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ORIGINAL

E-waste Management Using Blockchain Technology

Gestión de residuos electrónicos mediante la tecnología Blockchain

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ABSTRACT

Introduction: bridging the digital divide requires the provision of affordable, fair and quality ICT. With nearly two-thirds of the world's population still offline, there is a need to provide affordable web access for everyone. For developing countries, increasing the popularity of information and communication technology has become the most important factor in reducing poverty. The danger of electrical and electronic waste disposal contains hazardous substances, but most of the electrical and electronic equipment is still disposed of in an unhealthy environment in the field development area, affecting the level of contamination in Water, Air and Soil ultimately affecting people's health. Eliminating E-waste responsibility and protecting the environment is a challenge for countries. Smart cities can solve environmental problems through proper waste management for improving human health, protecting water resources, and reducing pollution.
Objective: in this paper, we explore how blockchain technology can help smart cities to manage E-waste by providing consistency, immutability, transparency, and accountability control in a distributed, reliable, and secure manner. We discussed the advantages of blockchain technology in various aspects of E-waste management, such as instant tracking and monitoring, E-waste disposal and E-waste management regulation compliance, proper disposal management, E-waste management, and material handling, etc. All examples of disposal services, but in our study we have found that there is no fool proof system to check the disposal of E-waste whether it has been disposed off Fully or Partially. We mainly focused on the tracking of E-waste management system for 100 % safe and eco-friendly disposal from the originating point of E-waste to end disposal point of total disposal.
Method: for this, we have used machine-learning model to find the existing percentage of disposal of E-waste at the end-point which reveals that it is never 100 %. And partial disposal of E-waste means we have still partial E-waste around us in different forms, which will be a threat for the society to be indulged in hazardous after effects of randomly dumping E-waste.
Results: after this we have modelled a Disposal Tracking System(DTS) using blockchain technology to create an E-waste data storage as Decentralized Shareable Ledger (DSL) which records the quantity and state of E-waste data from its originating point to a different level of disposal unit and finally reflect the balance of E-waste data as NIL at the end of last disposal point.
Conclusion: this system will helpful for safe and ecofriendly E-waste management and it provides complete transparency and traceability of E-waste during the life cycle of complete disposal. After implementation of this system any district or Block or Village authority can ensure to its citizens for E-waste hazards free environment and safety of natural resources

Keywords: E-waste Management; Block Chain; E-waste-data-storage; E-waste Disposal; Disposal Tracking System(DTS); Decentralized Shareable Ledger(DSL).

RESUMEN

Introducción: para colmar la brecha digital es necesario proporcionar unas TIC asequibles, justas y de calidad. Con casi dos tercios de la población mundial todavía desconectada, es necesario proporcionar un acceso asequible a la red para todos. Para los países en desarrollo, el aumento de la popularidad de las tecnologías de la información y la comunicación se ha convertido en el factor más importante para reducir la pobreza. El peligro de la eliminación de residuos eléctricos y electrónicos contiene sustancias peligrosas, pero la mayoría de los aparatos eléctricos y electrónicos se siguen eliminando en un entorno insalubre en la zona de desarrollo del campo, lo que afecta al nivel de contaminación del agua, el aire y el suelo, afectando en última instancia a la salud de las personas. Eliminar la responsabilidad de los residuos electrónicos y proteger el medio ambiente es un reto para los países. Las ciudades inteligentes pueden resolver los problemas medioambientales mediante una gestión adecuada de los residuos para mejorar la salud humana, proteger los recursos hídricos y reducir la contaminación.
Objetivo: en este artículo, exploramos cómo la tecnología blockchain puede ayudar a las ciudades inteligentes a gestionar los E-residuos proporcionando consistencia, inmutabilidad, transparencia y control de la responsabilidad de una manera distribuida, fiable y segura. Discutimos las ventajas de la tecnología blockchain en varios aspectos de la gestión de E-residuos, como el seguimiento y monitoreo instantáneo, la eliminación de E-residuos y el cumplimiento de la regulación de gestión de E-residuos, la gestión adecuada de eliminación, la gestión de E-residuos y el manejo de materiales, etc. Todos son ejemplos de servicios de eliminación, pero en nuestro estudio hemos descubierto que no existe un sistema infalible para comprobar si la eliminación de los residuos electrónicos se ha realizado total o parcialmente. Nos hemos centrado principalmente en el seguimiento del sistema de gestión de residuos electrónicos para una eliminación 100 % segura y respetuosa con el medio ambiente desde el punto de origen de los residuos electrónicos hasta el punto final de eliminación total.
Método: para ello, hemos utilizado un modelo de aprendizaje automático para averiguar el porcentaje existente de eliminación de residuos electrónicos en el punto final, que revela que nunca es del 100 %. Y la eliminación parcial de residuos electrónicos significa que todavía tenemos residuos electrónicos parciales a nuestro alrededor en diferentes formas, lo que será una amenaza para que la sociedad se vea inmersa en los peligrosos efectos secundarios del vertido aleatorio de residuos electrónicos.
Resultados: después de esto hemos modelado un Sistema de Seguimiento de Eliminación (DTS) utilizando la tecnología blockchain para crear un almacenamiento de datos de E-residuos como Descentralizado Shareable Ledger (DSL) que registra la cantidad y el estado de los datos de E-residuos desde su punto de origen a un nivel diferente de la unidad de eliminación y, finalmente, reflejar el saldo de los datos de E-residuos como NIL al final del último punto de eliminación.
Conclusión: este sistema será útil para la gestión segura y ecológica de los residuos electrónicos y proporciona una total transparencia y trazabilidad de los residuos electrónicos durante el ciclo de vida de la eliminación completa. Después de la aplicación de este sistema, cualquier autoridad de distrito, bloque o pueblo puede garantizar a sus ciudadanos un medio ambiente libre de residuos electrónicos y la seguridad de los recursos naturales.

