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A Block chain and Neural Network Approach to Enhancing Reverse Logistics of Electronic Gadget Life Cycle Tracking

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Abstract

INTRODUCTION: The significance of handling Reverse Logistics (RL) within the electronic goods sector has increased due to the emphasis on eco-friendly product disposal and the retrieval of components, driven by environmental concerns and regulatory demands. The refurbished and used mobile phone market size is valued at US$ 53.81 billion in 2022 and is expected to grow at a CAGR of 10.8% during the forecast period, reaching US$ 120.96 billion by 2030. With a lot of emphasis given on the RL aspects.
OBJECTIVES: This paper proposes a framework that uses blockchain based Hyperledger that records the life cycle history of the electronic gadget on an immutable ledger. Additionally, a neural network helps to calculate the quality index of the gadget and also the price.
METHODS: Quality Index (QI) considers various sensory data into account and estimates the status of the gadget with certain accuracy. Smart contract provides automated transaction options between targeted stakeholders that helps to mitigate the security issues that happened among the stakeholders of the RL process. The integrated frameworks act as a decision maker for evaluating the condition of the mobile product or further movement into the RL process.
RESULTS: In all, the traceability of product life cycle history assists in ensuring the quality of the returned products therefore optimizing the traditional quality inspection processes involved in reverse logistics of the electronic goods sector. The integration of blockchain and neural networks creates a robust and private ecosystem for stakeholders involved in reverse logistics.
CONCLUSION: The stakeholders of the entire mobile electronic gadget experience a transparent system that helps to achieve sustainable reverse logistics principles.

Keywords: Reverse Logistics, Block chain, Neural Networks, Smart Contracts, Electronic Gadget.

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1. Introduction

The growing technological advancement with shrinking life cycles of electronic gadgets is mounting a global concern of proliferation of e-waste (Electronic waste). Ping et al., 2024 pointed out that the lack of robust system in the field of e-waste management system for tracking, recycling and repurposing of electronic products. As told by authors that 4 to 5 percentage increase of e waste throughout the world every year and in their work also talks about the hazardous impact on human health [1]. The reverse logistics management system in the area of electronic good constitutes the process of collection, transportation and recovery of all types of used electronic goods to ensure the extraction of residual and safe disposal [2]. According to research data by the end of 2030, the volume of global e-waste is expected to reach upto 74.7 million metric tons, which shows a urgent need to rectify the current reverse logistic system. Reverse logistics has shown a tremendous evolution from a marginal operational concern to a strategic driver of circular economy and sustainability. This major shift is actually occurred due to the sudden rise of volume in electronic waste and the global pressure due to the environmental protection recovery mechanism under Extended Producer Responsibility (EPR) regulations [2]. Apart from that [3] focused on the continuous progress of RL, traditional RL model still suffer from the various challenges such as lack of transparency, data fragmentation, unstandardized quality control and inspection mechanism in the electronic sector. Moreover, [4] mentioned about the E Waste growth and the growth in consumerism in electronic gadgets, especially mobile phones, stands a top position in the area of e-waste due to their complex material composition.

As per the work carried out by [5] reverse logistics plays an important part to deal the sustainability issues associated with product life cycle of electronic products. The RL in electronic industry however faces various obstacles in path of recycling such as lack of transparency, traceability, stakeholder trust issues and improper infrastructure. In spite of providing economic benefits through remanufactured items, the recycling markets are dealing with fragmented information flows and uncertainties in quality standards, especially in high value discarded products [6]. These challenges can be tackled with the introduction of blockchain technology in reverse logistics infrastructure and provide a system with real time tracking, immutable data recording, authenticating the quality reports and ensuring the stakeholder accountability through immutable transaction logs; [8], [10]. In addition to that focused on proposing a framework not on the implementation. The transactions are encrypted and those can be a strong pillar to enhance the auditing ability in the reverse logistics context. The application of blockchain when combined with IoT sensors and smart contract for e-waste management has shown a great growth trends in terms of recycling rates, material recovery and key stakeholder participation [2].

