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Blockchain Enabled IOT-Based Water Management System for Smart Cities

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Abstract: The rapid urbanization, voluntary migration and population growth of cities lead to significant challenges to the management of vital resources, including the water supply. Faults in pressurized pipes cause spinning in meters and alarm mechanisms; thus, smart meters automatically collect information and generate error reports when they detect consumption anomalies. Due to these frequent inefficiencies and loss susceptibilities, conventional water management systems face significant waste and service difficulties. Blockchain and IoT (Internet of Things) technologies have the potential to completely transform the management of water supply in smart cities. The objective of this study is to develop a blockchain-enabled IOT model for a consistent and transparent water management system for the smart city dwellers. Real-time monitoring of water consumption patterns is possible by IoT devices, like flow rates, level with indication of pH, turbidity and TDS. Blockchain technology provides a safe, unchangeable ledger for tracking water usage data, which is an additional benefit of Blockchain enabled IoT. This paper aims to investigate the BIOT model of such a water management system for smart cities and its potential benefits and challenges. The integration of IoT and blockchain in water supply management can lead to significant improvements in water conservation, operational efficiency, and consumer satisfaction.

Keywords: **Smart City; Water Supply System; Internet of Things; Blockchain.**

I. INTRODUCTION

The rapid growth of urban population and the increasing complexity of urban infrastructure have necessitated the development of smart cities. Water supply management is one of the most important components of urban management because it is vital to maintain the health and welfare of city dwellers. The conventional water supply network faces difficulties, primarily from theft and leakage of water. The integration of blockchain technology with the IoT offers a promising solution to these problems [1].

The proposed model of Blockchain enabled Internet of Things (BIoT) in water supply can greatly benefit consumer satisfaction, operational effectiveness, and water conservation. In this study, IoT devices monitor various parameters, such as level, flow rates, and water quality. These devices can be deployed at different points in the water distribution network, including treatment plants, pipelines, reservoirs, and consumer endpoints of a smart city.

The analysis of the real-time data gathered by IoT sensors can detect leaks, foretell maintenance requirements, and improve performance of the overall water supply system. The smart meters installed on consumer premises can provide detailed usage data, helping utility providers gain a better understanding of consumption patterns and also implement demand management strategies. The IoT-enabled water quality sensors can continuously monitor the water quality parameters ensuring safe and clean water supply to the dwellers. However, resource management can be improved, and theft and leakage can be detected and prevented with the use of dedicated distributed ledger technology, i.e., blockchain [3].

Blockchain tracks transactions across different nodes in a distributed digital ledger system that has an enhanced security mechanism. The records of transactions likewise cannot be altered [4]. This technology offers transparency, security, and immutability, making it highly suitable for applications requiring trust and accountability. In water supply management, Blockchain can be used to create a transparent and tamper-proof record of all transactions and data related to water distribution and consumption [5]. This includes tracking water usage, billing information, maintenance records, and quality reports. By leveraging blockchain, stakeholders such as utility providers, regulators, and consumers can have access to a single source of truth, reducing disputes and ensuring compliance with regulatory standards. Furthermore, smart contracts, self-executing contracts with the terms directly written into code can

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automate various processes within the water supply chain. For instance, smart contracts can facilitate automated billing based on actual water usage data, trigger maintenance alerts based on predefined conditions, and manage water rights and allocations efficiently [6].

Thus, the integration of IoT and blockchain technologies offers a synergistic approach to overcome the challenges faced by traditional water supply systems. IoT devices generate a vast amount of real-time data, which can be securely and transparently recorded on a blockchain. This integration ensures data integrity, enhances security, and provides a comprehensive view of the entire water supply network [7].

This study aims to address water management challenges induced by theft and leakage in smart cities. By integrating IoT for monitoring and blockchain for secure data management, BIoT efficiently manages water distribution per multistory building in a smart city.

II. PROPOSED FRAMEWORK

The proposed framework includes multiple sensors (water level, water flow, TDS, turbidity, and pH) connected to the core controller as shown in fig. 1. The model is distinctly divided into two parts: one is the IoT water parameter monitoring environment, and the other is the blockchain distributed ledger technology. Prior to sending the data to blockchain, the core controller accesses sensor values and processes them. A core controller, the Raspberry Pi, is employed. Blockchain allows storage and retrieval of sensor data [8]. The monitoring system uses little power and has sufficient capacity for storing data.
Table I [9] shows IoT sensor devices that are connected to the core controller. The proposed BIoT model includes sensors like flow, level, pH, turbidity, TDS sensors, connected to a Raspberry Pi controller, to collect and process data.

