Blockchain-Based traceability system for enhanced humanitarian supply chain management

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Blockchain-Based Traceability System for Enhanced Humanitarian Supply Chain Management

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Abstract.
Traceability and transparency are crucial aspects of humanitarian supply chains to ensure the efficient delivery of aid. Existing research emphasises the need for improved traceability and transparency to address challenges like corruption, counterfeit goods, and inefficient distribution. Traditional systems, however, often lack the necessary infrastructure and mechanisms to achieve these objectives effectively. Blockchain technology offers unique capabilities to enhance traceability in humanitarian supply chains. This paper presents a conceptual blockchain-based system designed to record and verify the movement of humanitarian goods and resources and facilitate collaborations of key stakeholders throughout the supply chain. By enhancing traceability, transparency, and stakeholder collaboration, this system could contribute to the effective delivery of humanitarian aid, ultimately benefiting the affected communities in their time of need.

Keywords. Blockchain, Humanitarian Supply Chain Management, Traceability.

1. Introduction

In humanitarian supply chain management, ensuring the efficient, transparent, and accountable movement of goods and resources is crucial for providing timely assistance to affected communities [1]. However, challenges such as fraud, corruption, and lack of visibility often hinder the effectiveness of humanitarian operations [2]. To address these issues, emerging technologies like blockchain have shown great promise in revolutionising supply chain management by enhancing the traceability and transparency of processes [3].

This paper presents a blockchain-based system designed to record and verify the movement of humanitarian goods and resources throughout the supply chain, while considering the involvement of stakeholders such as the government, Non-Governmental Organisations (NGOs), and local communities. By leveraging the immutability, transparency, and decentralised nature of blockchain technology [4] and [5], this system aims to overcome the limitations of traditional humanitarian approaches and foster greater efficiency, integrity, and accountability and thus contribute to the effective delivery of humanitarian aid, ultimately benefiting the affected communities in their time of need.

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Smart contracts are utilised to automate verification processes, such as customs clearance, quality checks, and compliance with regulations. These contracts execute predefined rules and conditions, ensuring transparency and accountability throughout the supply chain [2]. By automating these processes, the system minimises manual intervention, reduces human error, and accelerates transaction processing, thereby increasing the overall efficiency of humanitarian operations.

2. Blockchain Technology Application in Traceability, Transparency and Collaboration in Humanitarian Supply Chain

Traceability and transparency are crucial aspects of humanitarian supply chains (HSCs) to ensure the efficient delivery of aid. Existing research, such as [6] and [7] emphasised the need for improved traceability and transparency to address challenges like corruption, counterfeit goods, and inefficient distribution. However, traditional systems often lack the necessary infrastructure and mechanisms to achieve these objectives effectively. Blockchain, which is a decentralised and distributed database that maintains a growing list of transactions, offers unique capabilities to enhance traceability in supply chains. By leveraging distributed ledgers and smart contracts, blockchain enables real-time tracking and verification of goods and resources [8] and [9].

It also facilitates donation management ensuring transparency in fund allocation and facilitating trust amongst stakeholders [1] and [10]. [11] and [4] highlighted the importance of stakeholder collaboration, trust-building, and participation in designing and implementing blockchain-based systems. Effective engagement ensures a shared understanding of goals, encourages data sharing, strengthens the overall resilience of the supply chain, and enhances stakeholder awareness about the technology and its importance in minimising coordination challenges of a lack of trust and information sharing [6].

2.1 Blockchain-enabled system: Transparency, Traceability, and Coordination applications

While designing the systems displayed in Figures 1, 2 and 3, important considerations should be made. One is the selection of the blockchain platform [12]. In this case, we recommend a permissioned platform, such as Hyperledger Fabric, which ensures controlled access to and privacy of sensitive data as only authorised parties can join, write, read, and commit in the network [13]. The data structure and smart contracts should be defined to include clear conditions and rules for contract execution [14] of relevant information like product identification, location, timestamp, responsible partners, and quality assessments. Network governance and access control guidelines [15] ensure that stakeholders have appropriate visibility levels and share data based on their roles and responsibilities. The user interface should be user-friendly [16] with appropriate access levels to enable stakeholders to input and access information related to the movement of goods/funds, tracking shipments, and reporting any anomalies.

For an effective implementation, these systems should be interoperable with existing systems used by stakeholders [15]. Privacy and data protection considerations must be integrated in the systems [17] and Zero-Knowledge Proofs (ZKPs) or selective disclosure to protect sensitive information shared on the blockchain can be used [18] and [19].

In this way, the humanitarian partner can establish trust and credibility in their qualifications without exposing sensitive information, and the verifier can be confident that the partner possesses the required qualifications without needing to access or store any personal or sensitive data. The cryptographic techniques behind ZKPs ensure that the proofs are valid, verifiable, and secure while preserving privacy [20].

An example of the use of blockchain technology to ensure transparency in disaster response is illustrated in Figure 1.