Authors [2], [10] emphasized the importance of integrating blockchain with Internet of Things (IoT), smart contract and taken based incentives in the reverse logistics particularly in the high impact sectors of e- waste such as battery recycling and mobile phones. The modern system not only provide a smooth path for recycling but also increases the credibility of remanufacturing by providing accurate valuation of product [6]. Nevertheless, neural network and artificial intelligence models are progressively used to assess the end of life status of products, simply the assembly and disassembly of product, and evaluate the recovery value [2], [7] used the empirical approach to validate their model and found that blockchain model can increase the recycling rate by 27% with improved material recovery by 18% and drastic improvement in stakeholder participation as well. The implication of data driven system improve the efficiency of RL system by managing proactive planning and minimizing the human interventions. The integration of blockchain encrypted product data blocks with the recycling testing centers allows the model to ensure the information asymmetry and provide a fair valuation of each remanufactured product [6]. This represents a critical issue of RL system i.e. limited traceability, undervaluing of high quality components/product and customer mistrust for recycled products. The paper presents a framework that describes how to use neural networks to calculate the Quality Index based on input data from the device under consideration. The paper organized as follows section 2 gives a detailed analysis on existing literature, section 3 deals with framework and Implementation, section 4 describes the results finally section 5 explains about the conclusive remarks.

2. Literature Review

The importance of safeguarding sensitive data handled by robots/sensors to maintain privacy and trust. It notes that while remote access improves operational flexibility, it also introduces security vulnerabilities through weak authentication and insecure interfaces that could be exploited by cyber attackers. Robots face threats from malware and various cyber-attacks such as viruses, worms, and ransomware. To counter these risks, it calls for a comprehensive cybersecurity strategy including secure design, strong authentication, encryption, and user training. Finally, it highlights the need for collaboration among industry, researchers, policymakers, and experts to build resilient robotic systems capable of resisting evolving cyber threats.

The development of density and environmental impacts of supply chains has led to an increased focus in the academic and industrial world in reverse logistics particularly when discussing the unbundling of digital technologies. As of late, there is evidence that block chain is a potential future tool on its way to more transparency, traceability, levels of trust, and even sustainability within the reverse logistical systems [8], [9].

Another source by [8] addresses the role of block chain as a solution to both trust and traceability gaps in circular supply chains because it offers immutable records during the reverse supply chain process. In their work, they prove the hypothesis that the implementation of block chain significantly enhances transparency of data, in turn, allowed them to comply with regulatory standards and make collaboration between stakeholders in industrial waste management networks much easier. The same results are reinforced by [9], who focus on the mutually beneficial application of block chain and IoT in tracking returned goods in real-time, which streamlines the reverse flows and minimizes the cost of operations. These improvements help to solve one of the most pressing issues of reverse logistics, tracking and audit of the return of products and recycling processes.

The idea of sustainability becomes one of the most significant. [11] summarize the evidence regarding the issue of blockchain as the driver of the increased rate of circular supply chain transitions due to its challenge in the control of the returns process and the transportation of hazardous wastes. This is because they advocate blockchain as a major facilitator of the circular economy paradigm because of its ability to trace the origin and nature of recycled material, an argument that has been confirmed by [12] who expose how blockchain enables checking of product authenticity and compliance to the environment when undergoing recycling. As a result, blockchain does not just facilitate operational quality but also informs committed environmental and social governance (ESG) undertakings of companies.

Even though it appears to be promising, blockchain implementation has multifold challenges in reverse logistics. [13] consider it to be trust-building and regulatory support that are essential enabling factors, and cost, interoperability and data privacy concerns the essential barriers to large-scale implementation. Such results are in consistent with those of [14], who also propose a structured framework where technological, economic, and cultural obstacles are placed in the center of the main adoption determinants. Literature consensus indicates that the implementation is an exercise that could be done in phases alongside processes that focus on organizational goals and regulatory structures to overcome such challenges.

At the same time, the sources also accentuate increased tendencies of incorporation of blockchain into artificial intelligence (AI) and Industry 4.0 technologies in order to drive reverse logistics effectiveness. [15] describes a strategic roadmap in manufacturing and supply chains in which the innovation benefits of predictive analytics and neural network applications controlled by AI further enhances the blockchain traceability by boosting the reliability of operation and decision-making. Apart from above [16] apply such ideas to the supply chain industry, showing how data analytics enhance reverse flow accuracies on forecasting and controlling risks. Such technological synergy can be described as enabling proactive provisions in reverse logistics management, minimizing waste and maximizing resource recovery, which is an effective reverse logistics digital transformation approach.

Even though the literature suggested a greater impact of blockchain and AI in reverse logistics, there is still some areas which remain untouched and can be considered as research gap. Most of the research studies have addresses the blockchain or Artificial intelligence independently. Few studies only have used the combined approach of blockchain and neural network to assess the quality of product to determine the economic value dynamically [17]. In the current study, researchers have tried to achieve this using quality index in the current framework.

Despite the fact, mobile phones contributes a significant part in e-waste globally, there are very few blockchain based reverse logistics systems are customized particularly to them, especially to deal with privacy preserving mechanism and quality index based condition estimation [6]. The models often lacks to track the product life cycle in real time, from product selling, usage, return, evaluation and resale. Researchers have not explored the automation in transaction execution in many RL system. Smart contract are adopted in many conceptual frameworks however their real life applications are still need to be explore, particularly in case of dynamic pricing or reverse logistics based on device diagnostics criteria.

