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Optimized Data Management in IoT: Leveraging Blockchain for Data Simulation

R. Sivasankari[1], R. Akila[2] and S. Revathi[3]
[1-3]Professor, Department of Computer Science and Engineering, B. S. Abdur Rahman Crescent Institute of Science and Technology, Vandalur, Chennai, Tamil Nadu, India.
Email: sivasankari.rp@crescent.education, rakila@crescent.education, srevathi@crescent.education

***Abstract*—Internet of Things and Blockchain are the two topmost sheering technologies that are already on their way to re-shape our future with digital world. The IoT has given the items around us a life of their own, making them communicate with one another and gather vast amounts of data which can be analysed and used to perform intelligent actions [1]. The current industry is being converted into an intelligent industry by the Internet of Things (IoT). But the innate nature of IoT give rise to a wide range of problems, including decentralization, poor interoperability, concerns about privacy, and security vulnerabilities. Blockchain technology presents prospects for tackling the obstacles associated with the Internet of Things [2]. This research idea proposes an innovative system based on blockchain tailored for simulating IoT data, leveraging the decentralized and immutable nature of Blockchain technology. We refer to this grouping of IoT and Blockchain as Blockchain of Things (BCoT).**
Specifically, we start by giving a quick overview of IoT the confluence of Blockchain and IoT and BCoT architecture. We accomplish thorough simulations to evaluate the system's performance, scalability, and security, revealing its potential to trans-form data simulation and management in IoT scenarios. The findings show that the Blockchain-based solution not only addresses present restrictions, but also offers a solid basis for upcoming IoT data simulation and applications.

***Keywords*— Internet of Things, Blockchain, BCoT architecture, IoT data simulation.**

I. INTRODUCTION

The IoT is a network of connected objects embedded with electronic devices, sensors, software, and other skills to permit them to gather and share data. Recent developments in Information and Communication Technology (ICT) have enhanced the transition from traditional computer aided manufacturing to smart manufacturing, characterized by data driven decision making [3].
By constantly recording the physical world, the IoT has given the items around us a life of their own, making them interconnect with each other and gather huge amounts of data which are analysed and used to inform intelligent actions. Our ideal of a seamless and seamless fusion of the digital and physical empires has come true thanks to the considerate physical world. However, the issue with current IoT solutions is that they re-quire a centralized object (such as a cloud server) to connect and communicate over the Internet, which puts a serious risk to the security of the massive amounts of delicate data being generated. In contrast, the original architecture design called for a decentralized entity, such as a distributed or peer-to-peer system.

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Hence, Blockchain enters the picture by offering a reliable and safe means of information ex-change via a distributed/P2P concept to achieve a number of goals, including resilience, auditability, data immutability, transparency, safety and confidentiality [4]. we will examine how to integrate the two technologies to get over their drawbacks and maximize their advantages [5]. By 2030, there will be 25.44 billion IoT devices in use, with that number likely to increase an-nually. A novel method, Blockchain-based storage system specifically designed for simulating IoT data provide a scalable, secure, and efficient solution for IoT data management.

II. Internet of Things

Due to recent advancements in the IoT (Internet of Things) and BDA (Big Data Analytics), The manu-facturing sector is transitioning from computer aided production to intelligent manufacturing, a para-digm shift. IoT is essential to this evolution in order to bridge the gap between the actual industrial environment and the digital world of computers, while BDA can assist in uncovering unseen values in vast amounts of data produced by IoT devices to enable intelligent decision-making. The Internet of Things creates a digitally connected physical environment where gadgets may communicate, share da-ta, and switch things remotely via the Internet—possibly without human interaction [6].

The following layered sub-systems make up a typical Internet of Things system:

Perception Layer: Smart meters, RFID, bar code/QR code, actuator, sensor, controller, and other wired and wireless devices are just a handful of the numerous devices that comprise the Internet of Things.

These gadgets are able to sense their surroundings and gather information from them. Certain ones, such as controllers and actuators, can act on the surroundings in the interim.

Communication Layer: A list of wired and wireless components, such as actuators, RFIDs, sensors, con-trollers, and other tags, must connect to Wireless Fidelity Access Points (APs), small base stations (BSs), and macro BSs in order to create an industrial network. Bluetooth, Near Field Communications (NFC), Wireless Highway Addressable Remote Transducer (WirelessHART), Low power Wireless Per-sonal Area Networks (6LoWPAN) [7], Low Power Wide Area Networks, and other communication protocols enable the network connection.

Industrial Applications: A wide range of industrial applications can be supported by IoT. Manufacturing, supply chains, the food industry, the smart grid, healthcare, and the internet of cars are examples of common industrial uses.

