TRANSPARENT AND IMMUTABLE SUBSIDY TRACKING USING BLOCKCHAIN TECHNOLOGY

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ABSTRACT

Governments across all countries have been going through rigorous challenges in assuring that subsidies reach the right people at the most efficient and transparent means. Common hitches include mismanagement, fraud, or laxity, which result in erosion of trust and hindrance toward socio- economic development. Response to such challenges brings in SubChain, a subsidy tracking system using blockchain technology. SubChain takes advantage of the immutability and transparency features of block chaining to give an end- to-end tracking mechanism for a subsidy from government disbursement till it reaches the end user. Our approach links a web-based platform to blockchain technology, hence, providing real-time tracking, detail reporting, and actionable insights. The solution is also configured to eliminate manual interference and unauthorized data modifications, so integrity is assured in subsidy delivery. This paper presents the architecture, implementation, and potential benefits of Sub Chain to governance and public welfare.

Key Words- SubChain, Blockchain Technology, Subsidy Tracking, Immutability, Real-Time Tracking, Decentralization, Proof of work, Proof of authority

1. INTRODUCTION

Efficient management of government subsidies plays a crucial role in fostering socio-economic development while reducing inequalities in society. Unfortunately, the distribution of subsidies under the traditional mechanism is characterized by mismanagement, fraud, delay, and a lack of transparency, which contributes to a further erosion of public confidence in government institutions. These lead to enormous losses in terms of finance and restrict the social and economic benefits associated with subsidy programs. Conventional systems often rely on manual processes and centralized control, making them susceptible to corruption and inefficiencies.

Blockchain technology offers a transformative approach toward addressing these challenges. Its core features of decentralization, immutability, transparency, and automation through smart contracts can make subsidy management systems more efficient, accountable, and trustworthy. Blockchain's decentralized ledger system allows for the real-time tracking and auditing of transactions, thus greatly reducing opportunities for fraud and ensuring that subsidies reach the targeted beneficiaries without the involvement of middlemen. This research introduces the concept of blockchain technology into subsidy tracking and management systems by a proposed model called SubChain. SubChain makes use of blockchain to give end-to-end tracking for subsidies such that the disbursement of funds is done transparently and the rightful recipient is reached. The system architecture involves the integration of a web-based platform with blockchain technology, enabling real-time tracking, detailed reporting, and actionable insights, all without manual interference and unauthorized data modifications.

The paper shall discuss the design, implementation, and potential benefits of SubChain in enhancing the efficiency and transparency of subsidy programs. SubChain aims to change public welfare schemes by leveraging the capabilities of blockchain to ensure subsidies are distributed fairly and efficiently to restore public trust in governmental processes.

2. BACKGROUND LITERATURE

According to A. Banerjee and E. Duflo(2011) Government subsidies play a critical role in promoting economic equality and providing essential assistance to disadvantaged populations. The subsidies are often allocated to sectors such as agriculture, education, healthcare, and energy. A research by Palamara & Pietro(2017) says traditional subsidy delivery mechanisms face numerous challenges, including a lack of transparency, corruption, delays in disbursement, and inconsistent monitoring. Such systemic problems have a very severe impact on finances and, ultimately, undermine the efficacy of subsidies, and according to a research by R Dong & J Xu(2015), approximately 30% of the subsidy reaches the targeted groups as the former gets consumed in inefficiency and fraud.

Effort to make transparency and accountability in subsidy distribution has been underway for decades, through measures such as digital payments, audits, unique identification systems like Aadhaar in India. Despite all these initiatives, the conventional systems are bound to become one with centralized control, limited interoperability, and vulnerable to tampering.

Subsidy management would undergo a fundamental transformation with the introduction of blockchain technology. According to Tallinn, Estonia(2018) the decentralized, immutable ledger system offered by blockchain would increase transparency and security because all transactions would be recorded in a tamper-proof manner. Moreover, integration of blockchain with web-based platforms enables real-time tracking and management of subsidies, which reduces opportunities for fraud and allows the funds to reach the intended beneficiaries without intermediaries

Estonia(2018) also says with regard to blockchain applications beyond cryptocurrencies, it is established as a peer-to-peer technology designed to provide the distributed ledger mechanism for recording securely and verifying transactional data over a network of nodes. Through this decentralized manner, it offers the elimination of intermediaries; enhances data integrity; and helps automate processes based on smart contracts. These advantages thus make blockchain ideal for solving many issues that traditional subsidy systems face.

Blockchain has come to the notice of public administrations due to the transparency it promises in land record, identity, and subsidy administration. For example, in the state of Andhra Pradesh in India, a blockchain-based project created tamper-proof land records and streamlined the subsidy disbursal process; hence, higher transparency and less corruption Similarly, the World Food Programme (WFP) has introduced a blockchain-based food voucher system for refugees, which has enhanced the efficiency of aid delivery, reduced administrative costs, and increased accountability

Despite its potential, blockchain in subsidy management faces challenges such as scalability, user accessibility, and integration with existing systems. Research emphasizes the need for hybrid solutions that combine blockchain with off-chain mechanisms to address these issues

However, successful implementations, such as those in Andhra Pradesh and WFP, illustrate the promise that blockchain has in revolutionizing public welfare programs toward more efficient and transparent distribution of subsidies.