The current proposed research is an attempt to fill these gap by adopting an integrated blockchain neural network based smart contract framework which specifically designed for the RL of mobile phones. This framework aims to optimize the product/ device assessment, increase stakeholder trust and improve RL sustainability. With the advent of technology, electronic gadgets manufacturing and their associated products have taken an emerging trend. With reduction in their life cycle day by day their reverse logistics aspects (Recycle, Reuse, Repair) becomes a tedious task in the current scenario.

As per [2] the numbers show that there is a significant increase in the e-waste quantities, almost seven percent per year and these numbers are doubling every year. The awareness provided to consumers helps a lot while recycling this waste to at least some extent. At the same time the manufacturer had the responsibility to track the device status and propose various mechanisms for their consumers to take that product in a win-win situation for both the parties. Some limitations are inhibiting the stakeholders particularly to companies to help in the process of the current health status or life cycle of the existing devices with a fear of loosing or tampering their trademark or intellectual data. However, the cryptographic techniques that are available definitely help to mitigate the security issues mainly the block chain will definitely be helpful due to its unique features such as transparency, immutability and security.

This paper introduces an integrating framework that integrates neural networks and block chain tracking the life cycle of a mobile phone in a secure, transparent record of a device's journey, while neural networks analyze data for real-time insights. This synergy aims to enhance traceability, optimize processes, and promote a circular economy, thereby addressing environmental concerns and advancing sustainable gadget life cycle management.

Blockchain and neural networks have turn out to be an emerging technology upgradation in the field of reverse logistics particularly in the recycling of mobile phones. Several researchers have explored the role of blockchain and neural networks in various logistic system to ensure the traceability, data security and accuracy and reliability in data transfer to avoid any kind of data leaking.

[17] presented a blockchain based framework for the remanufacturing and refurbishing activities (reverse logistics) for mobile phones. The study discussed the importance of data privacy, regulatory compliance and operational trust among key partners of supply chain. A significant contribution was their establishment of a local private blockchain utilizing smart contracts to uphold the chain-of-custody across all reverse logistics.

Researchers have discussed the collaboration of blockchain technology with digital product passport (DPPs) to control the data granularity and mitigate traceability challenge in reverse supply chains. This framework track the lifecycle of product in a transparent manner and improve the information reliability among stakeholders [18]. The strategic drivers and outcomes are investigated by [19] using Porter's value chain and transaction cost economics theories for the blockchain adoption in reverse supply chain. The empirical results of the study suggested that for logistics enterprises key important drivers are traceability, transparency and stakeholder collaborations, whereas high transaction cost and inconsistent data are considered as key barriers. [8] presented a Triple Retry framework similar to blockchain's core competencies i.e. trust, traceability and transparency for a reverse logistics system with core processes such as recycle, redistribute and remanufacture. Study frameworks has been validated through actual industrial application which proves the importance of decentralized platforms in product lifecycle visibility. Blockchain based traceability model using dual chain structure has been used for green reverse logistics. This method utilizes Merkle trees and a licensed chain to facilitate high-throughput traceability, thereby minimizing logistics waste and ensuring product returns to manufacturers [20].

The work supporting [21] regulatory policies related to waste management in India has drastically changed the scenario of E-waste Management. The certain guidelines were mentioned for all the entities involved such as manufacturers, refurbishers, and recyclers to relook the current reverse logistics practices or further enhancement. The challenges faced by the electronics industry during their reverse logistics process has been included. This mainly focuses on ease of understanding of complex topics. The integrated framework that proposed by [22] helps to understand the vehicle reverse logistics aspects in the context of block chain that add transparency and traceability throughout their life cycle. Interestingly, the reverse logistics of mobile phones in their work and used the concept of block chain to solve the security issue. [23] carried out comprehensive study that highlights the need of emerging technologies such as block chain in the context of Supply Chain logistics. It explores the possible applications and limitations in this area . In response to the growing importance of blockchain in waste management. Later [17] proposed a comprehensive blockchain-based framework for both forward and reverse supply chains in E-waste management. Their work contributes to the development of sustainable practices in handling electronic waste by leveraging the inherent features of blockchain technology. Furthermore, [24] emphasized on blockchain based framework that helps to fill the electrical vehicle discussed in their work. Also, a reputation system based on block chain for assessment of data credibility in vehicular networks, offering insights into enhancing trust and reliability in data exchanges within the automotive domain. neural networks were introduced by [25] to monitor the health status of the battery life time by comparing with the standard models. Some authors [26] describes about the combination of neural networks and several estimation methods to predict the reliability index of the electronic components.