Palabras clave: Gestión de Residuos Electrónicos; Cadena de Bloques; Almacenamiento de Datos de Residuos Electrónicos; Eliminación de Residuos Electrónicos; Sistema de Seguimiento de Eliminación (DTS); Libro Mayor Descentralizado Compartible (DSL).

INTRODUCTION

With the use of information and communication technology to bridge the digital divide, it is no surprise that E-waste is increasing at an alarming rate worldwide. E-waste is defined as “electrical and electronic products intended for complete or partial disposal or waste from production and processing”, while electronic products and electricity refer to “electrical material or electromagnetic energy”.[1,2] E-waste management, re-use of E-waste product is considered to cause serious health hazards and damage the environment when misused. It is necessary to encourage the recovery of all materials and benefits obtained from E-waste in order to protect natural resources.[3] The rapid development of ICT, modernization and technological change have caused the short working life of ICT equipment. In addition, the amount of electrical and electronic waste (EEE) in developing countries can be unmanageable.[4,5] Also, it emphasized that all countries are determined to “go green” while developing information and communication technology and pay attention to issues such as efficient use of resources and reduction of resources. Electrical waste, safety. Utilizing renewable energy sources and producing products that use the least amount of hazardous materials.[6] Electrical and

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electronic equipment (EEE) contains vulnerable and hazardous substances that can cause serious damage to the environment and public health if EEE is not properly disposed off at the end of its life. There are heavy metals (such as arsenic, cadmium, barium, lead, lithium, mercury, nickel, zinc sulfide) and other toxic substances such as PCBs (polychlorinated biphenyls). Hence these substances not disposed off in an environmentally friendly manner, it can cause serious damage.[7]

The reason for adopting Blockchain technology for E-waste management is a high level transparency and traceability of transactions. Blockchain technology is often associated with cryptocurrencies like Bitcoin. It is a decentralized database of information exchange that is verified and managed by a network of computers around the world. This information is not monitored by a central authority like a bank, but by a large community. No one can control it, and no one can go back and change or delete transaction history.[8]

Current Status of E-Waste and Its Disposal

There is no specific or ideal model for E-waste management in developing countries.

We recognize the three R of good environmental management i.e. Reduction, Reuse and Recycling. The aim is to reduce energy waste through smart production and maintenance, reuse energy products until they are useful, and recycle products that are not useful.[9,10] Smart E-waste management in developing countries should evaluate the E-waste problem and recognize that E-waste is a mixture of hazardous and non-hazardous substances, and E-waste management should be defined by considering the market entry of electrical and electronic products, the life cycle of information and communication technology tools, financial mechanisms.[11] Countries relies on many unorganized sources for recycling E-waste because there are only a few E-waste recycling organizations. More than 95 % of E-waste is used and processed in most slums of the country where untrained workers perform dangerous operations without tools, which is not only bad for health but also bad for the environment.[12,13]

E-waste Data Analysis

Using an E-waste data set obtained from kaggle.com following analysis is done using Tableau Data analysis tool to find the abandoned E-waste quantity out of total E-waste quantity and the result is presented below as a visual statistical view.

Process details

Data Set: ewaste.csv

The Dataset has the following 7 columns and approx. 210 rows containing data regarding various types of waste including Food, Civil work, Plastics, Tyres, ICT devices, papers, metals, etc.