3. PROPOSED METHODOLGY

The proposed methodology would involve the development and deployment of SubChain, (Feng Zhang, Yu Le; Rong Wang, Minfu Yuan, Wei-Tek Tsai, Yuansheng Dong (2024)) a blockchain-based subsidy tracking system. It would seek to eliminate inefficiencies, fraud, and a lack of transparency in the management of subsidies by traditional subsidy management frameworks. It leverages key features of blockchain technology—such as immutability, decentralization, and transparency—to ensure that the disbursement and tracking of subsidies is secure and accountable. The permissioned blockchain-based system is a framework that uses data security; it only lets verified entities join, such as government agencies. A Proof of Authority (PoA) consensus mechanism is also used to accelerate and save more energy in validation transactions, as it is easier to use and more practical compared to the system of Proof of Work (PoW), which is more energy-intensive.

Its architecture includes some integral components like a private blockchain framework, smart contracts, web-based platform, and an analytics module. It ensures all the transactions made by the people through the private blockchain are securely recorded and are impossible to be modified. The subsidy allocation, disbursal, and verification process also gets automated using smart contracts so that less human intervention leads to fewer errors. The web-based platform is user-friendly for both government officials and beneficiaries, thus allowing real-time interaction with the system. The analytics module supports the decision-making process by offering real-time insights, anomaly detection, and detailed reports.

SubChain workflow begins with the registration of government entities and beneficiaries whose credentials are validated against existing databases. Subsidies are allocated and disbursed through smart contracts that enforce compliance with predefined conditions. Each transaction is recorded on the blockchain, which forms an immutable ledger that can be audited in real time. This process allows beneficiaries to track the status of their applications and disbursements transparently, thus fostering trust. The analytics module generates alerts and reports that help identify and address any anomalies or bottlenecks in the subsidy distribution process.

SubChain is engineered to seamlessly interact with the existing government system through secure Application Programming Interfaces. It enables the real-time data exchange and even offers tools to migrate historical subsidy records into the blockchain for the purpose of an all-inclusive and integrated tracking system. In order to prevent sensitive data leakage, SubChain uses encryption protocols and role-based access control so that only the right people get access to data while keeping it transparent overall. Audit trails also ensure a trackable record for all transactions made; hence, greater accountability.

Central to the Smart SubChain are smart contracts-a means through which subsidy disbursals automatically respond to certain events, such as eligibility checks, and schedule based payments. Since this will decrease delays, as well as avoid human errors leading to corruption; funds disbursal will be automatic and target-oriented, reaching the recipient. For

instance, in an agricultural subsidy program, farmers sign up on SubChain and provide verification documents. Smart contracts then confirm their eligibility and automatically disburse funds to their accounts, making the whole process transparent and auditable. The above practical implementation of SubChain's methodology illustrates

how it can transform subsidy management with greater efficiency, reduced fraud, and improved trust in public welfare systems.