As an extension of the modern research, [27] present a futuristic roadmap, which combines blockchain technology with the Internet of Things (IoT) to be applied to the logistics and supply-chain logging. By the framework of decision making projected by the authors, it is possible to pursue the global aims of sustainability and security, hence, providing us with a rough, but sharp vision of how the logistics operations can be provided in the future.

3. Methodology

The fast development and abandonment of electronic gadgets are among the factors that have accumulated to create an environmental problem, which means that more electronic waste is created. There is the absence of a responsible reverse logistics system, as well as one that tracks the life cycle and thus has a transparent and efficient process. Current practices are inadequate in terms of real time observations, predictive maintenance and thus there is a lack of efficiency in management of gadgets. This lack of integrity among the stakeholders hinders synergy and sustainability practices as displayed in the Fig. 1. Postulated model of integrated Reverse logistics model of electronic gadget.

This issue explains why it is necessary to develop an innovative framework that considers both the blockchain and the neural networks combined where it is needed to consider the global impact and make the administration of the life cycle of electronic gadgets more efficient.

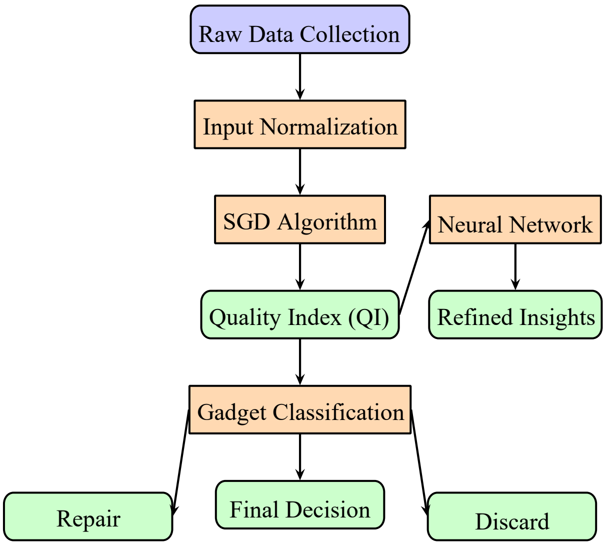

Figure 1. Proposed framework for the integrated Reverse logistics model of electronic gadget.

The framework in Figure 2 indicates the fine details of the above given framework which interprets the steps that are involved in computing the quality index together with integration with smart contract. This painting has two layers. The first layer is produced on the base of a neural network and the second one consists of Hyperledger (Blockchain) framework. The layers will collaborate with each other. Quality Index (QI) is one of the key indicators, which should be used to measure electronic devices, and combines numerous parameters including screen-on time, benchmark performance, drop cases, temperatures, refresh rate, etc. This versatile index is an indicator of overall performance, life of a product and the experience on the product shown in fig.3.

3.0. Case study

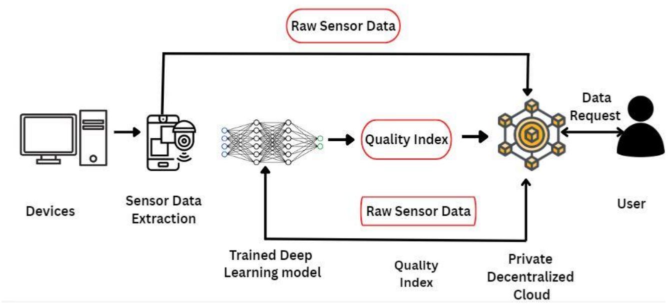

Figure. 2. Shows detailed view of the mentioned framework Electronic Gadget Life Cycle