TABLE I: Components of the IOT devices.

Sl. No.	Characteristic	Sensors Requirements
i	pH Value	E-201C
ii	Turbidity(max)	SEN0189
iii	Total dissolved solids (TDS)	Rk500-18
iv	Water flow	YF-S201
v	Water level	Robodo SEN18

IoT sensors enable continuous monitoring of water level, water flow rate, pH, total dissolved solids (TDS) and turbidity. Real-time data collection helps in early detection of leaks and losses. The smart meters measure water usage and detect anomalies, aiding the BIoT model in efficient resource management [10]. Also, BIoT data is used for prediction and forecasting equipment failures and scheduling timely repairs, thus reducing downtime and preventing leaks.
Fig. 1 shows the system architecture of BIoT. The sensor devices are connected to the controller, i.e Raspberry Pi. The integration of IoT sensors and blockchain at water supply network nodes is crucial (e.g., treatment facilities and distribution stations). All devices are linked to the central monitoring system, and a dependable communication network will be established. The blockchain stores the transactions between the consumer (sensor devices) and the recipient (the water monitoring unit). The data stored in Blockchain is unchangeable and time stamped, so no one can alter or manipulate it. Thus, a transparent and real time visualization of water supply and consumption by consumers at different points in the water distribution network.

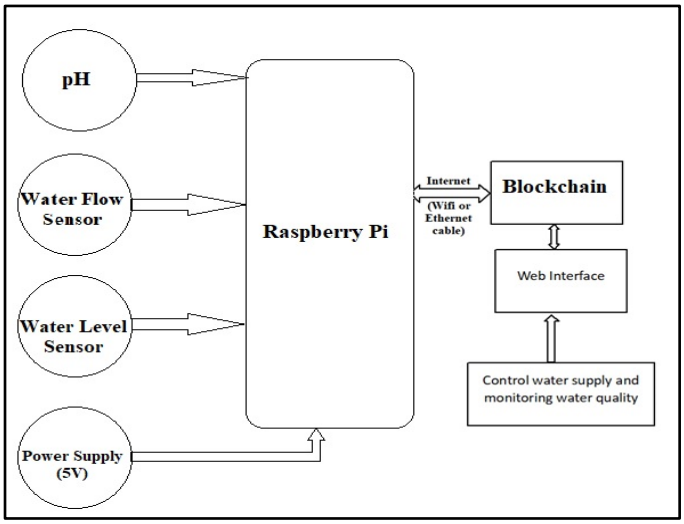

Fig. 1: System Architecture of the BIOT model

Tampering is difficult because every transaction is encrypted and connected to the one before it. By maintaining an immutable ledger, stakeholders can verify the authenticity of water data, reducing instances of corruption and data manipulation. Blockchain guarantees the security and veracity of the data collected by Internet of Things devices. Accurate documentation of water quality and usage is imperative [11]. Smart contracts can automate billing processes based on precise water usage data, reducing administrative costs and errors. The model can facilitate better demand forecasting and resource allocation, minimizing waste and improving the efficiency of water distribution networks and reducing water loss significantly [12]. Hang et. al. [13] mentioned that smart contracts improve consumer-provider trust by automating payments based on real-time data, thereby decreasing errors. The decentralized structure of the model guarantees the protection of water data against cyberattacks and unauthorized access. By guaranteeing that water resources are distributed and billed correctly, immutable records aid in the prevention of fraudulent activity [14]. This has been particularly beneficial in areas where water loss issues exist. Following data transfer to a blockchain, edge devices will filter and preprocess the data. Furthermore, smart contracts may be implemented and tested for automated processes such as maintenance alerts and invoicing. Fig. 2. shows that the data collected from nodes is saved on the server, where it is compared and verified through sensor hub (transmitter) & gateway (Raspberry Pi). Through data mining, data retrieval is possible to observe usage and wastage.