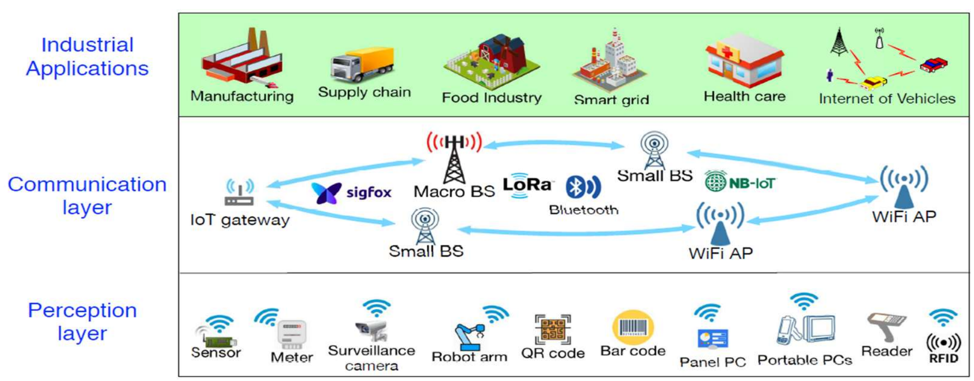

Figure 1. The layers of the Internet of Things.[8]

III. Blockchain Technology

A. Overview of Blockchain Technology

According to [9], A distributed ledger that spans the whole Blockchain system is all that makes up a Blockchain. A model Blockchain is made up of multiple interconnected blocks. Every block in the Blockchain except the first block, uses an inverted reference—basically, the parent block's hash val-ue—to point to the parent block, or the block that came before it.

Blockchains are considered to be data structures created using number of cryptographically connected blocks. For data and transaction management, it can assist as a tamper-proof historical ledg-er[10]. A Blockchain is formed of an ordered list of nodes connected by links known as chains. The nodes on Blockchain store data. This technology initially gained fame because of cryptocurrencies en-abling availability of a openly kept ledger of transactions [11].

It was Satoshi Nakamoto who first identified the Blockchain concept that powers Bitcoin. It is estab-lished that Blockchain possesses many crucial qualities, including immutability and security. This im-plies that it might offer a workable solution for several problems that conventional security systems run into, like centralized systems with bottlenecks and single points of failure in addition to privacy-related problems[12].
A network of peers maintains a distributed ledger that is unchangeable through the usage of Block-chain technology. Members of a Blockchain network must agree on transaction statuses in order for transactions published for the network to be considered legitimate. To make data hashing more secure, transactions are grouped together in blocks along with a collection of data, together with a timestamp, previous hash and nonce. This data is then entered into the hash function. Then, given certain guide-lines, a consent technology is used to select the node which adds this block to the Blockchain [13]. The organizational construction of Blockchain is shown in Fig.2.

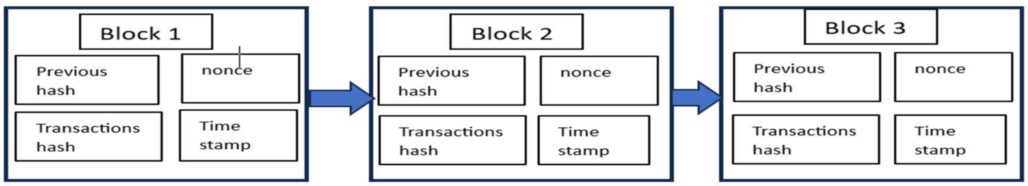

Figure 2. Blockchain organizational construction

IV. BLOCKCHAIN IN IOT

The practice of Blockchain provides safe and immutable transmission of data in the IoT net-works. Due to limited device resources, Blockchain integration into IoT presents issues that need for effective and lightweight solutions [3].
Blockchain is a decentralized ledger technology that enables preserving transactions over a network in a transparent and safe manner.[3]
Blockchain plays a big part in IoT storage, providing various advantages that help with the problems connected to storing IoT data. Additionally, Blockchain can increase reliability and scalability of IoT systems.[15]
Such Blockchain-IoT integration is referred to as BCoT. When compared to existing IoT systems, BCoT offers the below mentioned possible advantages and disadvantages.