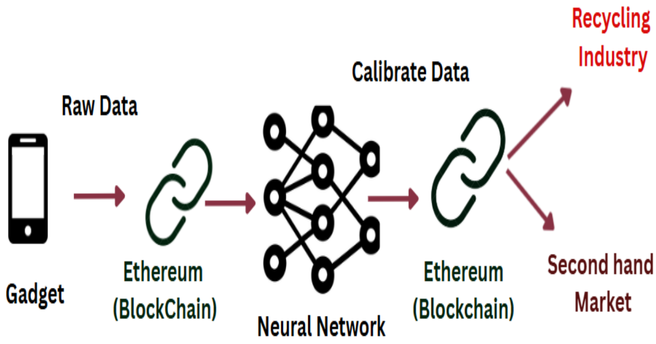

Figure 3. A Blockchain and Neural Network-Based Framework

3.1. First Layer: Stochastic Gradient Descent (SDG) Algorithm with Online Learning

An electronic gadgets QI development would require a more integrated case approach wherein the various parameters would be incorporated into a Stochastic Gradient Descent (SGD) algorithm with parameters optimised using the online learning optimization methods. Relative parameters like the screen-on time, benchmark scores and accelerometer-derived drop data can be helpful in the reports about the usage and letting on the durability. The data associated with the temperature of the processor and motherboard together with heating frequency gives the gist of the information about thermal performance. The display refresh rate of the display is significant and benchmark scores along with memory statistics are crucial indicators to get an idea of the processing abilities as a whole. Other facts such as Specific Absorption Rate (SAR) and sensor state are relevant in radiation exposure and functionality analysis of the devices.

The steps that were followed in the process of transforming raw data into some useful interpretations with the help of a neural network and the SGD algorithm can be observed in the Fig. 1. This starts by data gathering and then this becomes the foundation of the analysis process. Then these data are processed and an iterative optimization algorithm that has the ability of optimizing the model parameters so as to provide minimum loss in the loss function. The adjustment is a relevant factor to the improvement of the functioning of this model. When the SGD algorithm is run on the dataset, it shall generate a QI; this shall be used to measure how the model is performing. The generated index is then pumped into a neural network that is used as a mechanism of improving predictive abilities through utilization of QI. The data is then processed and refined by the neural network and eventually more fine tuned results improve the decision making and the understanding of the data as being composed of other related complex pattern. The correlation between the two optimization methods and the neural network gets harder in the process and thus, it is a powerful tool that can be applied in activities such as following up the life cycles of electronic gadgets since this is the accelerator of reverse logistics since it enables enhanced sustainability. Fig. 5 depicts the manner in which the SGD algorithm can be used with the input, normalisation and colour look analysis in the view of improved outcome of performance analysis.

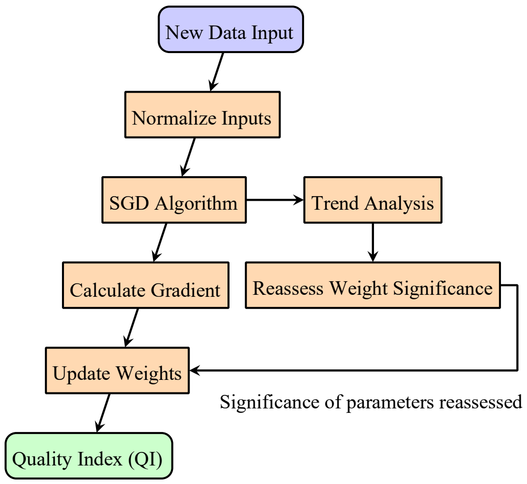

Figure 4. Flow Diagram of the SGD Algorithm with Input Normalization, Trend Analysis, and Weight Reassessment

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. To compute the QI using the SDG algorithm with online learning, we first normalize each parameter to a common scale [0, 1] using the formula:

$$X^I=(X-X_{min})/(X_{max}-X_{min}) \quad (1)$$

where X represents the original parameter value, and Xmin and Xmax denote the minimum and maximum values in the dataset.

Each parameter is assigned a weight based on its importance:

$$wS + wB + wD + wT + wR + wM + wSAR + wSS = 1 \quad (2)$$

For example, weights may be allocated as follows

wS =0.1 wB =0.2

wD =0.1

wT =0.15

wR =0.1

wM =0.15

wSAR =0.1 wSS =0.1

With the integration of online learning, the algorithm continuously updates the weights based on new data, which shows real-time changes in parameters. For example, if data shows that certain environmental conditions, such as high temperatures, adversely affect gadget performance, the algorithm increases the weight assigned to temperature metrics, thereby QI's predictive accuracy gets enhanced.

The Quality Index is calculated by summing the normalized values, weighted by their respective impacts:

$$QI = wS \cdot S' + wB \cdot B' + wD \cdot D' + wT \cdot T' + wR \cdot R' + wM \cdot M' + wSAR \cdot SAR' + wSS \cdot SS' \quad (3)$$

The last QI is 0 to 1(scaled-down) with the highest (1) representing the best quality according to the parameters computed. With the SDG algorithm being able to process these inputs and when combined with online learning sophisticated and flexible evaluation of electronic gadgets can be achieved. It equips the manufacturers with more in depth understanding about the performance of their products along several aspects and also provides advantage to the consumers so that their task of decision making becomes much easier in terms of overall reliability, efficiency and the user specific features of a gadget. Nevertheless, the online learning integration makes SDG algorithm responsive to the changes and emerging trends and conditions, thus resulting in the increase in the quality of effort put to the assessment of the product quality and consumer satisfaction.

