Eco Ledger: An Improved Wildlife Monitoring System Using Blockchain

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ABSTRACT

Innovative technical solutions are needed to assure data integrity and real-time monitoring in light of the declining biodiversity and the increasing difficulties in animal protection. In order to track and monitor wildlife, this article presents EcoLedger, a blockchain-based application that integrates GPS sensors enabled by the Internet of Things. With its tamper-proof ledger and precise geographic tracking of animals, EcoLedger is a centralized platform for academics and conservationists that helps preserve important data. The system offers a scalable and sustainable approach for animal conservation research by addressing important concerns including data quality, operational efficiency, and security. Through the integration of real-time tracking features and unchangeable data storage, EcoLedger promotes teamwork and offers revolutionary insights into species preservation and ecosystem management.

INTRODUCTION

The loss of biodiversity is emphasized in the review paper's opening as one of the most urgent global issues, with significant ecological and socioeconomic ramifications. Agriculture, climatic stability, and human livelihoods are all negatively impacted by ecosystem degradation and animal population declines. The importance of conservation initiatives in addressing these issues has grown. However, inefficiencies, errors, and a lack of scalability are common problems with traditional methods of wildlife monitoring and management. These approaches are susceptible to manipulation, data loss, and delays in usable insights since they mostly rely on human tracking, irregular data gathering, and centralized storage systems.

New technologies like blockchain and the Internet of Things (IoT) provide creative ways to get around these restrictions. Through sensors built into GPS-enabled devices, IoT makes it possible to collect data in real-time, allowing for ongoing monitoring of environmental factors and wildlife movements. By establishing a decentralized, unchangeable ledger for data storage, blockchain technology provides an extra degree of security by guaranteeing openness, reliability, and impenetrable record-keeping. These technologies work together to create EcoLedger, a system that will transform animal conservation initiatives.

EcoLedger provides real-time geographic tracking of animal movements and activities by combining blockchain technology with the Internet of Things. Additionally, the method guarantees safe data handling, encouraging cooperation between scientists, environmentalists, and legislators. EcoLedger aims to solve the drawbacks of conventional animal conservation techniques by providing an interactive platform for tracking, evaluating, and storing vital data. Additionally, by providing stakeholders with the means to examine habitat utilization, migratory trends, and reactions to environmental shifts, the platform facilitates proactive conservation measures. The introduction lays the groundwork for a discussion of EcoLedger's architecture, use, and possible uses while highlighting its revolutionary potential in biodiversity management and conservation research.

LITERATURE SURVEY

The review paper's literature study offers a thorough analysis of current research and technological advancements pertinent to animal conservation and monitoring. It highlights the advantages and disadvantages of the existing strategies and proves the necessity of an all-inclusive solution such as EcoLedger.

1. **Wildlife Monitoring Systems Based on the Internet of Things.**
   The use of IoT-driven systems for real-time animal tracking is a major topic of research. In a 2018 research, Patel et al. investigate how IoT sensors—specifically, GPS-enabled gadgets—allow for ongoing animal behavior and movement tracking. These sensors use communication protocols like LPWAN (Low-Power Wide Area Networks) to send data across vast distances. Although this method enables effective real-time updates, there are also serious drawbacks, including short battery life, device durability, and problems with data transfer in remote areas. Furthermore, the dependability of gathered data is diminished due to its susceptibility to loss and manipulation due to the absence of a strong data management structure.

2. **Secure Environmental Data with Blockchain.**
   The use of blockchain technology to provide safe, unchangeable data management for environmental monitoring is examined by Wang et al. (2021). Their work demonstrates how blockchain technology may produce decentralized, unchangeable records, improving ecological research's integrity and credibility. Features like smart contracts, which automate tasks like sending notifications in the event of unusual animal movements, significantly increase value. However, high processing costs and energy consumption—two important factors for wildlife monitoring initiatives with limited resources—often present difficulties for standard blockchain implementations.

3. **Geographical Resources for Protecting Wildlife.**
   The use of Geographic Information Systems (GIS) for mapping and visualizing animal habitats and migration patterns is examined in the study by Li et al. (2020). Researchers can efficiently examine animal migrations, habitat use, and population density thanks to GIS systems. These techniques' prediction power is further increased by combining machine learning and GIS, which provides insights into shifting animal trends. GIS systems' usefulness for real-time applications is constrained by their heavy reliance on static or batch-processed data. Additionally, these platforms frequently need for specific technical knowledge, which limits their use for non-technical users.

4. **Important Results and Identifying Gaps.**
   According to the literature review, IoT, blockchain, and GIS technologies are useful for monitoring and conserving animals, although they mostly work alone. IoT systems suffer with data security and longevity, but they are excellent at gathering data in real time. Blockchain offers unmatched data integrity, but it has issues with energy efficiency and scalability. Although they lack interaction with real-time monitoring systems, GIS technologies are effective for geographical analysis. various shortcomings highlight the need for an integrated solution such as EcoLedger, which combines the advantages of various technologies to produce a platform for wildlife conservation that is safe, scalable, and easy to use. The EcoLedger system solves the drawbacks of previous methods by combining these discoveries and providing a thorough framework for geographic analysis, safe data storage, and real-time tracking. By laying the groundwork for the suggested system, this literature review positions EcoLedger as a game-changing answer to contemporary animal conservation issues.

