Transparent Data Dealing: Hyperledger Fabric Based Biomedical Engineering Supply Chain

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***Abstract*— Blockchain is a decentralized and immutable technology which offers transparency for the digital world, where habitual technology does not. The novel blockchain technology may be employed by many sectors, i.e., healthcare, bank, government services, and supply chain. In particular, Biomedical Engineering Supply Chain (BESC) is a significant part of the medical sector that supplies equipment for the medical sector i.e., Covid-19 testing kit, PPE (Personal Protection Equipment), and medicine. The biomedical product should be able to be traced and the data secured; otherwise, the initial data may be modified and potentially risking patients and the public. Nevertheless, the conventional centralized technology creates a leakage point and as such, compromises data security. This paper proposes a new data dealing approach with using Hyperledger Fabric Blockchain-based BESC to alleviate the centralized controllable and operational issues. The blockchain-based BESC is a novel approach, which can control the users and subsequently eliminate the possibility of tampering within the blockchain system when stored.**

***Keywords*— Consortium blockchain, Covid-19, biomedical, transaction, security.**

I. Introduction

In 2009 [1], Nakamoto has developed Bitcoin application that was designed only for financial transactions [2]. Blockchain is a chain of the block that consists of hash key, timestamps, transactions, and previous block's hash key [2]. The hash key is 256 bits crypto key, and each block comprises of the current hash key and the previous block's hash key [3][4]. The timestamp is the block creation time, and each block must have one transaction [2]. The properties of blockchain are shown in Fig. 1.

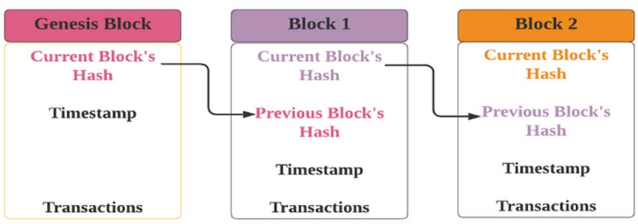

Fig. 1: Chain of blocks

As previously stated, Blockchain is a chain of the block that is created by the hash signature illustrated by Fig. 1. One of the growing interests on the blockchain is in healthcare, where many experts [5] believe that decentralized technology could solve some of its issues, such as data missing, data tampering, confidential data security. Blockchain offers a new approach to securing data in the storage and therefore, it is deemed that medical data can be made consistently available across all users instantaneously by employing blockchain in healthcare. Such approach is not possible on centralized system.

The recent COVID-19 pandemic has put emphasis on the efficiency for medical product supply. To date the World health organizations (WHO) has deemed that COVID-19 as a global pandemic [6]. Nearly 31,571,198 people are effected and 971,177 people has died in short time in the world by such disease. The only preventive measure to combat the spread of the disease is to protect health person from the virus. As a consequence, the demand for medical products and equipment are substantially increased. However, health system of every country faces significant challenges in tracking and keeping records of medical products. Limited capacities and in addition with conventional supply chain process, the pharmaceutical companies are unable to manage with the supply effectively. Moreover, the existing approach of supply chain may not be able to rapidly identify specific point within the supply chain that needs to be improved i.e., worker shortage, worker securities, privacy of product and shortage of medical essentials. The issue is also compounded with the widespread problem regarding poor health services, ineffective monitoring, inappropriate lab capability and restricted health care facilities.

The biomedical engineering is the application of the principles and problem-solving techniques of engineering to biology and medicine. Biomedical engineering improves the healthcare department by inventing and manufacturing the disease protecting equipment i.e. medicine, testing device, and chemical. Such equipment helps mass population to be protected from diseases outbreak such as COVID-19 [7]. The biomedical, medical engineering product of COVID-19 such as testing kit, facemask, and hand sanitizer are crucially needed in the fight against the COVID-19. Each disease require specialized medical equipment in disease treatment. To rapidly supply biomedical engineering products to emergency response teams in various countries, biomedical engineering supply chain is the best way to coordinate the supply of product systematically. However, the existing approach of supply chain is inefficient and consistent issue may persists, i.e. operational and disruption risk [8][9][10], product tracking and data tracing [11], conventional data transaction [12] and finding the data leakage point in the system [11]. As such, these are some of the generic issues that BESC may be able to alleviate. This paper proposed a Hyperledger Fabric Blockchain technology for the biomedical, medical engineering supply chain to upgrade the data security while controlling the user in the BESC system.