Columns

1. Waste-type
2. Total-waste-generated (in tons)
3. Waste-disposed (in tons)
4. Waste-recycled (in tons)
5. Waste-abandoned (in tons)
6. Recycling-rate (%)
7. Year (number)

For our analysis purpose, we have extracted only five columns (1-5) and the rows containing waste-type as ICT devices such as Keyboard & mouse, VDU(Monitor), CPU-cabinets, and Printers and after preprocessing we have got only 12 valid rows.

So, we have connected the cleaned the dataset in Tableau using its load data interface and generated column chart figure 1 by aggregating the data under each waste-type which depicts that against the total waste after disposal and recycling still there is remaining quantity of waste which is disposed as abandoned.

Proposed E-waste Disposal Tracking System

After study of prevailing waste disposal status, we have conceptualized a foolproof disposal system by integrating the Blockchain technology which is capable to safe disposal of E-waste in totality compared with originating volume.

As such in most of the countries, there is no defined agency or authority exclusively for E-waste management, hence we have proposed a specific E-waste disposal system at every district level of block level based on distributed network system and distributed database system (E-waste data storage). The whole system is consisting different functional blocks connected with each other and transactions related E-waste will be marked into distributed database (Decentralized Shareable Ledger) at every block based on Block chain transactional approach. We have presented the design model of the proposed DTS in figure 2, then we have elaborated the whole system with reference to the model.

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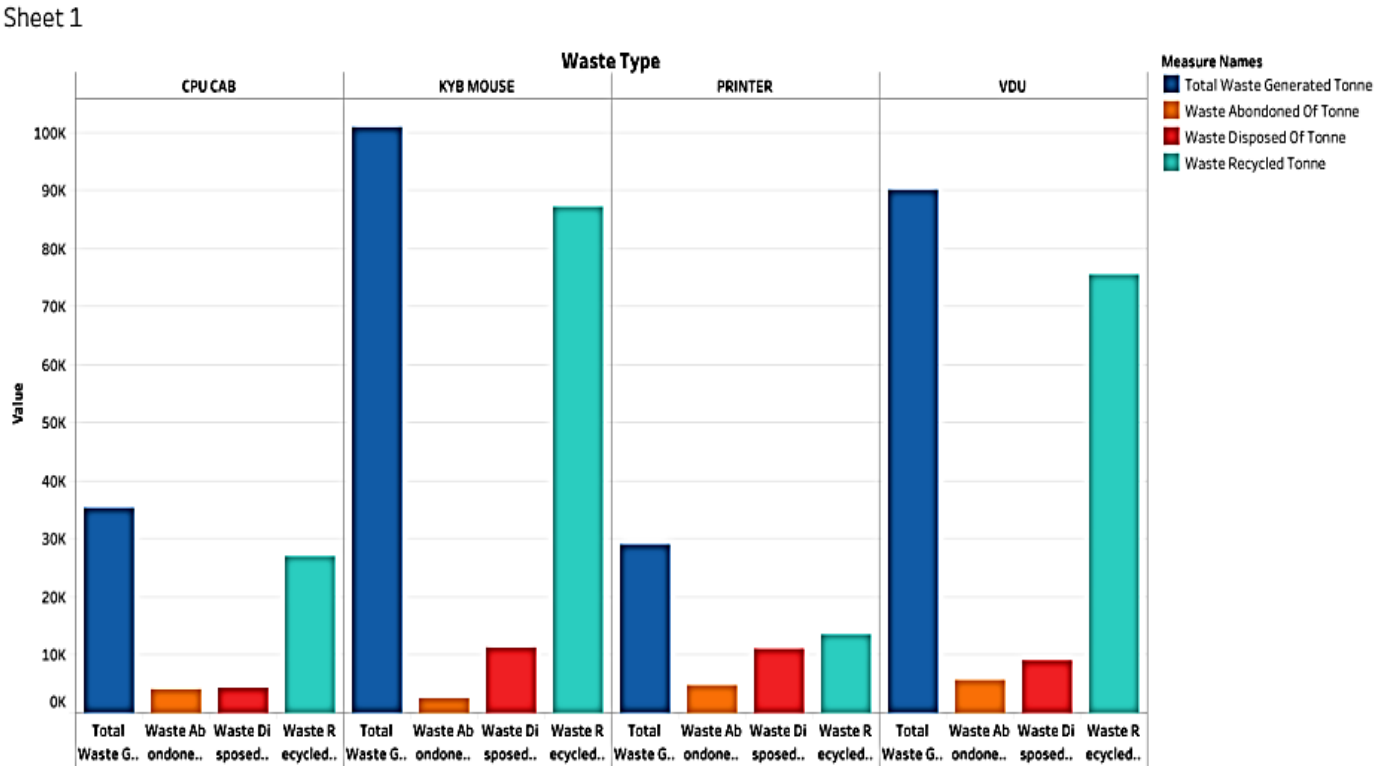

