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REVIEW ON E-WASTE TRACKING AND TRACING SYSTEM

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ABSTRACT

The growing global concern over electronic waste (e-waste) has prompted the need for efficient, transparent, and sustainable e-waste management solutions. E-waste contains hazardous materials that pose environmental and health risks, making its proper disposal and recycling critical. In recent years, the integration of Blockchain and Internet of Things (IoT) technologies has emerged as a promising approach to improving e-waste tracking and tracing. This review examines the potential of a Blockchain-based IoT-enabled system for managing e-waste, focusing on its key features, benefits, challenges, and impact on the e-waste management ecosystem. A Blockchain-based e-waste tracking system ensures transparency, accountability, and security by recording every transaction related to e-waste on an immutable ledger, thus preventing fraud and illegal disposal. IoT devices such as GPS, RFID tags, and environmental sensors allow for real-time monitoring of e-waste, enhancing the efficiency of logistics, recycling, and compliance with environmental regulations. Smart contracts automate compliance verification and payment processes, reducing human error and improving operational efficiency. Despite these challenges, Blockchain and IoT integration holds great promise for creating a more efficient and sustainable e-waste management system, fostering a circular economy, and reducing the environmental footprint of electronic waste. This review highlights the potential of this innovative system to address the e-waste crisis while emphasizing the need for continued research, technological development, and cross-sector collaboration to overcome existing barriers and realize its full potential.

Keywords: Blockchain, Smart Cities, Security, E-Waste, Traceability, Iot, Ethereum Etc.

I. INTRODUCTION

The rapid advancement of technology has led to an exponential increase in the production and consumption of electronic devices, from smart phones and laptops to home appliances and industrial machines. Consequently, the volume of electronic waste (e-waste) generated globally has reached unprecedented levels. In 2019 alone, the world produced an estimated 53.6 million metric tons of e-waste, with only a fraction being recycled properly. E-waste is a significant environmental and health threat, as it contains hazardous substances like lead, mercury, cadmium, and brominated flame retardants, which, when improperly disposed of, can contaminate the environment and pose serious health risks to communities. The challenge of managing e-waste efficiently and responsibly has garnered increasing attention from governments, industries, and environmental groups. Traditional methods of tracking and managing e-waste, which often rely on manual processes and disconnected systems, are inadequate to address the scale of the problem. These methods suffer from issues like lack of transparency, fraud, and inefficiencies in recycling and disposal processes. To overcome these challenges, innovative solutions leveraging emerging technologies, such as Blockchain and Internet of Things (IoT), are being explored. A Blockchain-based IoT-enabled e-waste tracking and tracing system offers the potential to address these inefficiencies by providing real-time, immutable, and transparent tracking of e-waste throughout its lifecycle from collection and transportation to recycling and disposal. By combining the security and transparency of Blockchain with the real-time data collection capabilities of IoT sensors, this system can provide a more robust solution for managing e-waste. The integration of IoT devices allows for continuous monitoring of e-waste, capturing data such as location, weight, type, and condition, while Blockchain ensures that all actions related to e-waste are securely recorded and cannot be altered. Additionally, smart contracts can automate compliance checks and financial transactions, improving operational efficiency and reducing administrative burdens. This review examines the key features, advantages, challenges, and potential impact of such a system on e-waste management. It explores how these technologies can revolutionize e-waste tracking and tracing, contributing to more sustainable and responsible e-waste recycling and disposal practices. While the system holds great promise, it also faces several hurdles that need to be addressed for its widespread adoption and implementation. Through this review, we aim to provide a comprehensive overview of the current state of e-waste tracking and tracing systems, highlighting both their potential and the challenges that need to be overcome to create a more effective and environmentally responsible e-waste management ecosystem.