II. Background

Hyperledger Fabric (HF) is an open-source permissioned blockchain introduced by the Linux Foundation [13] that contains a security infrastructure for authentication and authorization. Execute-Order-Validate architecture is a new approach to the transaction that enable HF to operate uniquely from other blockchain platform. Indeed, based on the consensus protocol, transactions are ordered in HF [14]. Then, in the execution phase, each peer executes transactions sequentially in the same order. In addition, it supports general-purpose programming language smart contracts i.e. chaincodes [15].

HF allows the creation of different channels within the same network. Every channel has its ledger, and only members of the channel has the copy of the ledger. Fig. 2 illustrates the channel concept [14][16].

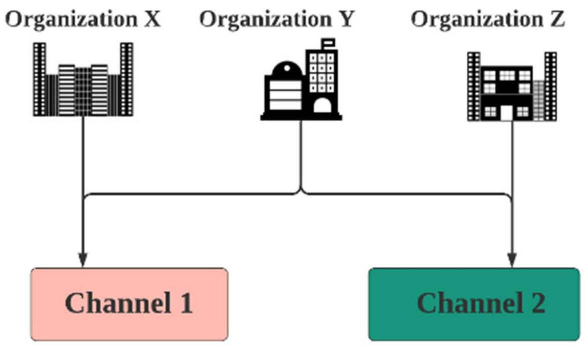

Fig. 2: Channel concept of Hyperledger Fabric

Fig. 2 represents two-channels and three organizations, where channel 1 members are Organization X and Organization Y, whereas channel 2's members are Organization Y and Organization Z. As such, Organization Y has both channels ledger because it connects with both channels. Similarly, Organization X has channel 1's ledger, and Organization Z has channel 2's ledger.

HF introduces orderer nodes to achieve consensus. Three ordering services are offered by HF [14].

- Solo: It has only one ordering node that makes it a single-point-of-failure. Thus, solo ordering service is not suitable for business [14]. However, it could be employed for non-critical operation such as education or product development.
- Kafka: Kafka follows the leader and follower approach, where the leader orderer sends the transactions to the follower orderer nodes. The choice of the leader is made dynamically, and as long as the majority of the nodes is up, the system is built to sustain using the Crash Fault Tolerant (CFT) mechanism [14]. The HF also has the option that supports multiple orderers, but the downside is the challenge to deploy [17].
- Raft: It is a new ordering service of HF and possess similar characteristics to Kafka and also has the same concepts i.e., follow the leader and follower methods. However, Raft is relatively simple to set up [14].

The supply chain is a process that connects the world and supplies the products from origin to end customers. Therefore, the supply chain require every sector to provide a product where it needs. To date, there are many types of the supply chain, i.e. food supply chain, pharma supply chain, biochemical engineering supply chain, and electronics product supply chain.

In particular, Biomedical Engineering Supply Chain is typically related to the medical sector, which deals with the supply medical products. The importance of such supply chain is apparent in the recent outbreak of coronavirus (COVID-19), where World Health Organization (WHO) has announced as pandemic leading to global emergency[18][19][20]. Under a period of a year, many parts of the world are locked down and borders are shut to prevent the virus from spreading. Some countries are severely affected e.g., USA, India, and Brazil. In addition, a counter measure has been taken to mitigate the coronavirus. As such, the demand for medical products and equipment substantially rises. Medical institution, hospitals and emergency response teams are in need of personal and protective equipment (PPE), testing-kit facemask, and hand sanitizer [21].

In spite of investing high amount of money to improve medicinal product, the healthcare system must also look to improving biomedical engineering supply chain system. It is to ensure rapid process of product supply. Also, the supply-chain industry is facing a lack of data transparency issue that ensure product security. The conventional data dealing method leaves the gap that enables malicious user tamper with confidential data. Therefore, an efficient BESC is essential to connect critical medical components with the medical professionals and it includes supplier, manufacturer, exporter, and importer.

In fact, blockchain potential use cases in healthcare vary accordingly to satisfy different requirements, such as data sharing, security, and data access. Blockchain is now showing enough opportunities to become an integral part of fighting against COVID-19 as it would enable efficient tracking and monitoring solutions, ensure a transparent supply chain of vital products. This paper discusses blockchain-based BESC to ensure product quality, traceability, and faster process that typical supply chain method could not support.

