposed method, the simulation application used is the Net Logo simulator which is installed on the Windows Operating system [8]. It represents the features and the parameters for each of the wireless sensor node in the network and helps in visualizing the overall process of sending fire prevention message to all the nodes in the forest. Once the Wireless sensor networks are linked, The FWI (Fire

Weather index) will be calculated and integrated with the communication protocol. Through the simulation process the analysis of various features of the system are assessed.

G. Performance analysis

The performance of the forest fire prevention systems in terms of efficiency, accuracy and reliability are evaluated. The plots representing the fire detection efficacy which depicts the capability of the system to detect the occurrence of forest fire at a region, Node power level which is the strength of the sensor nodes present in network and the overall power consumed by the system in detecting and passing the alerting message to base stations are compared of models and the best model is concluded.

V. Results and Analysis

This project compares the efficiency and reliability of the proposed fire monitoring system with the traditional systems existing. The performance of the early fire prediction system is measured based on the factors including fire prediction efficacy, Node power level and the overall power level of the model. The figures below depict the plots relative assessment of the system proposed with the traditional systems. “Fig. 4.” Is the graphical representation of the comparison done between the traditional or the old model and the newly developed model in terms of the fire detection efficacy. The fire detection efficacy is a measure symbolizing the performance of the model in predicting the forest fires as soon as possible. Fire detection efficacy denotes the ability of a system to detect the occurrence of fires quickly and accurately at a region. The higher the value this measure, the more effective is the system in detection fires at the earliest.

The plot in “Fig.5.” is constructed between the number of packets transmitted and the fire index percentage. It is clear from the graph that the efficacy percentage of the new model is higher in comparison to the old model, which proves that the new model has an accurate fire prediction capability. “Fig. 5.” is the plot which captures the changes in the power level of the sensor nodes of the forest area using the new prediction system.

“Fig. 6.” is the plot highlighting the changes in the nodal power of the sensors deployed in the forest area as time passes observed through the old fire prediction model. From the results depicted in “Fig. 5.” and “Fig. 6.” It can be inferred that the nodal power of the old model drains faster as time passes compared to the new fire prediction model. This shows that the nodal power of the new system surpasses the old system. “Fig. 7.” is a graphical comparison between the overall power used by the entire system for the process of predicting the forest fires at the earliest. It is clearly visible that the energy used by the new model is less compared to the old model. This shows that newly developed model is able to predict the forest fires by consuming less power than the old model, which saves a lot of energy consumed making it a economical system to predict forest fires at the earliest.

