

Real-Time Zigbee Sensor Network for Forest Monitoring and Wildlife Conservation

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Abstract

Tree smuggling, especially of high-value species like sandalwood and teak, poses a significant threat to biodiversity and forest ecosystems. These trees are highly sought after for their commercial value, making them frequent targets of illegal logging operations. This illicit activity not only depletes valuable natural resources but also contributes to deforestation and environmental degradation. In response to this growing concern, an IoT-based monitoring system has been developed to detect and prevent such activities. At the core of the system is a Node MCU microcontroller, integrated with multiple sensors such as accelerometers to detect tree tilting, fire sensors for identifying potential fire hazards, ultrasonic sensors for motion detection, and pH sensors to monitor soil health. These sensors provide real-time data, accessible via an Android smartphone application, enabling immediate awareness and action. Supporting components like buzzers, water pumps, and relays offer responsive measures such as alarms and fire suppression. This innovative solution aims to safeguard endangered tree species, mitigate illegal activities, and promote ecological sustainability through smart, technology-driven forest management.

Key words: ZigBee Technology, Wireless Sensor Network, Tree Monitoring, Real Time Monitoring, Environmental Sensors, Motion Detection, Low Power Communication, Forest Security System.

I. Introduction

In recent years, there has been a noticeable increase in the illegal exploitation of forest resources, especially targeting economically and ecologically important trees such as sandalwood, teakwood, pine, and rosewood. This illegal activity referred to as poaching or hunting of trees is not restricted to a specific country; rather, it is a global issue that poses a serious threat to the environment and biodiversity [1]. Alongside poaching, forest fires and illegal logging have become some of the most common and destructive hazards affecting forest ecosystems.

Forest fires have existed for as long as forests themselves and are particularly dangerous during dry seasons like summer, when vegetation is dry and easily flammable. A small spark from natural causes like lightning or human-induced sources such as cigarettes, open flames, or electrical sparks can quickly ignite a fire that spreads across the forest. These fires not only destroy trees but also endanger all forms of life in that ecosystem, potentially wiping out entire species.

Illegal logging, on the other hand, includes all unauthorized activities related to the harvesting, processing, and trade of wood. This can range from cutting trees without proper licenses, harvesting from protected areas, using unlicensed processing facilities, employing unregistered labour, and evading taxes or export duties. These illegal practices often flourish due to weak legislation, corruption, lack of oversight, and ineffective enforcement of forest laws. The environmental consequences are severe, including biodiversity loss, increased greenhouse gas emissions, and accelerated global climate change.

Currently, forest protection primarily relies on human guards, which proves inadequate due to the vastness of forest areas and the physical limitations of constant surveillance. Some regions use CCTV cameras, but installing and maintaining these systems across large forest zones is expensive and logistically challenging. Another method is the use of RFID tags, which work similarly to animal tracking systems, by tagging trees for identification. However, RFID systems do not offer real-time monitoring; they only alert authorities once a tagged tree is moved, which often happens after the damage is already done[2].

To address these issues, various researchers have proposed new technologies aimed at real time forest monitoring and protection [3]. This paper aims to survey and analyse those proposed solutions in an effort to identify more effective and efficient methods of preserving forest ecosystems.

Proposed System

The aim of this paper is to develop a wireless sensor node using a Wireless Sensor Network (WSN) to monitor forest activity [4]. The system is divided into three main modules: data capturing, data processing, and output. The data capturing module includes various sensors such as a sound sensor to detect unusual noises, a flame sensor for temperature changes indicating fire, a flex sensor to detect tree bending, and a camera for visual monitoring. These inputs are processed by a microcontroller. The output module is an Android mobile device that displays sensor data and provides live video streaming through an IoT application for real time monitoring.

Block Diagram

The anti-poaching system using Zigbee technology is designed to monitor and protect forests and wildlife from illegal activities. The system includes a sensor unit with PIR (Passive Infrared) sensors to detect motion and sound sensors to capture gunshots or unusual noises. These sensors are connected to a microcontroller, which processes the data. If suspicious activity is detected, the microcontroller activates a Zigbee transmitter to send the data wirelessly to a remote base station. At the base station, a Zigbee receiver collects the data and passes it to another microcontroller or computer for analysis. If a threat is confirmed, an alert is triggered through an alarm or GSM module to notify forest officials. The system is powered by batteries or solar panels, making it suitable for remote forest areas. Zigbee's low power and long-range capabilities make it ideal for real-time communication in wildlife protection systems.