III. Related Work

The current era of technology is raised by the blockchain that mainly offers high security technology. Blockchain may be able to confirmed that the data is secured in the storage which doesn't compromise with security. The acceptance of blockchain is increasing very fast because of the poor data dealing scheme of conventional technology. Basically, the issue of habitual technology is the development method called a centrally managed scheme. Malicious users may attempt to manipulate poor data dealing approach of conventional technologies to leak out confidential data. Conventional technology provide transparency by only the trusted person, which is the reason issues such as data tampering, leakage of confidential data, and data sharing are quite prominent [11][12].

In general, the significant issue is confidential data leakage that needs to be addressed, however finding the actual leakage point is difficult in the conventional data dealing method. In addition, the conventional approach is poor, which takes a long time to complete a process. This paper's aim is to provide a high level of data security with rapid process, complemented with using blockchain technology. This paper proposed Hyperledger Fabric Blockchain where users will be controlled and from this research, not only BESC but using this approach the supply chain industry will be benefited.

IV. System Architecture and Workflow

This section discusses the core system of HF blockchain-based BESC. The system architecture is illustrated by Fig. 3, where BESC is developed based upon the HF blockchain. The module of BESC is a supplier, manufacturer, warehouse, hospital, and admin. Each entity is designed to acquire a copy of the central ledger. The blockchain's stored data cannot be tampered and as a consequence, confidential data leak out will be impossible. The system workflow is also discussed in this section that illustrates the five steps shown by Fig. 4.

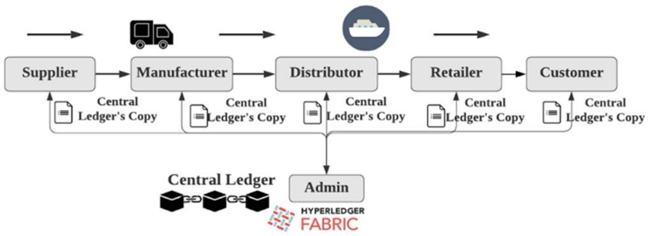

Fig. 3: HF Blockchain Based System Architecture

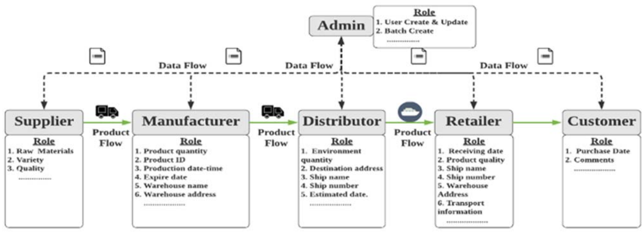

Fig. 4: Workflow of Biomedical Engineering Supply Chain

Admin: Admin user creates and updates, also creates a new batch that is the first stage of the medical equipment batch.

Supplier: Supplier provides the raw materials to the manufacturer for the production of medical equipment and updates the data in the system: materials name, quality, and variety.

Manufacturer: Manufactures the product that is batch initiated by admin and update the product information, i.e. product quantity, product ID, production date-time, expire date, warehouse name, and warehouse address.

Distributor: After production, the product goes to the distributor, which later sends it to the next destination i.e., retailer, and the user of the distributor updates the data such as warehouse environment quantity, a destination address, ship name, ship number, estimated date.

Retailer: The retailer is the sales point where the consumer can find their product. The retailer updates the data, i.e. receiving date, product quality, ship name, ship number, and transport information.

Consumer: Consumer is the final destination of this system. Consumer buys the product and updates the purchase date. In addition, this system provides an option to consumer to comments about the product.

This research follows such a transparent way where used pair-to-pair data dealing approaches that reduced the operational time and provide high data security.

V. Design and Method of Experiments

The Hyperledger blockchain platform evaluated in this experiment is Hyperledger Fabric v1.2. These experiments are conducted on a Lenovo Ideapad 320, and the machine specifications are Intel(R) Core(TM) i3-6006U CPU @ 2.00GHz, 8GB RAM, SSD 128GB, running Ubuntu 18.04. By varying the workload, two platform's performance will be evaluated to justify the proposed solution with 500 transactions and the metrics are execution time, latency, and throughput.

The first experiment is the scalability that is measured by varying the number of nodes up to 20 in this platform. In the second experiment, the transaction is measured from the submission of the transaction for consensus by the peers until added to the block. Execution time is the time required for a platform to add and execute a transaction successfully. The number of successful transactions per second is throughput and the latency is the time that takes to respond to each transaction [22].