II. LITERATURE REVIEW

- **A. J. Jara et. al. (2011):** The generation of electronic waste (e- waste) is determined as a substantial element of solid waste administration. However, encountering e-waste in landfills is not recommended as a result of its unsafe chemicals along with hefty steels. The presence of beneficial steels like gold plus copper highlights the significance of reliable waste administration. While some industrialized nations apply contemporary family e-waste administration methods Malaysia has actually not completely applied lawful structures for house e-waste. To sustain the idea of sustainability in smarter cities reliable administration of house e-waste is vital. This research discovers the application of wise collection systems in the Malaysian e-waste monitoring as well as reusing market.

- **Mithila et. al. (2023):** The arising field of IoT-based wise e- waste administration includes the combination of modern technology as well as ecological sustainability. Digital waste postures a worldwide obstacle, with possible negative results on both the atmosphere as well as public health and wellness. In this research, we present a wise e-waste monitoring system using IoT gadgets plus sensing units for tracking, arranging, plus disposal of e-waste.

- **Sumaiya et. al. (2023):,** The Net of Points (IoT) is playing a crucial duty in establishing cutting-edge applications for wise cities with garbage administration being a details location that take advantage of numerous IoT parts like RFIDs coupled with sensing units. To resolve the requirement for an effective coupled with economical garbage collection system, this paper presents a unique approach an smart garbage design for wise cities using a crossbreed hereditary formula (GA)-- unclear reasoning engine. The system wisely reviews, accumulates and also refines details with a blurry thinking engine, dynamically establishing just how to handle waste collection.

- **Niful et.al. (2023):** The incorrect disposal of digital waste money (e-waste) offers substantial ecological plus wellness dangers on an international range, motivating significant worries. Exact category of e-waste photos is necessary for efficient administration as well as reusing initiatives. This paper presents the E-Waste Vision Dataset a detailed collection including 8 unique courses of digital gadget pictures. Additionally, the paper provides EWasteNet an unique two- stream strategy for specific e-waste photo category capitalizing on a data-efficient picture transformer (DeiT). The very first stream uses a Sobel driver for side discovery, while the 2nd stream uses an Atrous Spatial Pyramid Pooling as well as focus block to order multi-scale contextual info.

- **Rehman et. al. (2023):** The rising international problem of digital waste recycling needs effective surveillance plus traceability of digital tools as well as connected company deals amongst stakeholders. Present centralized systems do not have openness, permanence together with safety and security, preventing detailed protection of the e-products life process as well as managing big quantities of information produced in supply chain procedures. In feedback, this paper recommends a blockchain-based IoT-enabled system that uses wise agreements to tape-record customer activities on an dispersed journal making certain openness, traceability, along with safety and security.

III. CURRENT CHALLENGES FOR E-WASTE TRACKING

The tracking of e-waste presents a complex set of challenges, stemming from the nature of electronic products, the diversity of disposal pathways, and the globalized flow of waste. Here are some of the key challenges:

- **Informal Sector Dominance:** A significant portion of e-waste is handled by the informal sector, making it difficult to track and regulate. This sector often lacks proper infrastructure and safety measures, leading to environmental and health hazards.

- **Lack of Uniform Regulations:** Varying regulations and standards across different countries and regions hinder the establishment of a cohesive global tracking system. This creates loopholes and allows for the illegal trade and dumping of e-waste.

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- **Complex Product Composition:** Electronic devices contain a wide range of materials, including precious metals, hazardous substances, and plastics. This complexity makes it challenging to dismantle, sort, and track individual components.
- **Insufficient Infrastructure:** Many regions lack adequate infrastructure for the collection, dismantling, and recycling of e-waste. This results in improper disposal practices, such as land filling and open burning.
- **Cross-Border Movement:** The global trade in e-waste, both legal and illegal, makes it difficult to track the movement of these materials. E-waste often flows from developed to developing countries, where regulations may be less stringent.
- **Data Collection and Monitoring:** Accurate data on e-waste generation and disposal is often lacking. This makes it difficult to assess the scale of the problem and develop effective management strategies.
- **Consumer Behavior and Awareness:** Low consumer awareness about responsible e-waste disposal contributes to improper handling. Many individuals are unaware of the environmental and health risks associated with e-waste.
- **Privacy Concerns:** Many consumers are hesitant to recycle electronic devices due to concerns about the data that is stored on the devices. This obstacle hinders the amount of electronics that are processed through the proper recycling streams.
- **EPR Implementation:** While Extended Producer Responsibility (EPR) policies aim to shift the burden of e-waste management to producers, their effective implementation remains a challenge. There is a need for robust monitoring and enforcement mechanisms.