Figure 1. Statistics of E-waste disposal (Yellow bar is reflecting abandoned waste)

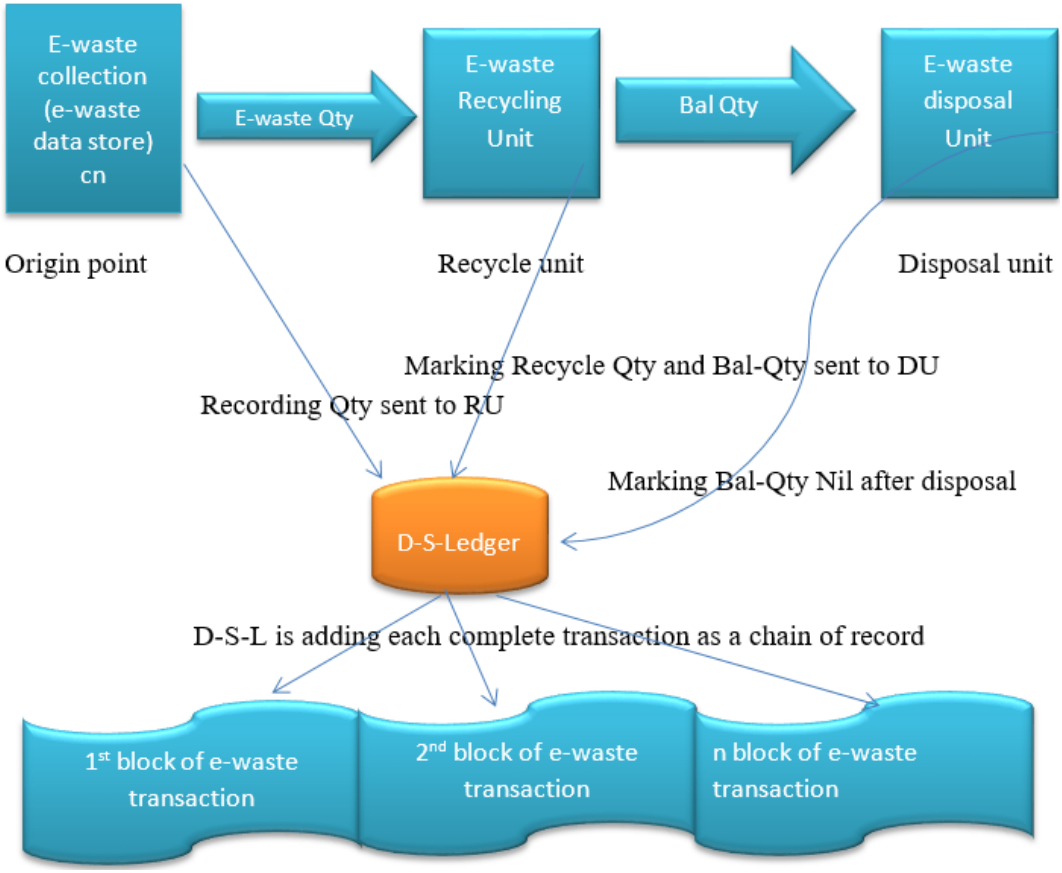

Figure 2. E-waste Disposal Tracking System(DTS)

With reference to Figure.2 DTS is having five main components which are Origin point, Recycle unit, Disposal unit, Distributed Shareable Ledger (Database) and transactional blocks stored in a database sequentially as

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chain of blocks. This system will be using private computer networks and protected databases accessible to internal and authorized users only, also this system will be made web enable to ensure its availability 24 x 7.

Origin Point

This module of the DTS, is the source of E-waste, its functionality is to collect all kinds of E-waste from various sources and store it in a E-waste store. It records all the input of (received) E-waste in the E-waste stock storage(database). Thereafter it issues acceptable quantity of E-waste to the Recycle unit, and also mark this transaction into DSL for record. So this module will be continuously doing the same task until the E-waste stock balance is nil.