3.2. Second Layer: Private Decentralized Cloud Storage.

The term "Private Decentralized Cloud Storage" is often used to describe the storage architecture that has two main properties: privacy (fine grained, access controls, encryption and user ownership of data) and decentralization (storage of data not solely with a centralized provider but rather distributed across multiple independent nodes). Creation of Private Decentralized Cloud Storage where the indices of the quality of the electronic gadgets and the input values would be stored provides a strong option in terms of transparency to the stakeholders. All the parameters, including screen-on time, benchmark ratings, drop rates, temperatures, refresh rate, and others are stored safely on the decentralized ledger pertaining to each device. This will give a permanent and traceable life history of the gadget performance in its life cycle.

This feature of the Private Decentralized Cloud Storage has ascertained the ability of stakeholders such as manufacturers, retailers and consumers to have real time status and information on conditions of any electronic gadget anytime. Smart contracts utilized through the Private Decentralized Cloud Storage will streamline the verification process since quality indices can be easily and quickly validated with regard to prequalified standards.

The Private Decentralized Cloud Storage diagram is an extensive system that dictates how electronic gadget data have been managed over their lifetimes. It begins with data ingestion, in which the device data on performance measures are gathered and transmitted to an impenetrable decentralized ledger. This keeps the information unchangeable and it cannot also be altered thus, leading to increased confidence among the stakeholders. Smart contracts automate the data verification and processing, which simplifies business operations and eliminates the necessity to involve human efforts to perform such operations. Access control mechanisms are used to defend the privacy of users and data integrity where only the authorized users will have access to sensitive data.

Round the clock monitoring and real time reporting makes the parties aware of the situation and state of a gadget: the maker, the retailer and the customers. This aspect makes proactive control easy since it is possible to make decisions which can be according to repair, resale, or recycling locally. An immutable audit trail is keeping the history of all interactions thus promoting compliance and accountability. In general, this system enhances transparency and collaboration by the stakeholders thereby promoting improved decision making by qualified decisions and more sustainability when it comes to governance of electronic gadgets.

This system based on blockchain has a number of benefits. First, it enhances transparency in the sense that it allows the stakeholders to follow the entire history of a gadget hence building trust and accountability. Since the Cloud Storage is also decentralized, it is also impossible that sensitive data in the system could be tampered with. The stakeholders can use proactive means to address such ill as malfunctions or failings, as well as the inefficiency that results in waste of resources in order to streamline the reverse logistics and reduce wastes.

Furthermore, collaborations among the stakeholders are simplified with the help of the Private Decentralized Cloud Storage. It gives real time overall feedback to the manufacturers about the quality of their products and the consumers are not misplaced when buying these products. The resale value is also bumped up due to the traceability of gadgets that have been instated under the framework since the entire history of the whole life cycle and condition of a gadget may be determined.

In short, the integration of the Private Decentralized Cloud Storage will increase the level of transparency, security, and collaboration across the entire electronic gadget life-cycle pictured in Fig.3. It gives the stakeholders access to real-time information and this results in improved decision making, accountability and overall efficacy in the upholding of quality and sustainability of electronic devices.

3.3. Integration of neural network with smart contract.

Within the suggested framework illustrated in Fig. 2, once the required extraction of certain pieces of data by each of the electronic devices is complete, including device-specific identifiers, the data will be initially stored on the Private Decentralized Cloud Storage. This provides the instant and safe storage of raw data, upholding transparency and immutability.

Thereafter, the neural network incorporated in each device reads the raw information in the Private Decentralized Cloud Storage. This information is fed into the neural network which evaluates and analyses it, and utilises the adaptive nature to identify an improved Quality Index depending on the gadget. Other data collected is structured and calibrated and then uploaded once again on the Private Decentralized Cloud Storage and this creates a comprehensive and verifiable record of the performance and usage patterns of the gadget over its life cycle. Such an iterative process that begins with the capture of raw data and ends with uploading processed information on the Private Decentralized Cloud Storage guarantees a secure yet transparent and step-by-step tracking of the electronic gadget life cycle. It presents the stakeholders with real-time and personalized information, which aids in the maintenance of a check and balance and the sustainability of electronic device management.

The neural network that is included in every device will access the raw data contained in the Private Decentralized Cloud Storage.

