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Smart Forest Corridor

An IoT-Based System for Wildlife Protection and Forest Monitoring

Survey Paper

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Abstract - Forests are important because they provide a home for many animals and plants. They also help to keep the environment balanced. Today, forests and wildlife face many problems, such as forest fires, habitat loss, animal movement near roads, and conflict between people and wild animals. These problems can cause harm to both wildlife and people. In many places, forest monitoring still depends on manual checking. This may take more time, especially when the forest area is large or difficult to reach. This survey paper studies how Internet of Things (IoT) technology can support forest protection through sensors, wireless communication, and remote monitoring. The main idea is a Smart Forest Corridor system that can detect animal movement, monitor temperature, humidity and smoke, and send warning messages to forest officers, drivers, and nearby villages. The proposed system may use an ESP32 controller, PIR and ultrasonic sensors, a camera module, DHT22 and MQ-2 sensors, LoRa communication, GSM or Wi-Fi connectivity, and a cloud dashboard. Solar power can help the sensor nodes work in areas where regular electricity is not available. The paper reviews related work on animal detection, LoRa-based forest monitoring, wireless sensor networks, and forest fire detection. It also explains the possible system design, benefits, challenges, and future improvements. The system discussed in this paper is a proposed design; its performance must be tested in real forest conditions before it can be considered a proven solution.

Keywords - Smart forest corridor, Internet of Things, wildlife monitoring, animal detection, forest fire detection, LoRa, wireless sensor network, ESP32, solar power.

Abbreviations

IoT – Internet of Things; PIR – Passive Infrared; WSN – Wireless Sensor Network; LoRa – Long Range radio communication; GSM – Global System for Mobile Communications; GPS – Global Positioning System; AI – Artificial Intelligence.

1. INTRODUCTION

A forest is not only a group of trees. It is a living place for birds, insects, small animals, and large wild animals. Forests also help people by supporting rainfall patterns, protecting soil, storing carbon, and keeping nature healthy. Many animals move from one part of a forest to another to find food, water, shelter, or a safe place to live. The natural paths used by animals are often called wildlife corridors. When roads, buildings, farms, or other human activities cross these paths, animals may come close to people and vehicles.

Wild animals crossing roads can lead to road accidents. At the same time, people living near forest areas may face problems when animals enter villages or farms. Forest fires are another serious issue. A fire that is noticed late can spread over a large area and damage trees, animal habitats, and nearby communities. These problems show why regular monitoring and early warning are important.

Traditional forest monitoring may involve forest staff visiting locations, watching from selected points, or responding after a problem is reported. These methods are useful, but they may not provide information from

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every location at every moment. Forests can cover large areas, and some places are difficult to reach. A monitoring system that collects information automatically can support forest staff and help them respond sooner.

The Internet of Things offers one way to build such a system. IoT connects physical devices, such as sensors and controllers, so that they can collect information and share it through a communication network. In a Smart Forest Corridor, sensors placed near animal paths and road-crossing points can detect movement. Other sensors can measure temperature, humidity, and smoke to help identify possible fire conditions. A controller can check the readings and send important events to a gateway or cloud platform.

The purpose of this survey is to study the main technologies used in wildlife detection and forest monitoring and to bring them together in one proposed system. The paper focuses on three main needs: detecting animal movement, warning people near road crossings, and finding possible forest fire conditions at an early stage. It also considers low-power operation and communication in places where mobile network coverage may be weak.

2. NEED FOR A SMART FOREST CORRIDOR

2.1 Wildlife movement and road safety

Animals may cross roads while moving between feeding areas, water sources, and resting places. Drivers may not see an animal early, especially at night, during rain, or on roads with poor lighting. A warning system near a known crossing point may give drivers more time to slow down. The warning should be based on a real detection and should be clear enough for drivers to understand.

2.2 Human-wildlife conflict

When animals enter farms or villages, both people and animals may be at risk. People may lose crops, and animals may be injured or frightened. An early message to the people responsible for the area can help them take suitable steps. The system should support safe response by trained forest staff. It should not encourage people to approach, chase, or handle wild animals.

2.3 Forest fire monitoring

A fire can begin in a small area and spread if it is not noticed. Temperature, humidity, and smoke readings can provide useful information about the surrounding environment. A single sensor reading may not always mean that a fire has started. For example, a sudden temperature change or smoke-like reading may happen for other reasons. It is therefore useful to check more than one reading and use suitable thresholds before sending a high-priority alert.