METHODOLOGY

1. **Data gathering (GPS and IoT sensors).**
   The first step of the system is to outfit animals with Internet of Things-enabled GPS sensors that can gather data in real time. Critical characteristics including location, movement patterns, and ambient variables are continually monitored by these sensors. The system makes use of effective communication protocols as MQTT (Message Queuing Telemetry Transport), LoRa (Long Range), or LTE to guarantee smooth data delivery. Even in isolated locations with poor connection, these protocols are made to manage data transport.

2. **Data Processing and Storage (PostgreSQL Database with Rust Backend).**

A backend system built with Rust, a programming language renowned for its strong performance and security features, receives the incoming data from IoT devices. This data is processed effectively by the backend, which guarantees dependability when managing high-frequency, large-scale data streams. A PostgreSQL database, which acts as the main repository for all wildlife-related data, including history and current records, is where the processed data is subsequently kept. PostgreSQL is chosen because of its scalability and strong support for intricate queries, which guarantee that the system can manage large datasets over time.

3. **Blockchain Layer Data Security and Transparency**
   The blockchain layer is incorporated into the system to guarantee data integrity and tamper-proof storage. The ledger records each transaction as a block, including updates on environmental conditions or animal movements. A decentralized, unchangeable record made possible by blockchain technology promotes openness and confidence among participants. Furthermore, the blockchain layer uses smart contracts to automate preset tasks, such notifying users when an animal enters a restricted area or displays unusual movement patterns.

4. **Front-end visualisation with Svelte and Flutter.**
   The user interfaces are made to make sure that various stakeholders may interact with them easily and intuitively: Conservationists can track the movements of animals in real time, access historical data, and receive warnings on their cellphones with an easy-to-use interface thanks to a Flutter-based mobile application. For researchers and administrators, a web application built using Svelte provides a simple yet effective interface. On desktop PCs, it makes sophisticated data management, analytics, and extensive monitoring possible.Both systems use Application Programming Interfaces (APIs) to connect to the backend in order to get and display historical and real-time data.

5. **Alerts and Real-Time Mapping.**
   To visualize wildlife movements in real time, the system integrates geospatial mapping technologies like OpenStreetMap and Google Maps. With the help of these tools, users may monitor the migration patterns of animals over time and follow their positions dynamically.
   Push notifications or dashboard updates are used to convey alerts created by blockchain-powered smart contracts, allowing for quick response in the event of important events like animals entering human habitats or abrupt changes in movement patterns.

6. **Reporting and Data Analytics.**
   Insights into wildlife behavior, habitat utilization, and migration patterns are obtained by sophisticated analytics using the data stored in PostgreSQL. To help stakeholders make data-driven decisions, analytical tools are included into the frontend interfaces to provide visual reports and summaries. Planning for conservation, allocating resources, and creating policies are all aided by these insights.

Overview of Workflow

Data Flow: IoT sensors gather and send data to the backend, which is built on Rust. It then processes and saves the data in a PostgreSQL database and generates blockchain transactions for safe documentation.

Frontend Access: Real-time updates and historical data visualization are provided by the Flutter mobile app and Svelte web application, which use APIs to retrieve processed data from the backend.

Mapping and warnings: Live animal movements are shown on geospatial maps, and blockchain smart contract-generated warnings are accessible on both platforms.

Data analysis: Researchers may examine patterns and conservationists can create successful intervention plans with the support of PostgreSQL-powered queries, which offer practical insights.

RESULTS AND DISCUSSION

Significant improvements in wildlife monitoring are demonstrated by the use of EcoLedger:

Real-Time Monitoring and Alerts: GPS sensors enabled by the Internet of Things allow for ongoing surveillance of animal movements. Smart contracts with blockchain integration generate notifications for preset criteria, allowing for quick response in urgent circumstances.

Collaboration and Data Integrity: Blockchain promotes trust among stakeholders by guaranteeing data security and tamper-proof storage. The online and mobile apps' user-friendly interfaces facilitate cross-organizational communication.

Geospatial insights: Interactive maps help with resource allocation and environment protection by visualizing animal movements, migratory routes, and possible conflict zones.

Obstacles: EcoLedger has to contend with issues like blockchain energy usage and IoT device robustness in harsh environments. Future improvements may involve extending environmental monitoring capabilities and incorporating machine learning to forecast migratory trends.

CONCLUSION

The EcoLedger system, which combines blockchain, geospatial, and Internet of Things (IoT) technology, is a revolutionary step forward in animal conservation. Several significant issues with conventional wildlife monitoring systems are resolved by EcoLedger, which combines safe, impenetrable data management with real-time animal tracking. The dependability and security of wildlife data are guaranteed by the system's capacity to gather precise, real-time data using IoT-enabled GPS sensors and the transparent, unchangeable nature of blockchain technology. Furthermore, the use of geospatial mapping technologies improves the visualization of animal migrations and the identification of important habitats, offering important information for conservation planning.

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