Then, the raw data of the Private Decentralized Cloud Storage becomes accessible to neural networks incorporated in each device. Neural network uses this data, analyses it, and utilizes its self-adjusting abilities to create a polished Quality Index that characterizes a particular gadget. Such structured and calibrated data, combined with the so-called unique device ID is subsequently uploaded onto the Private Decentralized Cloud Storage, establishing a verifiable record of the entire life cycle of the gadget including its product performance and trend of usage. Such an iterative process involving initial data storage of raw data and ending with the publication of refined information on the Private Decentralized Cloud Storage will be secure, transparent, and progressive with regard to tracking and monitoring electronic gadget life. It affords the stakeholders with the correct and personalized information, which promotes the accountability and sustainability of electronic device management.

4. Results and Discussions

In the framework which we have proposed, after the compulsory extraction of specific data points from each electronic gadget, including the unique device ID, the dataset is initially recorded on the private decentralized cloud like Hyperledger (blockchain). This ensures the immediate and secure storage of raw data, which maintains the transparency and immutability. The neural network and SGD algorithm embedded within each device accesses the raw data from the Hyperledger blockchain whenever required. The neural network processes and examines the data points, utilizing its adaptive power to generate a standardized QI which is gadget specific. This structured and calibrated data, along with the unique device ID, is uploaded back onto the decentralized cloud , creating a comprehensive and verifiable record of the gadget's performance and usage patterns throughout the life cycle.

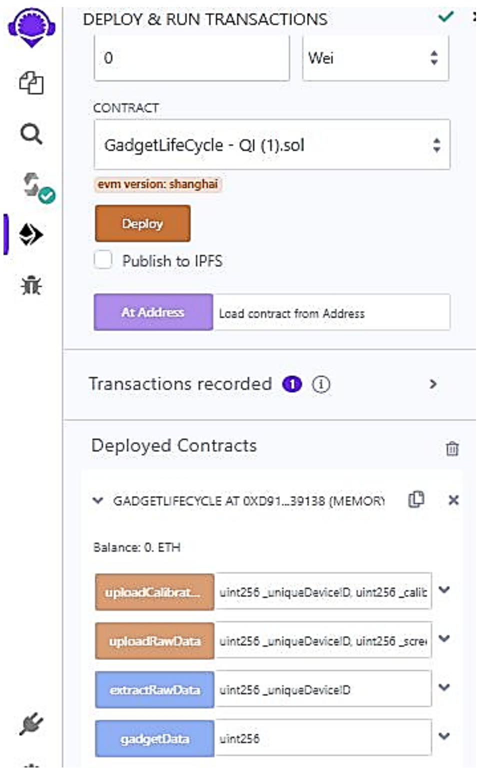

Figure 5. Showing the deployment of blockchain based smart contract transactions.

This repetitive process, starting with the blockchain storage of raw data and concluding with the uploading of refined information on the Hyperledger, gives surety of a secure and transparent approach to electronic gadget life cycle tracking. It also provides the accurate and individualized insights to its stakeholders, fostering accountability and sustainability in electronic device management

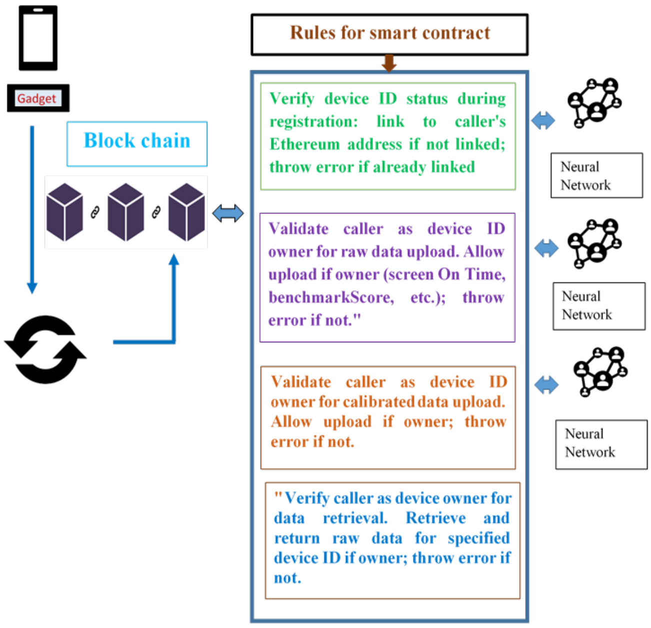

Figure 6. Proposed model diagram for working of smart contract in the blockchain.

1. **Device Initialization:** The device is manufactured, and a unique device ID is assigned during the production process. This step usually occurs off-chain and is not directly represented as a transaction on the blockchain.
2. **Device Registration: -** The device owner registers their device on the blockchain, associating their unique device ID with their Hyperledger address. A user initiates a transaction by calling the `linkDeviceID` function with the desired device ID. The transaction includes gas fees for computation.