IV. BLOCK DIAGRAM

The proposed system architecture of the Blockchain-Based IoT-Enabled E-Waste Tracking and Tracing System integrates key technologies IoT and blockchain to provide an efficient, transparent, and secure solution for managing e-waste. The architecture consists of several components working in conjunction to ensure real-time tracking, secure data storage, and improved accountability across the e-waste lifecycle.

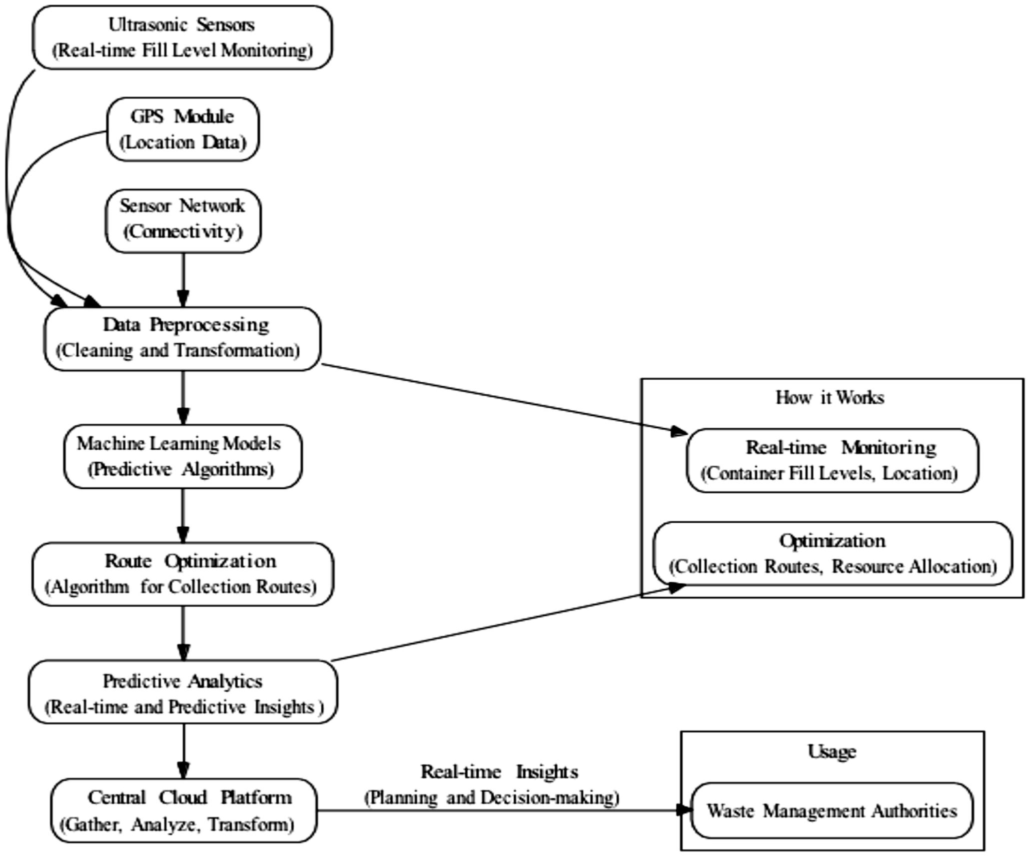

Figure 1: Block Diagram

V. MATERIAL AND METHOD

The **E-Waste Tracking and Tracing System** relies on a combination of physical materials, technological tools, software, and processes to monitor, record, and manage the flow of electronic waste (e-waste) through its entire lifecycle, from generation to recycling or disposal. Below is a detailed breakdown of the **materials** and **methods** typically used in such systems:

1. Materials

These are the physical elements used in the tracking, identification, and monitoring of e-waste:

a. Identification Tags (RFID, Barcodes, QR Codes)

- **RFID Tags:** These are small, passive tags attached to e-waste items. Radio Frequency Identification (RFID) allows the item to be tracked in real-time as it moves through the supply chain. RFID tags are non-invasive and do not require direct contact to read the data, making them suitable for automated and large-scale tracking.
- **Barcodes:** These are one of the most commonly used methods of tracking e-waste. A unique barcode is assigned to each e-waste item, which can be scanned at various points in the disposal/recycling process to track its movement.
- **QR Codes:** These two-dimensional barcodes are often used in consumer-facing systems, allowing users to scan and trace the history of their devices directly through a smart phone. They contain more data and are easier to scan via mobile devices.
- **GPS (Global Positioning System):** GPS trackers can be attached to e-waste transport vehicles (such as trucks or containers) to monitor their location in real time. This ensures transparency during the transport phase, particularly to prevent illegal dumping or unauthorized disposal.
- **E-Waste Containers and Collection Bins: Specialized E-Waste Collection Bins** Designed to safely store and transport various types of e-waste, these bins may also have RFID tags or QR codes for tracking purposes. These bins help ensure that e-waste is segregated and transported to proper recycling or disposal facilities.
- **Secure Data Storage Mediums Cloud Storage**: The centralized system where all e-waste tracking data is stored. Cloud platforms are often used for their scalability, security, and remote access features. Data regarding each e-waste item's lifecycle is logged, including collection, transport, recycling processes, and disposal. In some cases, businesses might use local servers or databases to store sensitive e-waste data, particularly in regions with limited access to cloud infrastructure.
- **Destruction Devices Shredders/Crushers**: Used for physically destroying electronic devices at certified recycling centers. The destruction of data stored in e-waste items (e.g., hard drives) is an important part of the system to ensure confidentiality and prevent data breaches.
- **Environmental Sensors Temperature and Humidity Sensors**: These are sometimes embedded into storage or transport containers to monitor conditions that could affect the safety of the e-waste, particularly for devices that contain sensitive materials (e.g., lithium batteries).

2. Methods

The tracking and tracing of e-waste involve several key methods and processes that are applied through technology, software, and operational protocols:

- **Data Collection and Entry :** The first step in tracking e-waste is gathering detailed information about each electronic item. Each e-waste item is tagged with a unique identifier (RFID, barcode, or QR code) at the time of collection. This ID is used to track the item throughout its lifecycle.Information about the item, such as its make, model, serial number, manufacturer, and condition, is recorded into the system. This is typically done via a mobile application or dedicated software by collection agents or during intake at recycling facilities.
- **Tracking the E-Waste Movement**: Once the e-waste is collected, it begins its journey through the waste management process. The movement of e-waste is tracked through a combination of technologies Each time an e-waste item moves from one location to another (from a collection point to transport, then to recycling), its RFID tag is scanned. This triggers an automatic update in the database, logging the location, time, and status of the item. If the e-waste is being transported over long distances, GPS tracking devices installed in transport

vehicles can relay real-time location information back to the system, ensuring the route and delivery to certified recycling centers are compliant.