Transmitter

The transmitter section of the block diagram is a crucial part of a fire detection and response system. It is powered by a dedicated power supply that ensures consistent operation of all components. At the core of the system is a Microcontroller Unit (MCU), which acts as the brain of the setup. The MCU receives input from several sensors, including an IR sensor that detects motion or obstacles, a tilt sensor that monitors changes in orientation, a temperature sensor that tracks heat levels, and a fire sensor that identifies the presence of flames or high heat. Based on the data collected from these sensors, the MCU processes the information and triggers appropriate outputs. These outputs include an OLED display for visual feedback, a driver circuit that controls a pump motor (likely used for fire suppression), a Zigbee transmitter that wirelessly communicates sensor data and alerts to a remote receiver. This integrated design enables real-time monitoring and rapid response in case of fire or hazardous conditions.

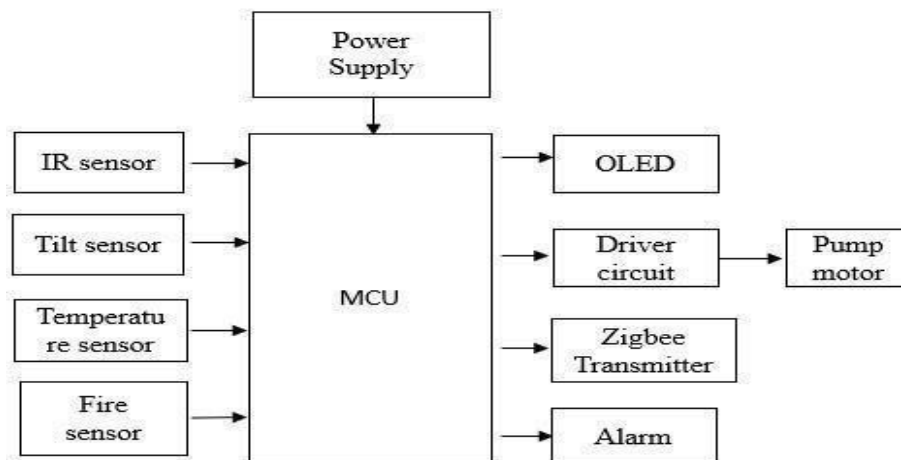


Figure:1 Transmitter

Receiver

The receiver section of the system is responsible for collecting and processing data transmitted wirelessly from the transmitter unit. It is powered by a dedicated power supply, ensuring reliable operation. At the centre of this section is a Microcontroller Unit (MCU), which serves as the control hub. The MCU receives data via a Zigbee receiver module, which captures the signals sent by the Zigbee transmitter in the transmitter section.

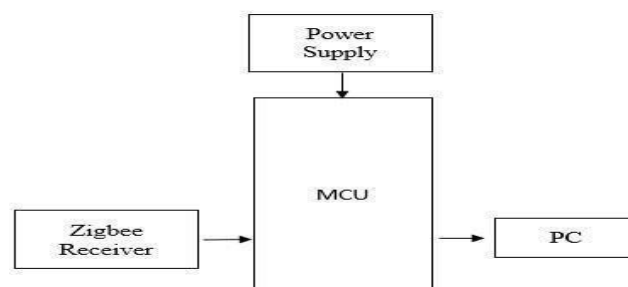


Figure:2 Receiver

This data typically includes sensor readings and emergency alerts, such as fire detection or abnormal temperature levels. Once the MCU processes this information, it sends the relevant data to a connected PC for monitoring, display, or further action. The PC

may be used to log data, trigger additional alarms, or alert authorities. Overall, the receiver section plays a critical role in remote monitoring and real-time response by ensuring that information from the sensing unit is effectively communicated and acted upon.

System Working

The Anti-Poaching Alarm System is a cutting-edge solution developed to combat illegal logging by providing real-time monitoring and instant alerts [5]. It relies on piezoelectric sensors, which are carefully installed on trees identified as high-risk targets within protected forest areas. These sensors are capable of detecting the unique vibration patterns caused by cutting instruments like axes or chainsaws. When such an event occurs, the piezoelectric material within the sensor transforms the mechanical vibrations into electrical signals. These signals are processed by a microcontroller equipped with sophisticated algorithms that can distinguish between normal environmental disturbances such as wind or animal activity and the specific patterns associated with tree cutting. Upon confirming a cutting event, the system activates its GSM module, which connects to the cellular network to send an alert message. This message includes the exact location of the tree and is sent to pre-assigned forest officials or monitoring teams [6]. Designed for autonomous operation, the system runs on batteries that can be supported by solar charging, allowing for extended functionality even in isolated regions. Through its rapid detection and alert capabilities, the system significantly strengthens efforts to safeguard forests from unauthorized logging activities.