2.4 Limits of manual monitoring

Manual checking is important and cannot be fully replaced, but it may be difficult to observe many locations continuously. Staff may also need to travel long distances to inspect a reported event. A sensor network can provide additional information between patrols. It can record the time and location of an event and help staff decide which location needs attention.

2.5 Aim of the proposed system

The aim of the Smart Forest Corridor is to combine animal movement detection, environmental monitoring, wireless communication, and warning messages in one system. The idea is to support safer movement for wildlife and people. The system is not intended to control animal movement or replace forest officers. It is a support tool that can provide timely information for better decisions.

3. REVIEW OF RELATED WORK

Several research papers have studied the use of sensors and wireless networks for monitoring animals and forests. Their work gives useful ideas for the proposed Smart Forest Corridor.

Miao et al. [1] presented a fog-based smart agriculture system for detecting animal intrusion. Their work uses low-cost sensors, cameras, computer vision, edge or fog computing, and LoRa communication. One important point from this study is that some processing can be done near the sensor network instead of sending

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every piece of data to a distant cloud server. This can help reduce delay and reduce the amount of data sent over the network.

Acharya et al. [2] studied a low-cost LoRa-based forest protection system. Their work is related to the use of long-range, low-power communication for forest monitoring. LoRa can be useful when sensor nodes are spread across a large area and need to send small amounts of information. However, the actual communication distance depends on the location, trees, hills, antenna placement, and radio settings.

Ojo et al. [3] evaluated a LoRa wildlife monitoring network in a forest vegetation area. This type of study is important because wireless signals can behave differently in a forest compared with an open field. Trees, wet leaves, uneven land, and other obstacles may affect the signal. A system should therefore be tested in the same type of environment where it will be used.

Knyva et al. [4] described an IoT sensor network for detecting wild animals near roads. Their system included passive infrared sensors, LoRa communication, solar energy, a gateway, and a thermal camera for checking detections. The study shows how sensor nodes can be placed near a road to collect animal movement information. It also highlights the value of using a camera or another sensor to confirm a detection.

Dampage et al. [5] developed a forest fire detection system using wireless sensor networks and machine learning. Their study monitored environmental values and used a model to help separate fire and non-fire conditions. The authors also discussed sensor-node design, solar power, and testing in forest locations. This work supports the idea that more than one environmental reading can be used when detecting a possible fire.

3. REVIEW OF RELATED WORK (CONTINUED)

Salaria et al. [6] discussed issues and challenges in wireless sensor networks for forest fire monitoring. Their topic is important because a forest sensor network must work with limited power, changing weather, and difficult communication conditions. Varela et al. [7] also studied wireless sensor networks for forest fire detection. These works support the use of distributed sensor nodes to collect information from different parts of a forest.

Al-Dahoud et al. [8] examined a forest fire detection system based on a low-cost wireless sensor network and IoT. Dasari et al. [9] also discussed forest fire detection using wireless sensor networks. These studies show that connected sensors can be used as part of an early warning approach. However, a practical system still needs careful sensor placement, regular checking, and a suitable method to reduce false alarms.

Aslan et al. [10] presented a framework for using wireless sensor networks in forest fire detection and monitoring. Their work is useful for understanding how sensor nodes can work together and how information can be collected from a wider area. A review published in 2024 [11] looked at the use of IoT and artificial intelligence in forest fire prevention, detection, and restoration. It points to the growing role of connected devices and intelligent data analysis in forest protection.

Uwanuakwa et al. [12] studied a traffic warning system for wildlife road-crossing accidents using artificial intelligence. The topic connects animal detection with road safety. A review on early forest fire detection using IoT-enabled wireless sensor networks [13] also discusses the use of connected sensors for early fire monitoring.

Schneider et al. [14] presented a multisensor approach for recognising wild animals on roads. Their 2026 study examined radar and infrared sensing for road-side detection and discussed the strengths and limits of these sensors. It shows that combining different sensing methods can improve the information available for warning systems.

3.1 Summary of the literature

The reviewed studies show four common ideas. First, sensors can help detect animal movement near roads and forest paths. Second, LoRa and other wireless technologies can connect sensor nodes over a wide area, although field testing is necessary. Third, temperature, humidity, and smoke information can support early fire alerts. Fourth, using more than one sensor or processing method can help reduce incorrect alerts. The proposed Smart Forest Corridor brings these ideas together in a single monitoring concept.