Recycle Unit

This module of DTS is the process module, its functionality is divided into two parts. First part is responsible for receiving the E-waste from Origin point and segregating recyclable E-waste and non-recyclable E-waste. Second part is responsible for recycling of segregated E-waste and marking the recycle E-waste Qty into DSL. thereafter dispatching the non-recyclable E-waste to Disposal unit and also marking the dispatched Qty of E-waste into DSL for record. In this module after completion of both task bal Qty of E-waste is nil, as Received Qty = Recycle Qty+Dispatched Qty.

Disposal Unit

This module of the DTS is second process module which is responsible for receiving the disposable E-waste Qty from Recycle module and carryout necessary operation for ecofriendly and safe disposal of entire Qty received, and marking the disposed Qty into DSL for record. So after completion of disposal operation E-waste Qty under this module is nil.

Distributed Shareable Ledger

This module of the DTS is Distributed database which is performing two task, first it is receiving transactional records from all other units (i.e. Origin point, Recycle unit, Disposal unit) and then secondly it is organizing all transactions related to one transaction Qty of E-waste originated from Origin point, then processed and reported transaction Qty from Recycle unit and finally processed and reported transaction Qty from Disposal unit, by integrating in a single block or database record and continually adding blocks in a chain fashion. This module is also helping the management to check and trace the transactions of E-waste status any time by displaying recorded blocks of E-waste transactions posted by that point of time.

Challenges in Implementing Blockchain for E-waste Management

Despite the potential benefits, several challenges exist in implementing blockchain technology for e-waste management. These challenges include the high energy consumption of blockchain networks, the need for standardized data protocols, and the integration of blockchain with existing e-waste management infrastructure.

Energy Consumption

One of the major concerns with blockchain technology, particularly with public blockchains, is the high energy consumption associated with the proof-of-work consensus mechanism. This has led to concerns about the environmental impact of blockchain, which could offset some of the sustainability gains achieved through improved e-waste management. Researchers are exploring alternative consensus mechanisms, such as proof-of-stake, that consume less energy and are more suitable for applications in sustainability contexts.

Data Standardization and Interoperability

Another challenge is the need for standardized data protocols to ensure interoperability between different blockchain systems and existing e-waste management infrastructure. Currently, there is a lack of consensus on data formats and standards for recording e-waste transactions on a blockchain, which can hinder the integration of blockchain solutions into existing workflows. Collaboration between industry stakeholders, regulators, and technology providers is needed to develop common standards that facilitate the seamless adoption of blockchain technology in e-waste management.

Adoption and Scalability

The adoption of blockchain technology in e-waste management also faces barriers related to scalability and user acceptance. Small and medium-sized enterprises (SMEs), which constitute a significant portion of the e-waste management sector, may lack the technical expertise and resources needed to implement blockchain solutions. Additionally, concerns about data privacy and the complexity of blockchain systems can deter stakeholders from adopting this technology. Addressing these challenges requires efforts to simplify blockchain

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platforms, provide training and support for users, and develop scalable solutions that cater to the needs of different stakeholders in the e-waste management ecosystem.

Future Directions

Future research in the application of blockchain technology for e-waste management should focus on developing energy-efficient blockchain models, establishing data standards, and exploring the integration of blockchain with other emerging technologies such as the Internet of Things (IoT) and artificial intelligence (AI).[14,15,16] IoT devices, for instance, can provide real-time data on the status of electronic products, which, when combined with blockchain, can create a comprehensive and dynamic system for tracking e-waste. AI can further enhance this system by providing predictive analytics and optimization algorithms for e-waste collection and recycling processes.[17] Additionally, policy frameworks that support the adoption of blockchain technology in e-waste management are needed. Governments and regulatory bodies can play a crucial role by providing guidelines, incentives, and funding for pilot projects that demonstrate the feasibility and benefits of blockchain-based e-waste management systems.

CONCLUSION

Therefore, with aforesaid details of the E-waste Disposal Tracking System (DTS), we summarized that this system will helpful for safe and ecofriendly E-waste management and it provides complete transparency and traceability of E-waste during the life cycle of complete disposal. After implementation of this system any district or Block or Village authority can ensure to its citizens for E-waste hazards free environment and safety of natural resources. As the functionality of each modules of DTS strictly ensuring that no abandoned Qty of E-waste is existing after completion of entire process of the system. So, finally we recommend this system to waste management authorities of the countries to adopt this system along with their existing waste management system or implement it as an exclusive E-waste management system for the safety of the citizens and natural resources and also supporting green computing approach.

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AVAILABILITY OF DATA AND MATERIALS

The datasets used in this research are publicly available and properly cited in our dataset section for

transparency and ease of replication.

COMPETING INTERESTS SECTION

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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