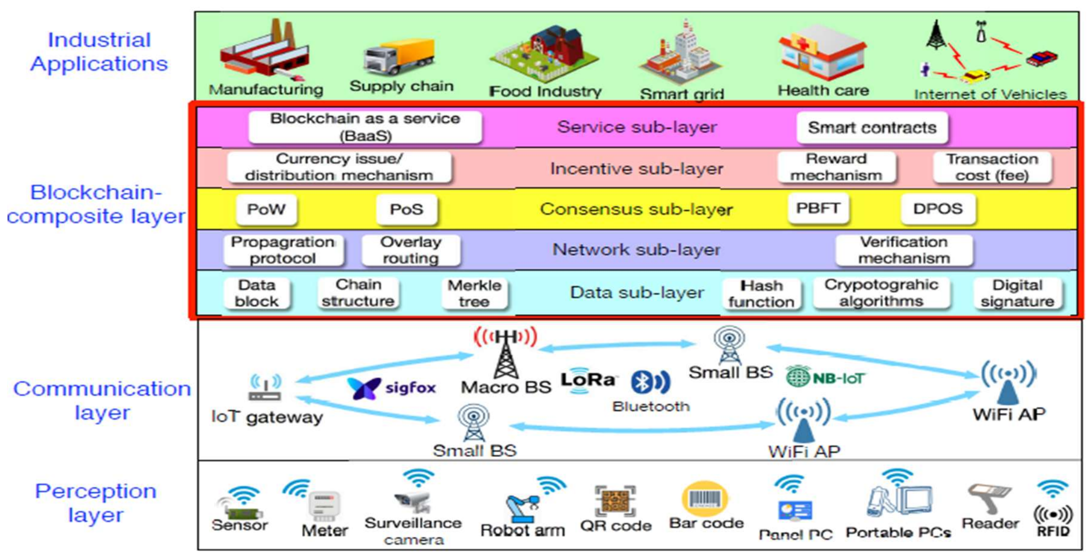

Figure 3. Overview of BCoT architecture [8]

Blockchain functions via a decentralized network of computers, defined to as nodes. A Block-chain is a record of every transaction made on the network by every node. As the data is dispersed among several nodes, the decentralized structure guarantees the absence of a lone point of failure.

V. RESEARCH GAPS AND SOLUTIONS

Traditional centralized storage solutions face scalability issues as a result of the exponential growth of IoT devices and the data they produce. Single points of failure, tampering, and data breaches are common problems with centralized storage systems. One of the biggest challenges is making sure that IoT data is secure and intact. The rewards of IoT system are outweighed by the service disruptions and deluge of sensor da-ta that result from this. Moreover, data interception is a possibility when IoT devices share data, raising questions about the correctness of the data that is gathered. Researchers hoping to capitalize on it are finding that the idea of fusing Blockchain with IoT is rather appealing.

A. Security

It is imperative to have an adaptable and secure access control mechanism in place when several users have to act together with an IoT device or system. One efficient solution is to use Blockchain-based technologies to deliver secure and supple access control. This can prevent undesired access by assuring that authorized users alone can interact with the device.[17]

Improving IoT storage using Blockchain comprises leveraging the important appearances of Blockchain concept to improve

- Confidentiality
- Integrity
- Availability

Confidentiality is the part pertaining to transaction data is connected to their privacy. As long as the system remains safe from both internal and external threats and the administrators of the centralized infrastructure can be trustworthy, such an approach is workable [14].

Integrity in Blockchain refers to the ability to store data that can never be altered once it is stored. (or would be very costly to do so). To lessen the reliance on third parties, [14] offers a Block-chain-based data integrity.

The third facet of security is availability, which Blockchains excel at achieving because Blockchains are considered to be distributed systems that continue to operate even when specific nodes are being attacked.

B. Addressing connection issue

Every node in a P2P Blockchain network maintains connection to other networks while using common protocols to function autonomously. It is potentially more likely for IoT devices to have secu-rity cracks because of the feature of Blockchain networks.

C. Ensuring privacy and transparency

The Blockchain computer architecture protects user privacy when mining and allows safe data storage by the use of homomorphic encryption technologies. Blockchain technology offers an un-changeable, transparent ledger for recording data transfers.

D. Improving data storage

Blockchain technology offers an unchangeable record of data transactions that are sequential-ly recorded and cryptographically connected. When IoT data is placed on a Blockchain, it becomes impenetrable and maintains its integrity over time. There is immediate detection of any attempt to change or tamper with the data, giving the stored information a high degree of trustworthiness. Securi-ty, resilience, and fault tolerance are improved by decentralization because there cannot be a single point of failure or control.

VI. IMPLEMENTATION

A. Blockchain Implementation

Classes like init are used to initialize the Blockchain with a genesis block (first block) and an empty list of current transactions; new_block and new_transaction are used to create new blocks and add them to the chain; hash is used to generate a SHA-256 hash of a block; and last_block is used to return the last block in the chain. valid_proof to confirm the proof of work, and proof_of_work to ob-tain a number that, when hashed with the prior proof, yields a hash with four leading zeros.

B. IoT Data Simulation

IoT data are simulated by creating a dictionary with a device ID, random temperature, random humidity, and a timestamp.

