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Use of IoT and WSNs in Conserving Flora and Fauna: A Review

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ABSTRACT: Conserving forests and wildlife involves protecting and managing natural ecosystems to ensure the survival of plant and animal species and the health of the environment for present and future generations. This includes habitat conservation, reducing human impact, tackling illegal activities, **Reforestation and Afforestation, Research and Monitoring, Community Involvement,** and promoting sustainable practices. By providing a constant stream of data, IoT **(Internet of Things)** devices help identify changes in the environment, allowing for immediate action to protect endangered species and preserve biodiversity. This real-time monitoring is essential for maintaining the balance and conserve Flora and Fauna in our ecosystems. Using **wireless sensors and IoT** for **forest and animal conservation** is a powerful, real-world application of smart technologies to protect biodiversity and ecosystems. The Internet of Things (IoT) combined with wireless sensor networks (WSN) is changing how forests and wildlife are monitored and managed, offering a more efficient and sustainable approach than traditional methods.

I. INTRODUCTION

Wildlife sanctuaries are vital ecosystems housing endangered and protected species, making it critical to preserve biodiversity and maintain ecological balance. While monitoring animals and habitat is challenging, including technological advancements such as IoT and Wireless Sensor Networks (WSNs) (1) can significantly improve wildlife sanctuary operations. The Internet of Things offers a system of interconnected devices and sensors collecting and exchanging real-time data, including temperature, humidity, and animal activity. Automation is equally valuable-leveraging technology to manage resources, monitors animal movements, and track weather patterns. By implementing IoT and WSN technology, wildlife sanctuaries can benefit from improved insights into the conditions of the sanctuary and behaviour of wildlife, ultimately promoting sanctuary preservation. The Internet of Things (IoT) along with automation is a great technological advancement that can bring about various benefits to wildlife sanctuaries. The monitoring of wildlife and their habitat is critical for sustaining and enhancing natural ecosystems. This article looks at the role of IoT and WSNs in automation for improvisation of wildlife sanctuaries.

Recent advancements in IoT technology and Wireless Sensor Networks have the potential to Forest and wildlife conservation. Multiple wireless sensors are strategically placed in the forest. These Sensors can monitor environmental conditions like temperature, humidity, and smoke, while also detecting vibrations from cutting trees or unusual sounds indicating human activity. This data is transmitted wirelessly to a central system for analysis and alerts.

II. IOT AND WIRELESS SENSOR NETWORKS

IoT with wireless sensors plays a crucial role in modern forest management, enabling the real-time monitoring and analysis of various environmental parameters. These sensors, deployed across forests, can detect and report on factors like temperature, humidity, smoke, and even vibration. This data is transmitted wirelessly to a central system for analysis, allowing for early detection of forest fires, monitoring of tree health, and prevention of illegal activities.

Step 1: Planning and Sensor Deployment
A network of wireless sensors (WSNs) is planned and deployed across the forest and Sensor nodes are installed on trees, soil, or animals, depending on the objective. The most commonly used sensors are, Temperature sensor to predict

the forest fire, Humidity sensor to detect drought conditions, soil and moisture sensor to monitor the Tree/Plant health, smoke/gas sensor to sense the fire/gas, Motion/PIR sensor to monitor the animal movements or poachers, acoustic sensors to detect the chainsaws/gunshots.

Step 2: Sensing the Environment Data

Each sensor node periodically senses data from its environment. Each node have the, Sensor unit (to measure), Microcontroller (to process data), Radio module (to transmit), Power supply (battery or solar).Every 15 minutes, a node records temperature, humidity, and gas levels.

Step 3: Wireless Communication (WSN Operation)

Data collected by the sensor nodes is transmitted wirelessly to a central monitoring system. Technologies used for this communication include:

- LoRaWAN: A Low-Power Wide Area Network (LPWAN) technology preferred for its long-range communication capability and low power consumption, making it suitable for transmitting data from remote forest locations.
- Zigbee: Another short-range wireless technology, suitable for communication between nodes within a small cluster.
- GSM/3G/4G: Used in areas with cellular network coverage.
- Satellite: Essential for communicating data from extremely remote areas where other network options are unavailable.
- Mesh Networks: In cases where direct communication with a central gateway is unreliable due to terrain or distance, mesh networks allow sensor nodes to relay data through intermediate nodes, creating a more robust and self-healing network topology.

Step 4: Data Aggregation at IoT Gateway

A gateway receives all sensor data and acts as a bridge to the internet. Gateway functions are, first it will Collects data from all nearby nodes and Filters or compresses data Then it will Sends data to cloud/server via cellular, satellite, or Wi-Fi Examples of gateways that can be used are Raspberry Pi with LoRa hat, Arduino with GSM module and many more.