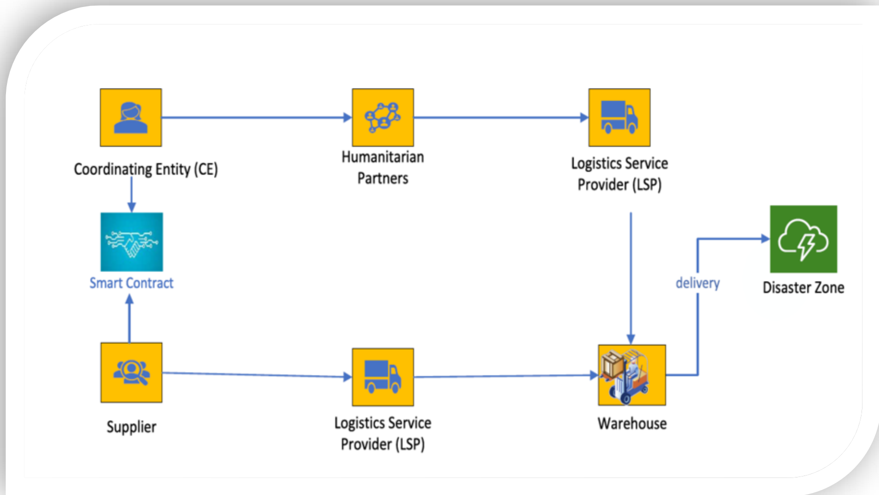

Figure 1: Blockchain-enabled transparency system in disaster response

The key steps of Figure 1 above are highlighted below:

1. a) Coordinating entity (CE) enters a smart contract with a pre-qualified supplier
   b) CE creates an order of the aid goods to the pre-qualified supplier and defines the consignee (central warehouse). They enter the details in the blockchain.
   c) Supplier enters the goods and carrier details into the blockchain and initiates delivery to the logistics service provider (LSP). He then handover the goods to the LSP, who accepts them, and enters these details to the blockchain.
   d) LSP handover the goods at the central warehouse and the consignee inspect and accept the goods and they both enter these details in the blockchain.
2. a) CE informs humanitarian partners (NGOs, donors, private companies) on the aid items required.
   b) Partners hand over the goods to the LSP who accepts them, and they both enter these details in the blockchain
   c) LSP handover the goods at the central warehouse and the consignee inspect and accept the goods and they both enter these details in the blockchain.
3. The goods are ready to be dispatched to the disaster zones/ to the victims who will then be identified through a pre-determined means, for instance verifying

their identity through fingerprints scans to authenticate the biometric information registered in the blockchain.

HSCs rely on donations for their operations and there has been a shift in how donations are made from giving physical items like food, medicines, and clothes to giving cash [21]. Cash donations are preferred as they are easier to make and empower victims to make more choices, thus restoring their dignity [22]. Organisations like the World Food Programme (WFP) accept donations in digital forms such as cryptographic currencies [1]. Figure 2 illustrates how blockchain can be used in disaster response and recovery to track donated assets, ensuring transparency, and reducing fraud and corruption.

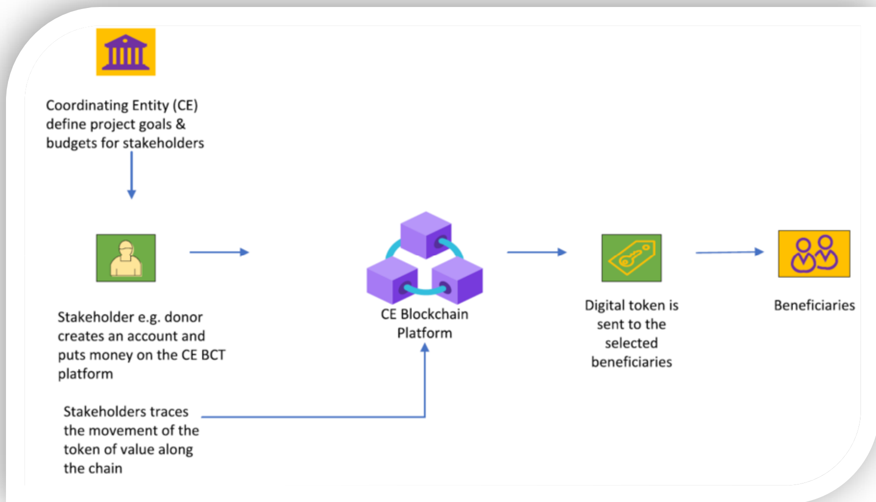

Figure 2: Blockchain-enabled traceability system for funds transfer

The following steps explain the Blockchain traceability system for funds transfer depicted in Figure 2 above.

1. The CE defines the project goals and the budget required from the stakeholders or the public, including the project details to register to the platform. Any willing stakeholders, e.g., a donor, creates an account in the CE platform and receives an encrypted private key and an anonymised public key.
2. The stakeholder then deposits some currency to the CE blockchain platform. If the currency received is in a fiat currency, the CE converts it into a digital currency and records its value as a token. The stakeholder can also trace the token movement.
3. The digital token is sent to the affected victim, who takes it to a local partner to the CE, e.g., a bank that converts the digital currency to fiat currency. The beneficiary can meet their needs and use the donation for income generation activities which helps victims to gain resilience after disasters.

