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Blockchain-based tractability framework for quality assurance in construction projects

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Abstract

The construction industry has a complex supply chain due to its collaborative working nature. Most of the stakeholders of construction companies are involved in every phase of a project life cycle. Lack of trust among the parties and related quality issues have obstructed the development of the construction industry in Sri Lanka. Project tractability systems powered by blockchain technology have addressed these issues successfully. This design framework that involves with consortium blockchain platform facilitates building trust among stakeholders of the construction company through providing a higher level of transparency and visibility of the quality control process. Real-time data capturing and fraud data avoidance were ensured with the integration of IoT modules to blockchain architecture. Cryptocurrency-based transactions were eliminated from the proposed framework, by considering the legal and technical constraints of the country. Apart from that this research introduces a techniques to develop a new blockchain using transaction selection and node validation by Etherium or Cardano based platforms.

Keywords: Blockchain, Construction Industry, Quality Assurance, Supply chain, Smart Contracts

Introduction

The Construction industry now and again changes with technological development. Quality, time, and cost are significant for the execution of effective undertaking in the construction industry (Aziz, 2013). A higher degree of uncertainty is associate with this industry, as it has a complex supply chain with many partners (Salama & Habis, 2009). Client, Architect, Town planners, Engineers, Surveyors, Contractor, Sub-Contractor, Supplier are ket supply chain partners as identified by (Yanga, et al., 2020; Seng, et al., 2018). This is a flexible industrial sector, where the client involves in the entire project life cycle to assure quality in each phase. Hence, trust among supply chain partners plays a vital role in customer satisfaction of the construction companies (Aziz, 2013).

Blockchain technology

The emergence of blockchain technology has broadened the avenue for quality improvement in the supply chain of many industries (Chen, et al., 2017). The blockchain concept was introduced by Satoshi Nakamoto, in 2008 through a cryptocurrency called "Bitcoin". This is a peer-peer decentralized, electronic currency scheme. Blockchain technology rapidly spread as a secure and encrypted mode of digital transaction (Turk & Klinc, 2017). The distributed ledger is the core concept of the blockchain. There is an ordered chain of blocks and each block incorporates a record of substantial organization movement. These blocks can be identified as encrypted bits of information (Benton &

Radziwill, 2017), which connect with cryptographic hash values. Elimination of middlemen and decentralization ensure the trust of the participant in the blockchain network. The smart contract was introduced by blockchain 2.0, which is an interesting and amazing application (Turk & Klinc, 2017). Business rules and constraints related to two or more parties can convert into smart contracts (Perera, et al., 2020). This provides a higher level of accuracy to any process without the interference of an external application.

Research problem

The use of information technology in the construction industry is relatively less. Though the systems like Business Information Management (BIM) were evolved, still construction companies struggling to adapt to those in an uncertain, complex and, challenging environment (Turk & Klinc, 2017; Epasinghe, et al., 2018). There are new concepts like build and design which are rapidly spread all over the world due to the lower level of risk, less project time and, cost (Ruvinda & Banmunuarachchi, 2020) but the Sri Lankan construction industry failed to hit the higher performance in build and design sector due to the issues in project transparency. A study by (Joseph & Jayasena, 2008) showed that the public sector of Sri Lanka mostly preferred to use Measure and pay methods in construction projects due to the features like accountability and project transparency. Hence the development of trust with effective mechanisms has become a challenge to construction companies.

Research objectives

There is a lengthy supply chain for a construction project. To build a blockchain-based framework all the essential supply chain partners, who are associate with the different stages of the project life cycle should be added to the system. Placement and connection of entities at the appropriate levels through a decentralized system have ensured and enhanced transparency and traceability of the whole business process. Sri Lanka lags behind new technologies like blockchain hence cryptocurrency-based digital transactions do not take place in the country. Therefore this study was conducted with the general objective of development of a quality management system for the construction companies, which facilitates real-time information gathering, assessing the quality standard in and process validation while maintaining the transparency of the quality management system to build trust among the stakeholders.

Blockchain Development and Methodology

Framework definition

There are outer environment parties as well as inner environment parties that should be included in this proposed system. Confidential information and business secrete should not visible to the outer environment. By considering business risks and required functionalities have to select the appropriate network.

Blockchain networks

Description of the Blockchain Network are given in Table 1.