Step 5: Cloud Integration and Storage

Data from the gateway is uploaded to an IoT cloud platform like: AWS IoT, Google Cloud IoT, Azure IoT Hub, ThingSpeak, etc. In the cloud, Data is stored, organized, and analysed. Historical trends are built and Alerts/triggers are configured. This Data will be accessible via mobile apps, dashboards, or websites.

Step 6: Data Analysis and Decision Making

Forest rangers or environmental researchers use Real-time dashboards and AI/ML analytics tools to detect patterns, for example, Sudden temperature rise indicates potential fire, Unusual sounds detects possible poaching, Animal migration shows the ecological change. Based on insights, quick and informed decisions are made.

Step 7: Alert Generation and Actions

The system sends automated alerts via SMS, email, or app when anomalies are detected. Like, Smoke detected alarm for Fire alert to ranger, Animals detected near village Warning to nearby residents, Sound of chainsaw Alert will be sent to patrolling team and many more. This Ensures rapid response to conserve wildlife and prevent damage.

Step 8: Long Term Monitoring and Research

Stored data will be used for the Wildlife behaviour analysis, Climate impact studies, Deforestation tracking and Conservation policy planning. This Data will support Sustainable Flora and Fauna conservation.

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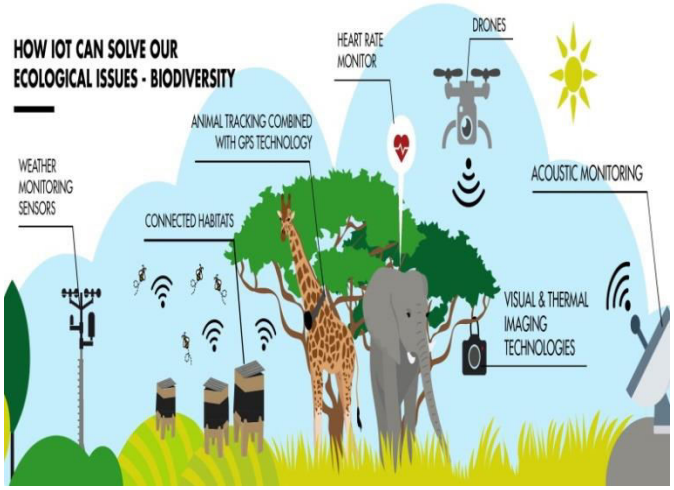

Figure 2.1: IoT technology used in Flora and Fauna conservation.

As observed in the figure 2.1, many advanced IoT devices are used to monitor, track and save the animals and forest resources.

III. IOT FOR FLORA CONSERVATION

IoT sensors and devices play a pivotal role in forest conservation and environmental monitoring. These sensors come in various forms, each tailored to specific monitoring needs. They work in harmony with advanced data analytics, contributing to a deeper understanding of ecosystems, facilitating conservation efforts, and aiding in the protection of our planet's precious natural resources (4).

3.1 Forest Fire Detection

Forest fires pose a serious threat to the environment, causing ecological, economic, and human losses. Traditional methods like human observation and satellite monitoring have limitations in real-time monitoring and accuracy. Wireless Sensor Networks (WSNs) and the Internet of Things (IoT) offer a cutting-edge solution for early and efficient forest fire detection.

Figure 3.1: Forest fire detection by sensors

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WSNs consist of a large number of interconnected sensor nodes strategically placed throughout the forest as shown in the figure 3.1. These nodes, often powered by rechargeable batteries and solar panels, collect environmental data continuously. By using suitable sensors, fire can be easily detected and informed decisions are taken. Heat Sensors measure temperature changes, which can indicate the presence of a fire or smoke. Smoke/Gas Sensors can detect the presence of smoke particles and gases like carbon monoxide (CO), which are early indicators of a fire. Humidity Sensors can monitor the moisture content in the air and fuel, as dry conditions significantly increase fire risk. Flame Sensors can be used to detect ultraviolet (UV) and infrared (IR) radiation emitted by flames and Wind Speed/Direction Sensors will provide data for predicting fire spread patterns.

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The sensor data is transmitted wirelessly to a central monitoring system using various communication protocols. Further Data is sent to a cloud server for storage and processing. When potential threats are detected, the system triggers immediate alerts to relevant authorities. Timely detection allows for rapid response and can potentially minimize the damage caused by forest fires, including loss of lives and natural resources.

3.2 Detecting Forest poachers and illegal logging with IoT

IoT technology offers a promising solution to combat illegal activities in forests, including poaching and logging, by leveraging a combination of sensors, communication protocols, and data analysis techniques.

Acoustic sensors and vibration sensors are directly attached to the valuable trees in forest. They will sense suspicious noise and vibrations caused by the wood cutting or movements. This sensor data sent to concerned authorities via WSNs in order to take immediate actions. Real-time tracking of illegal activities can help deter future offenses and protect vulnerable forest areas.