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4. PROPOSED SMART FOREST CORRIDOR SYSTEM

The proposed system is made up of sensor nodes, a controller, a communication link, a cloud platform, and warning devices. Each part has a separate role. Sensor nodes collect information from the forest or road-side area. The controller checks the sensor readings. The communication unit sends important information to a gateway or server. The server stores the data and displays it on a dashboard. Alerts can then be sent to forest officers, drivers, or nearby villages, depending on the type of event.

4.1 Animal movement detection

A Passive Infrared (PIR) sensor can detect changes in infrared energy caused by movement in its detection area. An ultrasonic sensor measures distance by sending and receiving sound waves. A camera module can provide an image or video for further checking. These sensors can be used together so that the system does not depend on only one reading. For example, a PIR detection may be checked against a second sensor before the controller records it as an event.

When movement is detected, the controller can record the time, sensor-node identity, and location. If the node is placed near a road crossing, it can activate a warning board or siren. A message can also be sent to the forest control room. The exact warning method should be selected carefully so that it informs people without disturbing or attracting the animals.

4.2 Environmental and fire monitoring

The DHT22 sensor can measure temperature and humidity. The MQ-2 sensor can respond to certain smoke and gas conditions. These readings can be checked against values set during testing. If the readings suggest a possible fire, the controller can send an alert with the node location and the sensor values. A trained person should verify the alert before taking action. The MQ-2 is not a complete forest-fire detector by itself, so it should be treated as one part of a wider monitoring method.

4.3 Controller and decision process

An ESP32 microcontroller is suggested as the main controller because it can read sensor information and support wireless communication. The program can check whether readings cross selected limits. It can also compare information from more than one sensor and separate normal readings from possible events. The limits should not be selected only by guesswork. They need to be checked through safe tests in the expected environment.

4.4 Communication and cloud monitoring

LoRa can be used to send small sensor messages over a longer distance while using relatively little power. A gateway can collect these messages and forward them through GSM or Wi-Fi to an IoT platform. A web or mobile dashboard can show recent events, sensor status, and stored readings. If mobile coverage is unavailable, the local LoRa link may still carry information to a gateway, but the gateway needs a working connection to send data to a remote cloud service.

5. MAIN HARDWARE AND SOFTWARE

5.1 Hardware components

The ESP32 is the main processing unit in the proposed design. It reads the sensor values and controls the output devices. An Arduino board or Raspberry Pi may also be used for selected development or processing tasks, depending on the final design. The project should choose one main controller for the first working model to keep the system simple.

The PIR sensor is used for movement detection. The HC-SR04 ultrasonic sensor can measure the distance to an object within its working range. A camera module can support visual checking. The DHT22 sensor measures temperature and humidity, while the MQ-2 sensor is used for smoke or gas sensing. The LoRa SX1278 module can provide communication between sensor nodes and a gateway. A SIM800L GSM module can send information through a mobile network where coverage is available.

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A solar panel and rechargeable battery can provide power to sensor nodes placed away from buildings. The power unit needs protection from rain, heat, and physical damage. The battery capacity and solar panel size must be selected based on the power used by the controller, sensors, communication module, and warning devices. The system should also monitor battery level so that low power can be reported.

5.2 Software components

Arduino IDE can be used to write and upload the controller program. Embedded C or C++ is commonly used for microcontroller programming. Python may be used for server-side processing or data analysis if needed. MQTT is a messaging method that can transfer small updates between devices and a server. ThingSpeak or another IoT platform may be used to display and store sensor data. The selected platform should be checked for its data limits, connectivity needs, and long-term cost.

5.3 Basic working sequence

During normal operation, the sensors collect readings at set time intervals or when movement occurs. The controller checks the readings and removes clearly invalid values where possible. If an event is detected, the controller prepares a message containing the node identity, time, event type, and measured values. The message is sent through LoRa to the gateway. The gateway forwards it to the cloud when an internet connection is available. The dashboard then displays the event, and the system sends the required warning.

5.4 Power and outdoor protection

The equipment will be placed in an outdoor environment, so the enclosure must protect it from rain, dust, heat, and insects. The sensor position should not block animal paths or create a danger for wildlife. Solar power can reduce the need for frequent battery replacement, but cloudy weather and shade may reduce charging. The design should include safe battery charging and a plan for maintenance.