Hyperledger Caliper is the tool used to quantify blockchain performance. It allows users to test different blockchain platform to obtain the result. This paper used a modified version of Hyperledger Caliper. Hyperledger Caliper has some characteristics i.e., resource usage and transactions per second (TPS) and it generates HTML reports. The experiment conducted in this work is basically to calculate the execution time. The architecture of evaluating the performance of the blockchain platform has mainly four layers such as performance analysis layer, adapter layer, interface layer, and blockchain framework. The architecture of evaluating the performance is shown in Fig. 5.

The major layer of Caliper architecture is the adaption layer. This layer is mainly for the integration of different blockchain implementations into the evaluation system. For every blockchain platform to be tested, the adaptor is responsible to translate between the blockchain protocol and the Caliper north bound interfaces (NBIs). The interface layer is responsible for providing multiple blockchain north bound interfaces that are used to deploy, invoke, and query smart contracts. The function of the performance evaluation layer is to perform stress tests on the implemented blockchain platform, where the blockchain network details and test parameters are provided as input for each test.

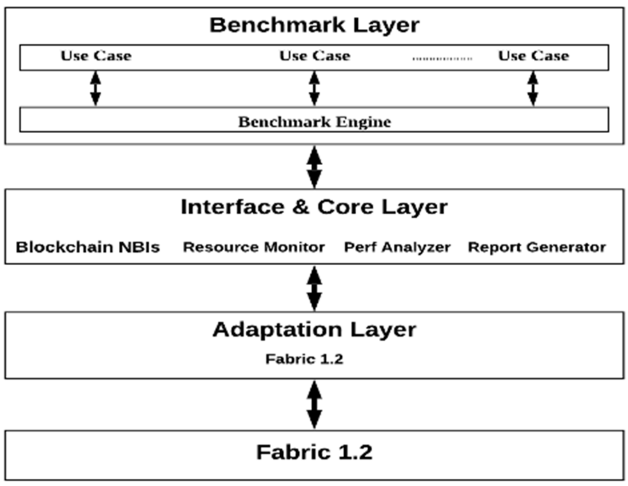

Fig. 5: The architecture of evaluating the performance

Twenty nodes are created to see the node creation time of the proposed system that represents in Fig. 6. The minimum node creation time is 8 seconds at 9 nodes and the maximum node creation time is 31 seconds for 18 nodes. Therefore, the average node creation time is 16 seconds of the proposed system.

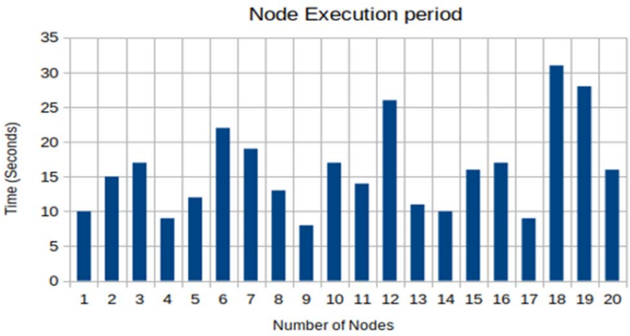

Fig. 6: Node Execution Time

For comparative analysis, the experiment is conducted based on 500 transactions for both the proposed system and the compared system. The proposed system requires 0.09 seconds for first transaction and the compared system i.e., Ethereum need 0.21 seconds for the first transaction.

The proposed system is compared with the Ethereum platform, i.e., transaction time, latency time, and throughput time. The comparative analysis of the proposed system is shown in Fig. 7 through Fig. 9. The execution time of Hyperledger and Ethereum with varying number of transactions is 1, 100, 200, 300, 400, 500 in scale.

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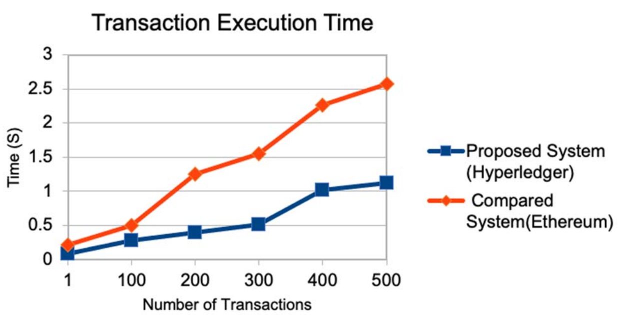