3.3 Monitoring Forest Health and Ecosystems

Traditional forest monitoring methods, such as ground patrols and satellite imagery, have limitations in terms of coverage, real-time data collection, and early detection of threats. With the advent of IoT, however, a new era of forest monitoring has emerged.

Varieties of sensors are used to monitor the health conditions of the forest environment. Like, Rate of rainfall, Temperature, humidity, soil quality, soil moisture, Air quality, Wind speed and direction, insect infestations if any. This early identification can avoid many risks that may imbalance the forest health factor. Analysis of this Real time data can even avoid the future problems (5).

IV. IOT FOR FAUNA CONSERVATION

The Internet of Things (IoT) provides a powerful and comprehensive approach to wildlife conservation in forests, which helps to address threats and facilitate effective management of Fauna in the Ecosystem.

4.1 Animal Tracking and Monitoring

IoT sensors are can monitor each and every movement and behaviour of animals. Smart collars, GPS enabled collars, Acoustic sensors, cameras can be used to study and monitor the wildlife behaviour including habitat, migration patterns, feeding habits and diseases if any. An animal wearing a GPS collar can be seen in figure 4.1.

Figure 4.1: Animal wearing a GPS enabled collar.

By analysing this data, researchers and forest authorities can gain valuable insights into the lives of endangered species, allowing for more informed conservation decisions.

One more advantage of using IoT in wildlife conservation is the use of virtual fences. Virtual fences use IoT sensors to create digital boundaries around protected areas, alerting authorities when animals approach the boundaries and

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allowing them to intervene if necessary. This technology helps to reduce human-wildlife conflict, protecting both endangered species and human communities.

4.2 Anti-Poaching Systems

Anti-poaching using IoT system provides Sensor-based perimeter protection, drones with cameras, gunshot detection systems, and smart fencing (embedded with IoT sensors) can detect intruders, trigger real-time alerts, and aid in apprehending poachers.

Figure 4.2: Working of Anti-Poaching forces.

Forest authorities will get the alerts regarding gunshots, chainsaw noises or vehicle movements using acoustic sensors. They can use Drones which are equipped with thermal and night vision cameras that enable to detect poachers even in darkness or dense vegetation and provide real-time data to the investigation teams. Working of anti-poachers team can be observed in the figure4.2.

4.3 Animal Census and Population Monitoring

The Internet of Things (IoT) is transforming wildlife conservation efforts by enabling more efficient and accurate methods for identifying endangered species and conducting animal censuses. This is achieved through a combination of sensors, data analytics, and connectivity, allowing for real-time monitoring and data-driven conservation strategies.

Camera traps equipped with motion sensors are used to automatically detect and identify different species, including endangered ones, based on visual cues like fur patterns, shapes, and movements. This reduces the need for manual identification, which is time-consuming and prone to human error. IoT can also facilitate genetic monitoring by assisting in the collection of genetic data from animal population which helps assess genetic diversity, inbreeding risks, and adaptation potential of species, guiding long-term conservation decisions (2).

V. PRESENT CHALLENGES AND FUTURE TRENDS IN IOT

While IoT holds immense potential for conservation, it also presents several challenges and ethical considerations.

1. Maintenance and Deployment of IoT and WSNs are difficult in vast and remote areas. Harsh and environmental conditions may not support all the time for real time data collection (3).
2. Limitations on usage of resources, Infrastructure, Sensor's durability, problems in power supply leads to failure in the operation of technology.
3. Technical Issues like, Connectivity, Data Overload, Data analysis and processing, security vulnerabilities can even challenge the working of IoT(7).

Future Trends in the field of IoT can be noticed as follows.

1. Advancements in Sensor Technology and Data analytics will leads to invention of small sized, energy efficient and highly durable sensors which works efficiently in any critical conditions(8).
2. Big Data and Cloud Computing can be used to collect, organise, store and analyse the large volumes of data from various sources (8).
3. Integrating IoT data with Geographic Information Systems (GIS) will enhance spatial analysis and provide a deeper understanding of forest ecosystems and their dynamics.

4.IoT technology will empower citizen scientists to contribute to conservation efforts. Mobile apps and DIY sensor kits will enable individuals to collect and share valuable data, fostering broader public participation in conservation (6).

VI. CONCLUSION

In conclusion, the blend of IoT and WSNs transforming the field of Flora and Fauna Conservation by providing advanced tools and approaches for balancing our ecosystem. From GPS trackers to Virtual fences, IoT enabled devices are collecting the real time data like, animal movements, poachers actions, presence of any fire, rainfall conditions, soil moisture, insect infestation, migration of animals, animal behaviour, overall environmental factors, human threats, and many more data will be collected from various sources. This data will be stored, analysed and used by researches, concerned department authorities and Conservationists to make smart decisions that protect our planet's precious wildlife. The potential of IoT in Flora and Fauna conservation is vast, by addressing challenges and embracing future trends, great strides in protecting the natural world can be achieved.

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