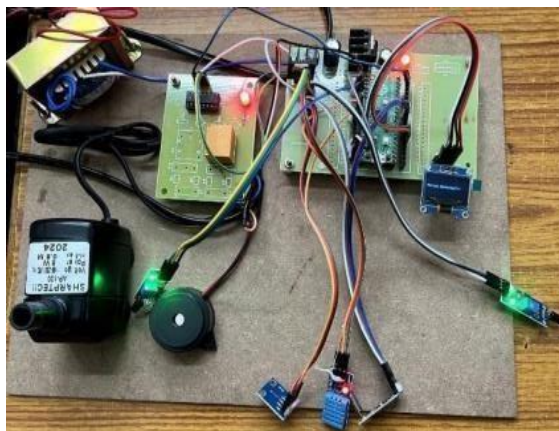


Figure 3: Simulation result of Anti-Poaching System for protecting forest and wildlife

Simulation and Results

The Anti-Poaching Alarm System has shown strong performance in real-world conditions, effectively detecting illegal tree-cutting and sending immediate alerts [7]. This quick notification system enables forest rangers to respond promptly, often arriving at the site before the offenders can escape. The presence of these sensors acts as a deterrent, making trees less likely to be targeted by poachers. The system has also revolutionized forest patrol strategies by allowing rangers to focus on specific areas where threats are detected, rather than conducting broad, time-consuming patrols. Moreover, it gathers valuable data on when and where illegal logging occurs, helping authorities identify trends and improve future prevention efforts. Its affordability and minimal maintenance requirements make it a practical solution for protecting large forested regions. By turning forest surveillance into a proactive defence mechanism, the system greatly reduces illegal logging and strengthens conservation efforts.

II. Conclusion

The Anti-Poaching Alarm System offers a smart and practical solution to the problem of illegal logging by combining piezoelectric sensors with GSM technology to create a fast-response alert network. This innovative setup transforms at-risk trees into active monitoring units that can detect the vibrations caused by cutting tools in real time. Once such activity is sensed, the system immediately sends a location-based alert to forest authorities through the GSM module, drastically shortening the time between detection and response. This swift notification process not only boosts the likelihood of intercepting illegal loggers but also acts as a strong deterrent, as the increased risk of capture discourages potential offenders. By providing instant alerts from remote forest areas where human patrols are often scarce the system addresses a major weakness of conventional monitoring methods. Importantly, it achieves this with low costs and minimal maintenance needs, making it suitable for broad implementation across diverse forested regions. Field trials have demonstrated its reliability in both detecting illegal activity and preventing future incidents. The Forest Guardian system, therefore, represents a valuable tool in forest conservation, showing how even straightforward technological solutions can empower nature to signal distress and enhance efforts to safeguard endangered ecosystems.

References

1. H. C. Hamza, H. V. Krishna Raj Nair M. K., and S. A. Gafoor, "Trees Theft Control System," 2013 Texas Instruments India Educators' Conference (TIIEC), India, 2013.

2. N. Shilpa and Ch. Sun Dharani, "IoT Based Anti-Poaching of Trees," International Journal of Engineering and Advanced Technology (IJEAT), vol. 8, no. 5, pp. –, June 2019.
3. S. Gaikwad, R. Patil, A. Khandare, and A. Rai, "Design of WSN Node for Protection of Forest Trees Against Poaching Based on Zigbee," CONECCT, 2015.
4. S. Veerasingam, S. Karodi, S. Shukla, and M. C. Yeleti, "Design of Wireless Sensor Network Node on Zigbee for Temperature Monitoring," 2019 International Conference on Advances in Computing, Control and Telecommunication Technologies, 2009.
5. P. Madhavi, S. K. Razeen, S. K. Nowshad, Y. Susmitha, and M. Sweety, "IoT-Based Anti- Poaching Alarm System for Trees in Forests," International Journal of Emerging Technologies and Innovative Research (JETIR), vol. 6, no. 4, April 2019, ISSN: 2349- 5162.
6. J. K. Jayaram, J. K. Janani, R. Jeyaguru, Kumaresh, and N. Muralidharan, "Forest Fire Alerting System with GPS Coordination using IoT," 2019 5th International Conference on Advanced Computing and Communication Systems (ICACCS), Coimbatore, India.
7. A. Divya, T. Kavithanjali, and P. Dharshini, "IoT Enabled Forest Fire Detection and Early Warning System," 2019 Proceedings of the International Conference on Systems Computation Automation and Networking (ICSCAN), Pondicherry, India, 2019.