***Table 1**: Blockchain Network*

Blockchain Type	Description
Public Blockchain	This is an open-source network, where no restriction on the network participants. The Authority of the network has decentralized, hence anyone can enter the network and be able to access (read, write and edit) (Alam, 2019). Once the entered data validate through the network, changes or modifications of the entries are restricted through the system (Benton & Radziwill, 2017).
Private blockchain	Private blockchains networks consist of pre-selected participants. Permission of the authorized party of the blockchain is essential to join the network (Perera, et al., 2020). There are different access levels within the network, thus able to differentiate the users who can write, read and edit blockchain. Private networks also use distributed ledgers, but there is less level of decentralization than public networks. This facilitates, pre-define participant, to reach the information, validation, and verification of each transaction that happen among the nodes (Lin & Liao, 2017).
Consortium blockchain	Consortium blockchain can be identified as the most suitable platform for construction projects where many parties work collaboratively. Previous studies by (Zhong, et al., 2020; Perera, et al., 2020; Nanayakkre, et al., 2021) also suggested a consortium blockchain network for the construction industry where the governance of the network always keeps with the construction company. Separate networks can form by looking at the flow of items, network administration will assign to reliable executive-level employees of the company (e.g. project manager, project engineer). The authors proposed to create project-wise consortiums where all the partners of a project will appear within the same consortiums. When creating the communication channel for each consortium, able to assign several governance bodies by considering different levels of partnerships and strategic alliances among the supply chain partners. The reliability of the machine can improve with the sharing governance. The higher degree of transparency reduces the risk of sharing governance among the partners.

Development of the system architecture

The architecture of the proposed Blockchain model illustrates in the Figure 1 and description given in Table 2.

***Table 2**: Layers in Blockchain Architecture*

Layer	Description
Layer 1	Data Input Layer: IoT module has been integrated to boost the performance of quality management. It's supported by different types of sensors such as temperature sensors, to monitor the quality of raw material input and Infrared

	sensors to read the measurements in construction sites. The use of Radio Frequency Identification (RFID) together with Global Positioning System (GPS) technology assure the quantity, quality, and presence of material at the appropriate location. Researchers (Alam, 2019; Chen, et al., 2017) who have done blockchain applications to various industries have integrated IoT modules to gather information as well as to communicate. Project details and policies in ERP and other Information Systems (IS) have also been entered into blockchain through this layer to boost supply chain performance (Hader, et al., 2020). Also (Farouk & Darwish, 2020) has proposed reversed logistic e- supply chain by linking ERP with blockchain technology.
Layer 2	Ledger Layer: Data entered into the blockchain, will be stored as ledgers in the second layer. Quality ledgers of products, quality ledgers of process, and assets ledgers with participants are some of them. Need to keep copies of public ledgers as well as private ledgers for the execution of smart contracts. There are techniques relevant to ledger layers such as encryption algorithm, hash code, and digital signatures which are all fueled by the advanced data structures. These ledgers appear as a linked list of block in this layer, and each block link to the previous list through hash pointers in blockhead as shown in figure.
Layer 3	Contract Layer: This layer is crucial for quality assurance. Acceptance and the rejection of the materials, process, and legal constraints handle through smart contracts, which is hard to handle with any other technology. Approval of legal activities such as tenders, acceptance of orders, and processes such as design and development tackle through the smart contracts by considering client requirements and company policies.
Layer 4	Business Service Layer: Every Application that is running on a blockchain platform is listed under this. There is a wide range of soft wares and decentralized applications which have been introduced to an assessment of quality, procurement processing, Supplier Relationship Management (SRM), Customer Relationship Management (CRM), and smart contract execution.

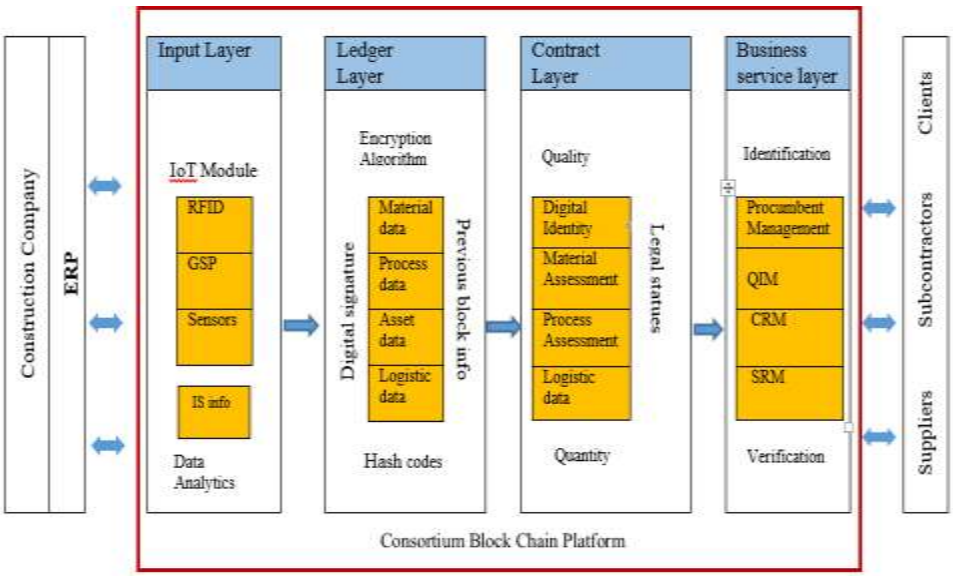

***Figure 1**: Architecture of the proposed framework*

Development of business applications

Identification of the appropriate blockchain platform is the first step. Several blockchain platforms were designed for commercial purposes. Different algorithms, consequence mechanisms, and languages are associated with those platforms. By assessing features of blockchain platforms Etherium and Cardano have selected for this proposed framework. As per the studies by (Nanayakkara, et al., 2021; Bahalul Haque & Rahman, 2020) lucrative features of these blockchain platforms were gathered in table 3.