Fig. 7: Transaction Execution Time

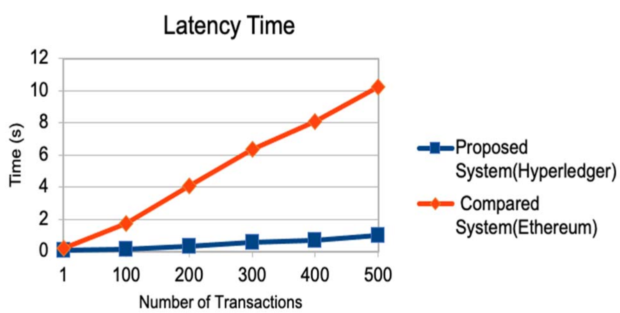

Fig. 8: Latency Time

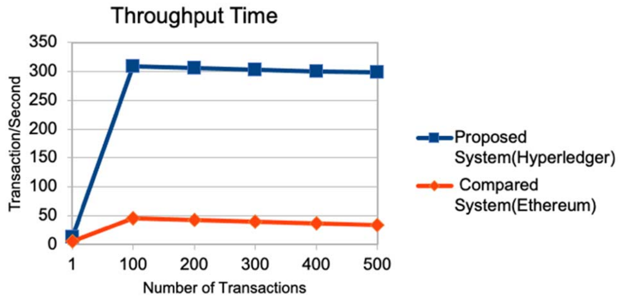

Fig. 9: Throughput Time

The outcome of the proposed system is compared with other researcher's work, where the latency and throughput of Hyperledger are better than the Ethereum. In 2017, Dinh [23] works on the benchmarks of different blockchain network were the platforms Ethereum, Hyperledger, and Parity. The latency of Parity is better than Ethereum and Hyperledger. However, the throughput of Parity is quite poor if compared against Hyperledger and Ethereum. In any number of transactions, the performance of Hyperledger is consistently higher than Ethereum and parity. Another researcher Suporn [24] works on the same benchmarks but there were 2 platforms Ethereum and Hyperledger. It is observed that the outcome is comparable to the proposed system. The latency and throughput of Hyperledger are consistently better than Ethereum. The difference of proposed system with other research works are blockchain's type, applications and, performance, where the proposed system used private blockchain and supply chain application. In contrast, other research works employed public blockchain and cryptocurrency application. The proposed system's outcome is discussed in the subsequent section.

VI. Results and Discussion

The performance of Hyperledger Fabric is analysed and compared with Ethereum based on the execution time, average latency, throughput.

This work investigates the execution time of varying the number of transactions with different platforms. The execution time is shown by Fig. 7, where two different line graphs shows the transaction execution time each of the systems. The Hyperledger transacted time is 0.12 second less than the Ethereum system for first transaction. The transaction execution time increases with the number of transactions. But at 300 number of transactions, Ethereum execution time is faster when compared with the Hyperledger. At 500 number of transactions, the execution time of Hyperledger is 1.12 seconds, however Ethereum require only 2.58 seconds. Therefore, the Hyperledger fabric transaction execution time is better than the Ethereum execution time.

The comparison of latency in five sets of experiments for each platform is presented in Fig. 8. The latency of each platform for the first transaction is 0.07 seconds of the Hyperledger platform and the latency of Ethereum platform is 0.20 seconds. When the number of transactions is increased from 200 to 300, the latency is high in both platforms when compared with other data set. The latency is increasing as the transactions increased in both platforms. But the latency growth rate of Hyperledger fabric is slower, as opposed to latency growth of Ethereum which is comparatively high.

The throughput (transaction/second) of Hyperledger and Ethereum are shown by Fig. 9 in unit of transaction per second. At the base point 100, both platforms achieved maximum throughput of Hyperledger 309.54 transactions per second and Ethereum 45.09 transactions per second. At the base point 500, Hyperledger throughput is 298.33 transactions per second and Ethereum throughput is 33.53tns/s. Gradually, the throughput decreases with the number of increasing transaction. Hyperledger has picked up higher throughput from the beginning than Ethereum in all of the data sets.

Ethereum consistently performs poorly where Hyperledger performs better in the term of transaction execution time, latency, and throughput.

VII. CONCLUSION

Blockchain brings out many significant features, which introduced a novel dealing approach. Since 2008, the technology has been rapidly expanding and also being increasingly accepted because of the immutable and transparent features. On the other hand, the conventional dealing method is immature and lack of transparency. This research focused on the data security and the process time. To that end, the efficiency of the proposed method is more secured and faster than conventional technologies. In addition, the proposed system performs faster process as compared to other blockchain platforms. This novel dealing method substantially reduces the processing time and also offers the ability to control users action.

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