- **Data Management and Integration:** Once collected, the data is fed into a centralized database or cloud-based platform. The platform serves as the core of the tracking system, enabling the following:
- **Data Entry and Verification**: Data related to each e-waste item is entered into the system either manually (by waste handlers or collection staff) or automatically (via RFID or barcode scanners).
- **Real-Time Monitoring**: The platform continuously monitors the progress of the e-waste items. It updates the status at each stage of the lifecycle, whether the item is being transported, dismantled, recycled, or disposed of.
- **Compliance Checks**: The system automatically checks whether e-waste disposal complies with regional or international regulations. Alerts or warnings can be generated if the waste is not processed at a certified facility.
- **E-Waste Recycling and Disposal**: When e-waste reaches a recycling or disposal facility, the system tracks further: Recyclers may scan items again upon arrival. At this stage, data regarding the dismantling process, hazardous material removal, and resource recovery (e.g., gold, copper, and plastics) is logged. Once the e-waste is fully processed or destroyed, the system records the final action, whether that's safe disposal or material recovery. The item is marked as "processed" or "destroyed" in the system.
- **Reporting and Analytics:** The system generates various reports to facilitate compliance, provide transparency, and improve operational efficiency Regulatory Compliance reports are used by businesses to ensure they are adhering to local or international e-waste management regulations. Waste Auditing trail of the e-waste journey can be produced, showing where, when, and how each item was processed. **Performance Analytics** Insights into the efficiency of the recycling process and the environmental impact of the e-waste can help improve the system. Analytics also help in identifying trends or illegal activities (e.g., unauthorized e-waste disposal).
- **Integration with Other Systems**

Enterprise Resource Planning (ERP): The tracking system often integrates with a company's existing ERP system to ensure that the lifecycle of e-waste is accurately logged and tied to financial or operational metrics.

Government Compliance Systems are Integration with government databases ensures that the tracking system complies with national or international waste management standards.

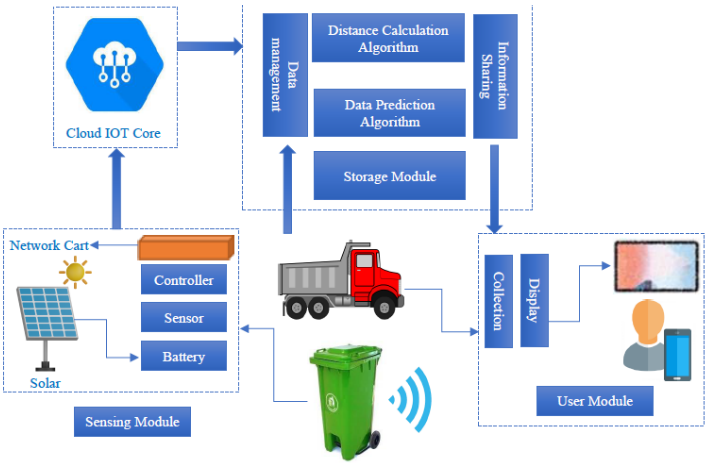

Fig. 2 Architecture of the proposed work

3. Methodology Workflow:

Here's a general workflow outline of how materials and methods are used:

- **Collection Stage**: E-waste is collected from consumers or businesses. RFID tags or barcodes are assigned. Data about the items is logged into the system.
- **Transport Stage**: E-waste is loaded into transport vehicles. GPS and RFID tracking is used to monitor location and route.

- **Recycling/Disposal Stage**: At recycling centers or disposal facilities, items are scanned again for further tracking. The recycling process (dismantling, resource recovery, destruction) is recorded.
- **Data Logging & Reporting**: After processing, the final actions are logged in the system. Compliance reports and recycling reports are generated.

VI. CONCLUSION

An E-Waste Tracking and Tracing System integrates physical materials (tags, containers, sensors) with sophisticated tracking technologies (RFID, GPS) and data management platforms to ensure e-waste is handled responsibly. The system facilitates transparency, compliance with environmental regulations, and efficient resource recovery, contributing to sustainability in electronic waste management. The E-Waste Tracking and Tracing System represents a critical step forward in the management of electronic waste, a growing global concern. With the rapid increase in electronic consumption, managing e-waste in a sustainable, environmentally responsible, and legally compliant manner has never been more important. The system provides a transparent, efficient, and secure method for tracking e-waste through its entire lifecycle—from generation to disposal or recycling.

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