Table 3: *Details of Blockchain platforms*

Etherium	Cardano
A popular platform	Rising popularity
Uses proof of work technology	Proof of stake technology
High support community	Satisfactory support community
Popular in apps development	Evidence-based and peer-reviewed

Transaction selection

In blockchain development, every function or task that is made through the network is recognized as a transaction (Bahalul Haque & Rahman, 2020). The occurrence of all the transactions will be notified between the peers. Sender's public key and private key are essential to exchange information among peers, and blocks are using to store all types of data.

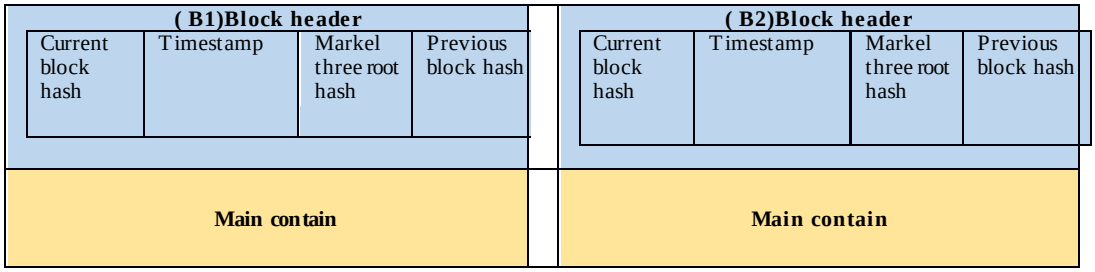

Figure 2*: Block Structure*

Apart from main data, blocks have timestamps of the transaction, block hash, and market root hash values (Bahalul Haque & Rahman, 2020), as in figure. In this proposed system, the main content will include quality-related data such as quantity, quality certifications of suppliers, and manufacturers' detail. Timestamps assure the time and date that every item adds to the inventory and is released from the inventory. Usually, data that is transferred through the network is encrypted using a hash function (SHA256 or any other), which acts as a unique identifier for each block (Mahmud, et al., 2018). Markel three function is essential to the generation of hash values. This performs the complex mathematical hash calculation, which resulting 64 character codes (Lin & Liao, 2017). This calculation uses all the transactions relevant to a single block.

Node validation

Single change made on data items leads to changes in the hash value. Hence it facilitates checking whether any update has been done on existing information or not (Bahalul Haque & Rahman, 2020). A higher level of quality of all the material in inventories is ensured regardless of the number of suppliers and contractors through this mechanism.

The proposed system should be developed with some priority flags to recognize the necessity of adding the node to the blockchain. When there are nodes with the same priority level, nodes to be validated validate can select by considering their arrival time to the mining pool. Smart contract-based secure mechanism able to use for the miner registration and block validation in this proposed system (Zhang & Lee, 2019). Construction firms handle several projects simultaneously, with different suppliers, subcontractors, and contractors. Consortium blockchain network facilitates provide visibility of selected contracts only to selected parties. Accordingly, miners' registration and validation of critical quality-related information can hand over to authorized parties of the company (Dib, et al., 2018). When the validation is performed, the relevant block will be integrated into the blockchain and notification will be broadcast to every peer in the network. This also provides the transparency of transactions, as every miner receives a copy of information through distributed ledger technology (Zheng, et al., 2017).

Conclusion

Consortium blockchain networks provide a strong background to maintain privacy levels among the participants in a construction project through the use of permissoned and permission-less members in the network. Necessary aspects of ERP outputs are supposed to add to the ledgers, hence participants in the blockchain will access only specific detail of the Authorized project. IoT module enhances the accuracy of the input data relevant to quality assessment by avoiding human errors. Quality measures were empowered through smart contracts, which are validated by the responsible pool of miners (consists of internal and external parties). Smart contract-based miner registration and node validation mechanism have been suggested to use to achieve a higher level of accuracy while maintaining the simplicity of the system. Due to the current legal and technical constraints of the country, cryptocurrency base transactions were avoided from this proposed framework. Future research avenues are there to link cryptocurrency-based digital transactions to boost overall performance in the construction industry.

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