6. EXPECTED BENEFITS AND PERFORMANCE EVALUATION

The Smart Forest Corridor is expected to provide useful information to forest staff and nearby communities. It may help detect animal movement near selected crossing points, provide warnings to drivers, and send alerts when animals are detected near villages. Environmental sensors may also help identify conditions that need fire inspection. A dashboard can make it easier to view events from more than one sensor node.

The main benefit is early information. The system cannot stop every road accident or forest fire, but it may help people respond sooner when a sensor detects a possible event. It may also reduce the need for staff to visit every monitoring point only to check whether the equipment is working. Stored data can help identify places where animal movement is reported often and where more attention may be needed.

6.1 Performance measures

The system should be tested using clear performance measures. Detection accuracy can show how often the system correctly identifies an event. False alarm rate can show how often it reports an event when there is no real event. Response time can measure the time between detection and delivery of an alert. Communication range can show how far sensor nodes can send messages reliably in the selected forest area. Battery life can show how long a node can work before it needs charging or maintenance.

Other useful measures include the number of missed detections, the percentage of messages successfully received, the time taken to restore a disconnected node, and the performance of the system during rain or high humidity. Tests should be repeated at different times of day and at more than one location. The results should be recorded honestly, including cases where the system does not work as expected.

6.2 Challenges and limitations

A forest is a difficult place for electronic equipment. Trees, hills, and wet vegetation may weaken wireless signals. Rain, dust, heat, insects, and animals may damage sensor nodes. PIR and ultrasonic sensors may also produce incorrect readings due to moving branches, people, or other objects. A camera may need more power and may not provide clear images in darkness or heavy rain. Smoke sensors can respond to conditions other than a forest fire.

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The system also depends on suitable sensor placement and regular maintenance. LoRa may provide a long communication link, but it does not guarantee coverage in every forest. GSM and Wi-Fi need network access at the gateway. Cloud services need internet access and may have service or data limits. Privacy should also be considered when cameras are used near roads or villages. Images should be collected only when needed and handled responsibly.

6.3 Safety and practical use

Alerts should be sent to responsible forest staff and should not ask members of the public to approach wild animals. Warning boards must be visible and easy to understand. The system should be treated as an additional source of information, not as a replacement for trained officers, official fire response, or road safety rules.

7. FUTURE SCOPE

The proposed system can be improved in several ways. One future improvement is the use of artificial intelligence to identify animal species from camera images. This may help forest staff understand which animals are using a corridor. However, the model would need a suitable collection of images and careful testing in local forest conditions. It should not be assumed that a model trained in one place will work equally well in another place.

Another improvement is to use edge computing. In this method, some data processing takes place near the sensor node or gateway. The system may send only important events instead of sending every image or reading to the cloud. This can reduce network traffic and may help when internet access is weak. A more advanced network could also connect several LoRa nodes and gateways to cover more than one corridor.

GPS information may be added where it is suitable and safe. It could help identify the location of a sensor node or support approved wildlife research. Drone-based observation and satellite information may also provide a wider view of forest conditions. These options would need permission, trained operators, and proper care to avoid disturbing wildlife. A mobile application could provide push notifications to authorised forest officers and local response teams.

The system may also be connected to forest department maps or a Geographic Information System (GIS). This could help show where animal detections and possible fire alerts occur. Over time, stored data may help identify common crossing areas and changes in animal movement. Such information should be interpreted by people who understand the local forest and animal behaviour.

8. CONCLUSION

This survey paper studied the use of IoT for wildlife protection and forest monitoring. The reviewed research shows that sensors, wireless sensor networks, LoRa communication, solar power, and data analysis can support animal detection and forest fire monitoring. Based on these ideas, the Smart Forest Corridor is proposed as a system that combines animal movement detection, environmental sensing, warning messages, and remote monitoring.

The proposed design uses PIR and ultrasonic sensors, a camera, temperature and humidity sensing, smoke sensing, an ESP32 controller, LoRa communication, a gateway, and a cloud dashboard. It may provide early information to forest officers, drivers, and nearby villages. At the same time, the system has limitations related to sensor accuracy, wireless coverage, power supply, weather, maintenance, and false alarms.

The design described here is a proposal based on the reviewed studies and the project concept. A working prototype must be built and tested before any claim can be made about its accuracy, range, response time, or battery life. Field testing with the guidance of forest professionals will be important. The main goal is to support safer wildlife movement and safer roads while helping people protect forest areas.

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