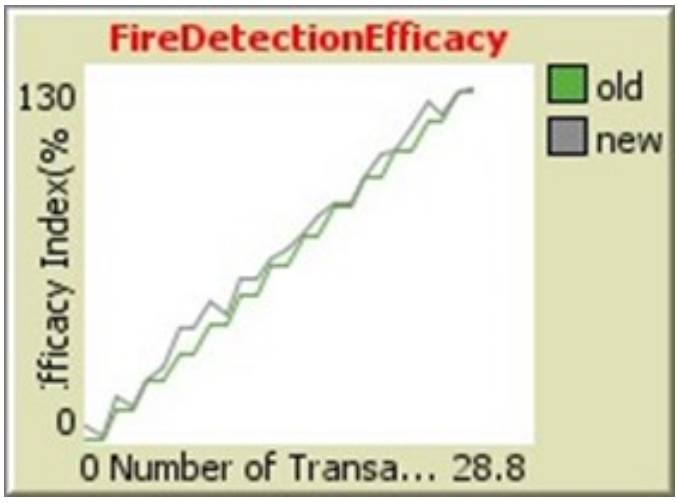

Fig. 4. Comparison between the Fire detection efficacy of old and new model

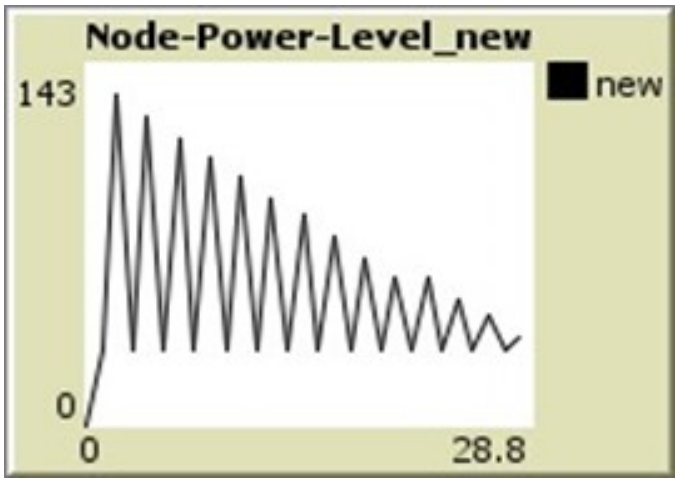

Fig. 5. Node power level of new model

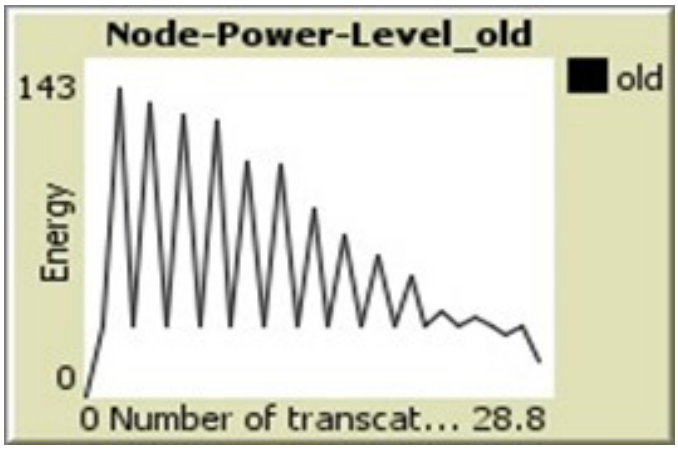

Fig. 6. Node power level of old model

Fig. 7. Comparison of power level between old and new model

VI. Conclusion

By analyzing all the results from the above graphs, it is observed that the new forest fire prediction model has outperformed the traditional system in terms of Fire detection efficacy, Node power level and the overall power consumed by the model. It could be concluded that the new model has provided with more accurate, reliable and earlier forest fire detection results outweighing the old fire prediction model.

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References

[1] Liu, B., 2006, September. A study on wireless sensor networks location. In 2006 International Conference on Wireless Communications, Networking and Mobile Computing (pp. 1-4). IEEE.

[2] Hefeeda, M. and Bagheri, M., 2007, October. Wireless sensor networks for early detection of forest fires. In 2007 IEEE International Conference on Mobile Adhoc and Sensor Systems (pp. 1-6). IEEE.

[3] Lim, Y.S., Lim, S., Choi, J., Cho, S., Kim, C.K., Hu, Y.W.L.H., Zhang, H., Hu, H., Xu, B., Li, J. and Ma, A., 2007, November. A fire detection and rescue support framework with wireless sensor networks. In 2007 International Conference on Convergence Information Technology (ICCIT 2007) (pp. 135-138). IEEE.

[4] A. Seetharam, A. Bhattacharyya, M.K.Naskar and A. Mukherjee, "Determination of the Number of Nodes for a Power Efficient Deployment Strategy in Wireless Sensor Networks", WPMC 2008, Lapland, Finland.

[5] Tao, H. and Zhang, H., 2009, November. Forest monitoring application systems based on wireless sensor networks. In 2009 Third International Symposium on Intelligent Information Technology Application Workshops (pp. 227-230). IEEE.