Figure.7. Transaction of device registration

The Fig. 5 shows the of screenshot that describes the smart contract deployment in hyperledger block chain. The contract between various parties and the self-execution logic that is mentioned in the model in Fig.6.

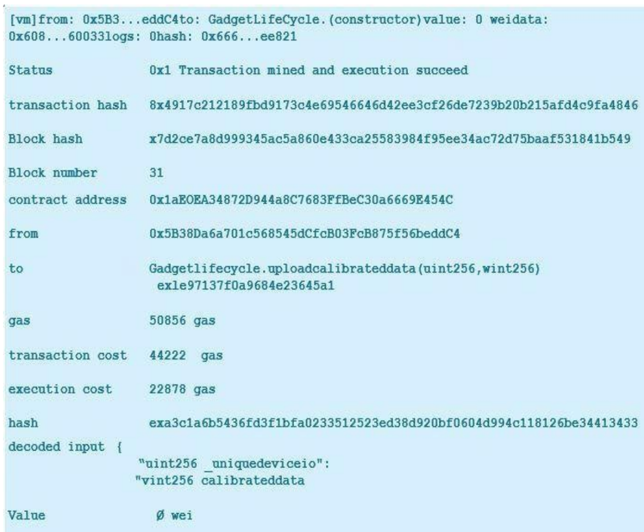

Figure 8. Blockchain transaction Data Retrieval, Data update, etc.

The various proof of concept transactions of smart contracts were shown in Fig 7 it mainly talks about various parameters that were used to calculate the quality index embedded in a smart contract is shown and Fig 8. In which the has values are shown.

The process of classification in the framework illustrated in Fig. 1 is crucial for determining the appropriate actions for electronic gadgets based on their QI. After the QI is calculated, it feeds into the gadget classification module, which evaluates the device's performance to categorize it into distinct classes. This process identifies whether the gadget should be repaired, discarded, or deemed in optimal condition. If repairable, the gadget is classified for repair to promote sustainability; if irreparable, it is classified for discard to facilitate efficient waste management. Overall, this classification supports informed decision-making, ensures the effective resource utilization and contributes to sustainable electronic device management.

5. Limitation

The above framework may not be suitable for normal devices. However, the Specialized low-power hardware such as NVIDIA Jetson AGX Orin, Google Edge TPU and Intel Loihi 2 allows for running neural networks with low-energy consumption. These super-sophisticated devices handle complex AI-tasks on the spotlight and conserve power and are less dependant on the cloud. Combined with the support of clouds, this setup balances the device limits and performance quite well.

6. Conclusion and Future Work

The framework which we proposed, consists of neural networks, Private Decentralized Cloud Storage, and mandatory data extraction, provides a novel approach for enhancing electronic gadget life cycle tracking. This combination has transparency, accountability, and sustainability, yet it opens several ways for further exploration.

As electronic devices evolve, the framework has to accommodate dynamic data inputs and update its neural network algorithms accordingly. Leveraging edge computing for local data processing can enhance efficiency and reduce dependency on the main systems.

Additionally, the framework's resilience against cyber threats and security vulnerabilities needs thorough assessment. Leveraging decentralized technology(blockchain) and neural networks along with SGD algorithm as a main component is ensuring the data integrity and addresses security concerns. Future research will be focused on the implementation of strong encryption methods and exploring advanced algorithms.

Accessing the economic and environmental outcomes of full-fledged adoption is also important. Considering the cost-effectiveness and ecological impact will provide insight into the framework's reliability. Understanding its economic feasibility will help stakeholders evaluate the return on investments, and evaluating environmental effect suits with sustainable electronic waste management goals.

Although the present framework shows a significant advancement in electronic gadget life cycle management, ongoing research and development are important for its future growth. Problem addressing related to security and ecological impact will optimize the framework's effectiveness and will ensure its relevance in the rapidly changing domain of electronic devices. Future efforts will be focused on these areas to ensure the framework's potential for sustainable and efficient life cycle tracking. Future work can focus on positioning the framework in contrast to existing models of e-waste to emphasize its novelty, solving implementation challenges, quantifying the sustainability benefits, and ensuring data privacy and compliance to be more relevant for practice.

Future work may include clearly situating the framework with respect to existing models of e-waste and reverse logistics to testify to the novelty of the framework in terms of accuracy and automation. Sustainability challenges such as infrastructure and adoption by stakeholders, along with quantification of sustainability outcomes and socioeconomic benefits, can make it more practical. Moreover, empirical validation methods should be detailed and aspects of data privacy, security, and also regulatory compliance should be included to further improve its credibility and applicability

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