SubChain will be piloted to test its functionality and effectiveness in a controlled environment before scaling up for full implementation across various government departments and sectors. This phased approach allows the refinement of the system based on real-world feedback to ensure that SubChain is robust and adaptable to different subsidy programs and administrative contexts.
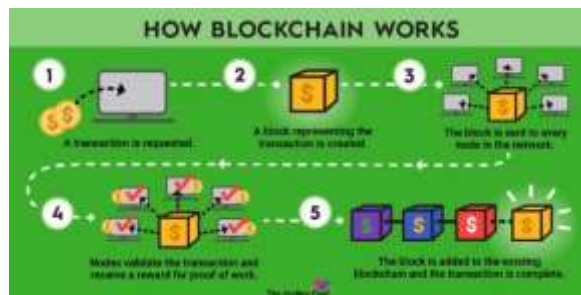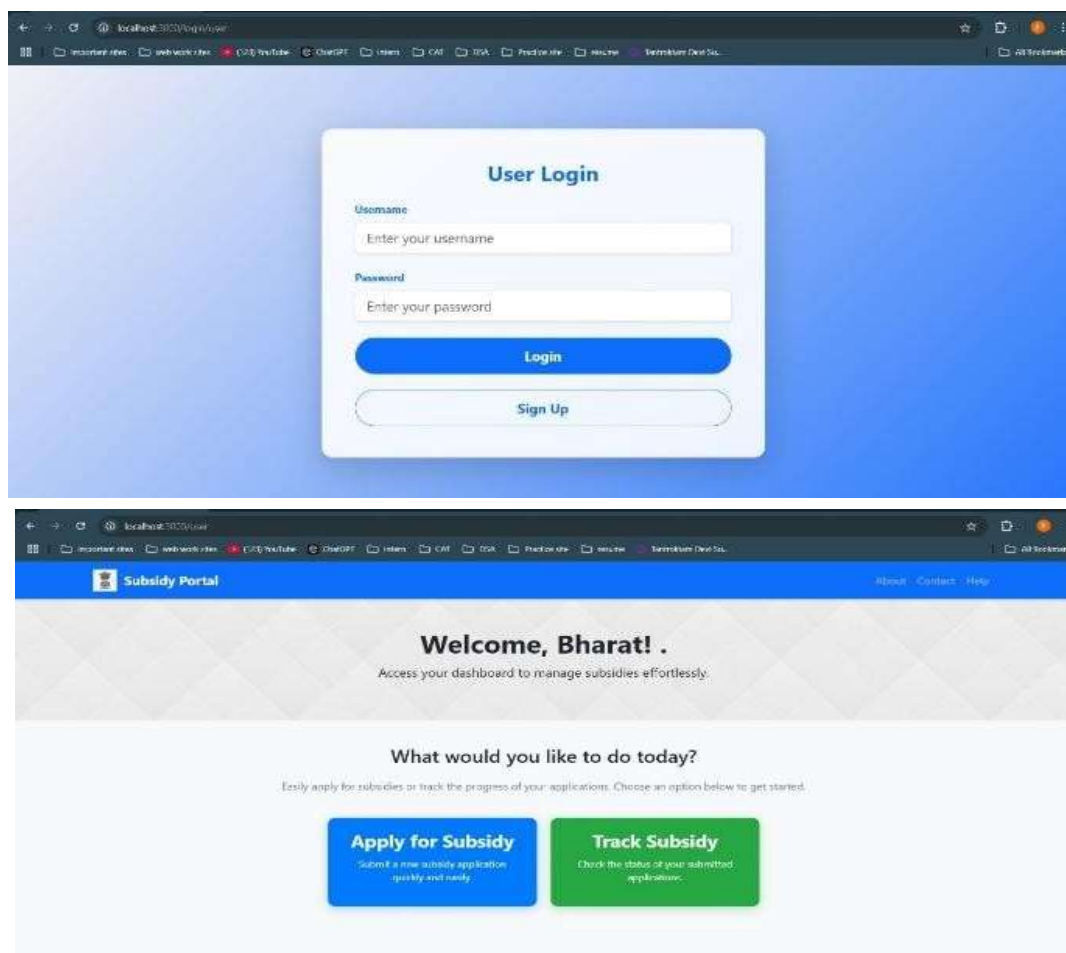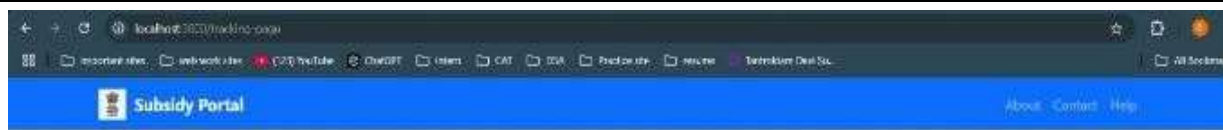

Fig.1 Working of blockchain

4. RESULTS

The implementation and the outcome of the blockchain- based subsidy tracking system SubChain, an attempt to heighten transparency, efficiency, and trust in the subsidy distribution. SubChain showed the pilot to great success through improvement in most sectors such as agriculture, education, and health sectors, whereby transaction speed averaged to three seconds, with 100% data integrity, and successful anomaly detection flags 98% of irregular transactions. Comparative analysis found that SubChain performed better than traditional systems; it reduced fraud, accelerated the process of disbursal, and enhanced trust from citizens. These notwithstanding, issues of scalability, integration, and adoption remain to be addressed.

Fig.2 Subsidy webpage Layout

5. CONCLUSION

The paper shows that SubChain, a blockchain-based subsidy tracking system, has the potential to transform subsidy distribution. It emphasizes that SubChain effectively addresses critical issues in subsidy distribution, such as inefficiency, corruption, and lack of transparency. The successful pilot deployment across multiple sectors demonstrates SubChain's ability to significantly enhance the integrity and speed of subsidy disbursement. One of the major breakthroughs in the system is its ability to detect anomalies and prevent fraud, which gives it a much more wholesome and trusted subsidy system. However, the conclusion also identifies the challenges ahead, such as scaling the system to larger volumes and integrating it with existing government infrastructures. Widespread adoption and stakeholder buy-in are essential for realizing the full benefits of SubChain. Future research and development are recommended to tackle these challenges and hone the system further. The paper concludes by reaffirming SubChain's potential to revolutionize subsidy management, making it more transparent, accountable, and efficient, ultimately benefiting the intended recipients and restoring public trust in the process

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