C. Storing IoT Data on the Blockchain

IoT data are stored on Blockchain by generating IoT data for a given device ID, creating a new transaction with the generated data, performing proof-of-work to find a valid proof, and then creating a new block containing the transactions and finally adds it to the Blockchain.

VII. OUTPUT

A. Simulate storing data from IoT devices

The output represents a sequence of blocks that have been mined and added to a Blockchain. Each block contains several key components such as index, timestamp, transactions details, timestamp, proof, previous hash.

```
Block 0:
  Timestamp: 2024-12-01 16:46:32
  Transactions: []
  Proof: 0
  Previous Hash: 0
  Hash: edd890f4370dcc22a3068755f9097789ddb36566713785905df566f39850860b
--------------------------------------------------

Block 1:
  Timestamp: 2024-12-01 16:46:32
  Transactions: ['Alice pays Bob 10 BTC', 'Bob pays Charlie 5 BTC']
  Proof: 88914
  Previous Hash: edd890f4370dcc22a3068755f9097789ddb36566713785905df566f39850860b
  Hash: 2b32d5688de7dd7061be8e57697aadac4467fdf41e011421d071f14038d4ef19
--------------------------------------------------
Block 2:
  Timestamp: 2024-12-01 16:46:33
  Transactions: ['Charlie pays Alice 3 BTC']
  Proof: 49714
  Previous Hash: 2b32d5688de7dd7061be8e57697aadac4467fdf41e011421d071f14038d4ef19
  Hash: 62c33f8dcaf1c042785188ec1adc7192dc86fbb2d2d5d3ba3e5f3f62e94415b2
```

VIII. RESULTS

Every cycle duplicates the generation of random data points by IoT devices.

The blockchain receives IoT data that has been structured into transactions. Blocks are mined from transactions, and proof-of-work is simulated. The blockchain grows as blocks are mined, with each block containing IoT data transactions.

The graph in Fig. 4 shows the relationship between the block index and the number of transac-tions in the Blockchain network.

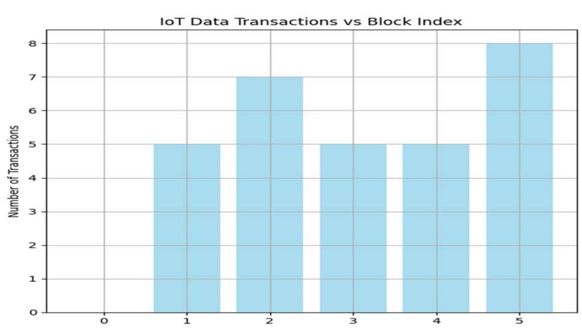

Figure 4. IoT Data Transactions vs Block Index

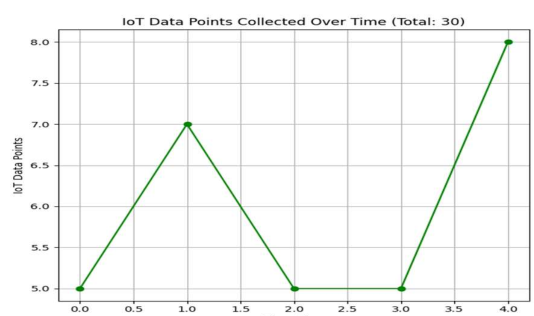

Figure 5. IoT Data Points Collected Over Time

The line graph in Fig. 5 represents the accumulation of IoT data points over simulation time. These graphs provide insights into the blockchain's storage and IoT data collection trends.

IX. CONCLUSION

The rapid expansion of the Internet of Things (IoT) necessitates robust, scalable, and secure solutions for data storage and management.

It is required to have an adaptable and secure access control mechanism in place when several participants need to interrelate with an IoT device.

One effective solution is using Blockchain-based technology to handle varying data volumes and numbers of nodes, by maintaining high transaction throughput and low latency, facilitating efficient data processing. While the Blockchain-based IoT data simulation system addresses several issues, other areas require more investigation.

Future research could concentrate on optimizing Blockchain protocols for increased efficiency, raising interoperability standards, and developing privacy-preserving mechanisms.

FUTURE ENHANCEMENTS

To address the evolving needs of IoT ecosystems and fully leverage blockchain technology, several enhancements can be explored. These improvements focus on scalability, efficiency, security, interoperability, and practical implementation challenges.

Use off-chain scaling techniques, including as sidechains and payment/state channels, to manage large transaction volumes without taxing the primary blockchain.

The blockchain is divided into smaller, more manageable shards using sharding, each of which processes a subset of transactions.

Through the parallelization of transaction processing over multiple nodes, it improves scalability.

Discover faster and more energy-efficient consensus techniques like Proof of Authority (PoA), Delegated PoS (DPoS), or Proof of Stake (PoS) that are optimized for resource-constrained Internet of Things (IoT) devices.

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