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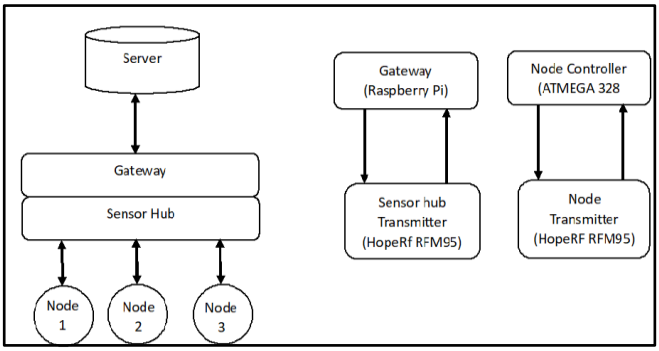

Fig.2 Overall Topology of BIOT architecture

Since 20% of the population is anticipated to be affected by water scarcity by 2025, the efficacy of this BIoT model justifies its importance as crucial.

III. MATHEMATICAL MODEL

Effective water management depends on the sensor data gathered from multiple Points of Use (PoUs). Fig. 3 explains the mathematical model of the proposed BIoT. At each point of use, all the IoT device sensors collect data on endpoint usage in the water distribution network. The output from sensors helps in calculating water supply to each PoUs, avoiding wastage and leakage of water. Raspberry PI gathers sensor data, and uploads it for remote monitoring and the processed data is stored on a blockchain.

1.

S_M = Water Monitoring System

$$S_M = \{T_1, T_2, T_3, \ldots T_N\} \quad \text{.....(1)}$$

Where T_1 represents location 1
T_2 represents location 2
T_N represents location Nth
I_M = Input; IM = $\{I_1, I_2, I_3, \ldots I_N\}$
O_M = Output; OM = $\{O_1, O_2, O_3, \ldots O_N\}$
F_M = Functions, FM = $\{F_1, F_2, F_3, \ldots F_N\}$

$$T_1 = \{I_1, O_1, F_1\} \quad \text{…….. (2)}$$
$$T2 = \{I2, O_2, F_2\} \quad \text{……(3)}$$
..
$$T_n = \{I_n, O_n, F_n\} \quad \text{……..(4)}$$

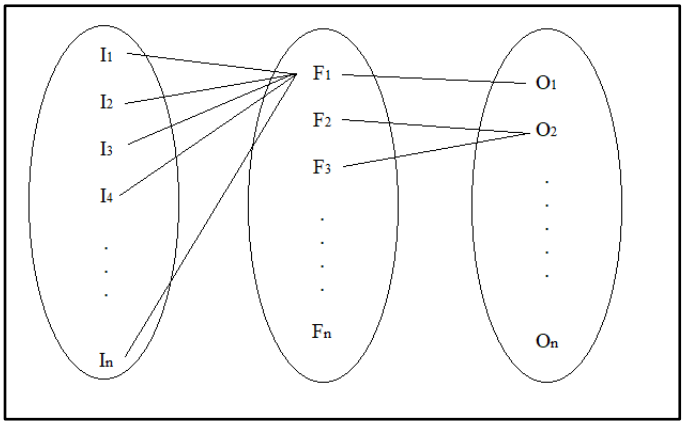

Fig. 3 Venn Diagram of the BIOT model

The data from these sensors is measured and stored in a database. The integration of the Water monitoring IoT unit with blockchain technology brings a new horizon to the application scenario for state-of-the-art technology. Fig. 4-7 shows the GUI displays various PoUs nodes of water usage data with prediction of water losses.