Coordination is vital in any disaster management process [23], and Figure 3 illustrates how blockchain can aid in the coordination of stakeholders. Since each disaster is unique, the trusted CE is responsible for coordinating all the humanitarian partners and registering the ones needed for each disaster. In elaborating on blockchain usage in coordination in our paper, we categorise stakeholders into Primary and Secondary stakeholders as represented in Figure 3 in a circle and rectangle, respectively. Primary stakeholders can trigger the disaster management, while Secondary stakeholders are needed in a complementary basis. For instance, NGOs who are primary stakeholders can get into smart contracts with suppliers, who are secondary stakeholders to supply key medical supplies. In some disasters like terrorism, the host government adds the military to the blockchain for improved response. Smart contracts can be used with shelter providers like hotels for temporal accommodations.

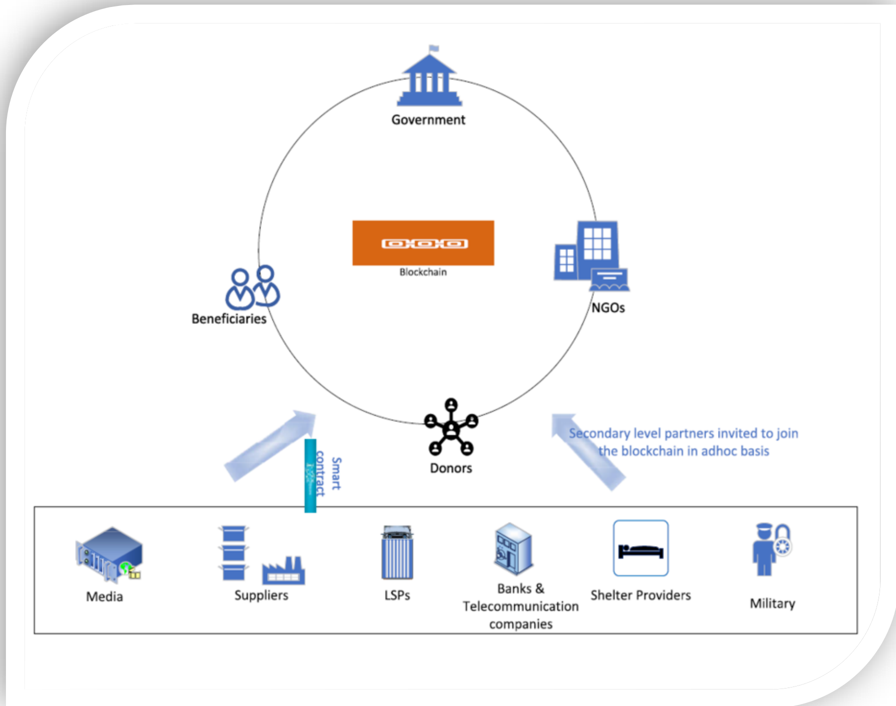

Figure 3: Blockchain-enabled system for coordination of humanitarian supply chain partners

In Figure 3 above

1. The government, NGOs, local communities/beneficiaries, and donors are represented as separate entities, indicating their primary involvement and participation in the humanitarian process.
2. The blockchain network acts as a shared infrastructure, connecting the stakeholders and providing a transparent and immutable ledger for recording and verifying humanitarian data.
3. HSC participants, represented in the circle (primary participants) and rectangle (secondary participants) interact with the blockchain network through smart contracts to verify and execute supply chain processes, thus ensuring transparency, accountability, and adherence to predefined rules and conditions.

3. Gaps and Further Areas of Research

This research recommends the following areas for further investigation.

1. Research on the legal and regulatory challenges associated with implementing blockchain-based traceability solutions in HSCs.
2. Evaluate the impact of blockchain-based traceability systems on the efficiency, effectiveness, and accountability of HSCs and quantify the benefits.
3. Investigate innovative approaches to improve the scalability and performance of blockchain-enabled networks specifically tailored for HSCs.
4. Focus on developing interoperability protocols and standards that enable seamless integration between different blockchain platforms and existing information management systems.
5. Examine new governance models and incentive mechanisms for blockchain-based HSCs. Investigate how decentralised decision-making processes and token economies can promote collaboration, accountability, and fairness among stakeholders.

Conclusion

In this paper, a Blockchain-Based Traceability System for enhanced humanitarian supply chain management was developed. By leveraging the inherent features of blockchain, such as data immutability, cryptographic security, and smart contracts, the traceability system can provide a comprehensive and trustworthy view of the humanitarian supply chain. It enables stakeholders to coordinate and accurately track the movement of humanitarian goods, verify their authenticity, and ensure compliance with regulations and standards. However, successful implementation requires careful consideration of technical, organisational, and regulatory factors to ensure the scalability, interoperability, and sustainability of the Blockchain-Based Traceability System. By embracing this technology and addressing its associated challenges, the humanitarian sector can unlock new possibilities for improving the delivery of essential goods and services, ultimately contributing to positive social impact and sustainable development.

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