[6] Zhang, J., Li, W., Yin, Z., Liu, S. and Guo, X., 2009, May. Forest fire detection system based on wireless sensor network. In 2009 4th IEEE conference on industrial electronics and applications (pp. 520-523). IEEE.

[7] Kumari, J.J.J., Thangam, S. and Raja, A.S., 2023, October. Efficacious Routing Approaches in Vehicular Ad hoc Network: An Empirical Study. In 2023 First International Conference on Advances in Electrical, Electronics and Computational Intelligence (ICAEECI) (pp. 1-7). IEEE.

[8] Thangam, S. and Kirubakaran, E., 2009, April. A survey on cross-layer based approach for improving TCP performance in multi hop mobile adhoc networks. In 2009 International Conference on Education Technology and Computer (pp. 294-298). IEEE.

[9] Zhu, Y., Xie, L. and Yuan, T., 2012, July. Monitoring system for forest fire based on wireless sensor network. In Proceedings of the 10th World Congress on Intelligent Control and Automation (pp. 4245-4248). IEEE.

[10] Demin, G., Haifeng, L., Anna, J. and Guoxin, W., 2014, September. A forest fire prediction system based on rechargeable wireless sensor networks. In 2014 4th IEEE International Conference on Network Infrastructure and Digital Content (pp. 405-408). IEEE.

[11] Owayjan, M., Freiha, G., Achkar, R., Abdo, E. and Mallah, S., 2014, April. Firoxio: Forest fire detection and alerting system. In MELECON 2014-2014 17th IEEE Mediterranean Electrotechnical Conference (pp. 177-181). IEEE.

[12] Ghayvat, H., Liu, J., Mukhopadhyay, S.C. and Gui, X., 2015. Wellness sensor networks: A proposal and implementation for smart home for assisted living. IEEE Sensors Journal, 15(12), pp.7341-7348.

[13] He, D., Chan, S., Guizani, M., Yang, H. and Zhou, B., 2014. Secure and distributed data discovery and dissemination in wireless sensor networks. IEEE Transactions on Parallel and Distributed Systems, 26(4), pp.1129-1139.

[14] Cantuna, J.G., Bastidas, D., Solórzano, S. and Clairand, J.M., 2017, April. Design and implementation of a Wireless Sensor Network to detect forest fires. In 2017 Fourth international conference on eDemocracy eGovernment (ICEDEG) (pp. 15-21). IEEE.

[15] Pai, M.L., Varsha, K.S. and Arya, R., 2020. Application of artificial neural networks and genetic algorithm for the prediction of forest fire danger in Kerala. In Intelligent Systems Design and Applications: 18th International Conference on Intelligent Systems Design and Applications (ISDA 2018) held in Vellore, India, December 6-8, 2018, Volume 2 (pp. 935-942). Springer International Publishing.

[16] Jan, S.U. and Khaliq, F., 2018. An Improved Forest Fire Alerting System Using Wireless Sensor Network. Advances in Networks, 6(1), pp.21-39.

[17] Dasari, P., Reddy, G.K.J. and Gudipalli, A., 2020. Forest fire detection using wireless sensor networks. International journal on smart sensing and intelligent systems, 13(1), pp.1-8.

[18] Pushpalatha, R., Kutty, G. and Gangadharan, B., 2021. Sensitivity analysis of WOFOST for yield simulation of cassava over the major growing areas of India. Journal of Agrometeorology, 23(4), pp.375-380.

[19] Harshaw Kamal, S., Ragul Raj, R.K., Sabari, T. and Karthika, R., 2022. Performance analysis of different deep learning models for forest fire classification. In Disruptive Technologies for Big Data and Cloud Applications: Proceedings of ICBDCC 2021 (pp. 143-151). Singapore: Springer Nature Singapore.

[20] Hari, A. and Manjusha, R., 2023, April. Network Topology and Sensitivity Analysis. In 2023 Second International Conference on Electrical, Electronics, Information and Communication Technologies (ICEEICT) (pp. 01-06). IEEE.