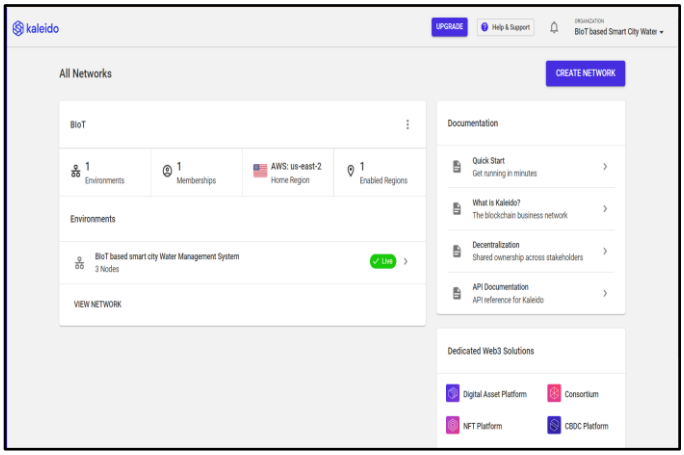

Fig 4. All networks in Blockchain interface

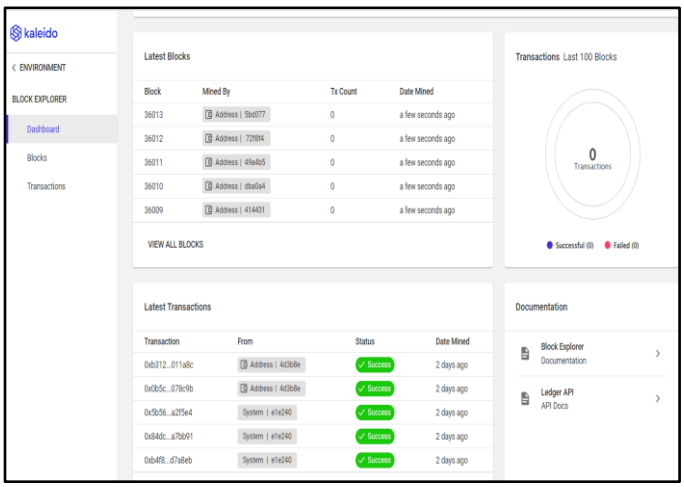

Fig 5. Experimental Dashboard in Blockchain

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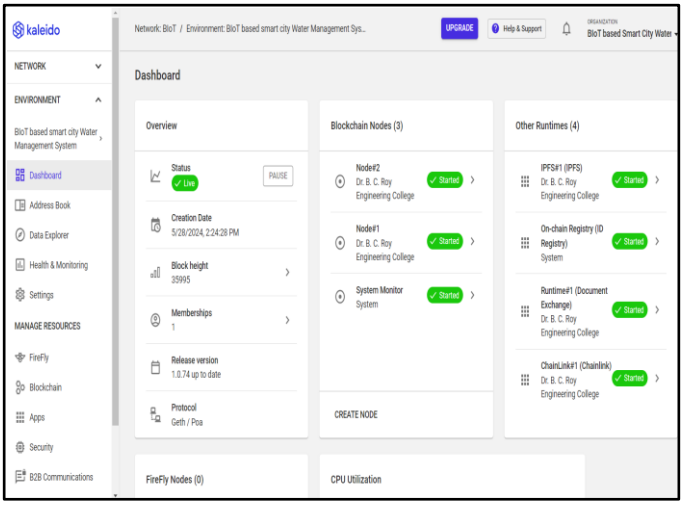

Fig 6. Final Status show in Blockchain

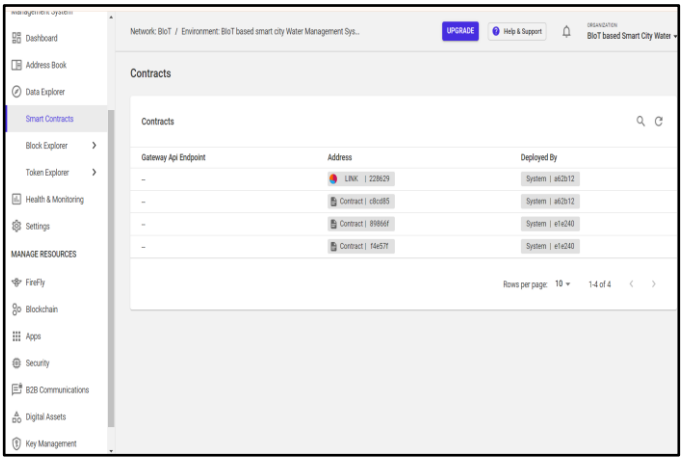

Fig 7. Smart Contracts in Blockchain Interface

IV. CONCLUSION

The present proposed model shows a decentralised water management system using blockchain enabled IoT technology. Traditional centralised water management suffers from low trust, inefficiency, and data storage risks. This Blockchain enabled IoT framework is applicable to water supply management in multi-dweller buildings of smart cities. The appropriate mathematical model is explained to aid in detecting water losses and thus leads to forecast and optimal utilisation. This research can be used as a milestone to develop more efficient water management systems and BIoT frameworks for smart cities. The advantages of the system include reliable and secure storage of water resource data, high efficiency of information transmission, and high traceability of water quality problems. However, the integration of blockchain technology with IoT devices into water management systems may face some challenges, such as data sharing between departments, legal aspects related to the blockchain, and the lack of a standard system.

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