



Interoperable Health Care System Using Blockchain Technology

K. DAHRI⁺⁺, M. A. MEMON^{*}, K. KHOUMBATI^{*}, I. A. ISMAILI^{*}

Institute of Information and Communication Technology, University of Sindh, Jamshoro, Pakistan

Received 4th August 2018 and Revised 29th April 2019

Abstract: The need for integration is not new but it existed since applications moved from central processors to distributed systems and networks. This need has emerged as disparate Information Systems (IS) that automate business processes which run on different computer platforms and have been based on a diversity of standards, operating systems and computer languages. In healthcare, interoperability is the important because of different information systems (IS) to communicate, interchange data, and use of the exchanged information among systems. Blockchain technology can address the interoperability challenges in healthcare systems; it can help healthcare providers, healthcare stakeholders and researchers to share health data in secure way. In this paper, we have proposed a Blockchain based healthcare systems which can address the interoperability issues in healthcare in secure in transparent way.

Keywords: Healthcare systems, Blockchain, Interoperability, Information system, Blockchain based Healthcare

1. INTRODUCTION

Patient's health care data is usually dispersed and scattered across many hospitals, medical laboratories, basic healthcare units or drug stores, this happens because life events can take patients to different locations where they leave their medical history or data to the health service providers. The patients' data then remain in the custody of the health service providers who won't allow patients to access or modify their personal data and data remains isolated and not shareable among different stake holders due to the lack of trust, data security or privacy issues.

Sharing health care data is very essential part of any advanced health care system but at the same time, it is big challenge for system designers to design system with high reliability and security so that while sharing healthcare data privacy is not compromised. Along with data sharing other interoperability challenges like tracking changes in data, originality of data, localized management of independent healthcare information systems (IS), data security, data integrity and data consistency also need special consideration of systems designers (Ekblaw, 2016).

To address these interoperability challenges of health care systems there should be some standard or system which can allow users while data sharing across clinician, medical laboratories, dispensaries, clinics and patients without the help of any application. Moreover, there should be some mechanism for the integration of different stakeholders of healthcare systems so that they can also provide better medical facilities in case of emergencies.

Blockchain is a decentralized peer-to-peer distributed ledger technology which provides features like security, immutability, data sharing, data integrity, decentralization and mobility etc. (Linn, 2016) Blockchain is the fundamental component or foundation for the Bitcoin, which is divided into three parts, a distributed network, a shared ledger and digital transactions. Blockchain technology can address the interoperability challenges in healthcare systems; it can help healthcare providers, healthcare stakeholders and researchers to share health data in secure way. (McGhin, 2019).

(Linn, 2016) have proposed a public Blockchain access control manager for healthcare system stakeholders to store patients' records on Blockchain which can be used by different stakeholders securely. (Alonso, 2019) have done state of the art in research on Blockchain in healthcare, they have studied and analyzed publication since 2016 and concluded that this innovative technology can offers better way of exchanging information among interested parties of health care system with security and privacy.

Besides these proposed studies and models various implementations like Health Data Gateway (HDG) an application for smart phones and tablets for the patients to manage their own data (Yue, 2016). MedRec (Ekblaw, 2016) a project of MIT media lab and Beth Israel Deaconess Medical Center, the purpose of this project was to give permission to patients and other interested parties over healthcare data and to maintain log data on Blockchain. Actual data is not stored on Blockchain

⁺⁺Corresponding Author: kamran.dahri@usindh.edu.pk

^{*}Institute of Information and Communication Technology, University of Sindh, Jamshoro, Pakistan

only the permissions and data usage logs are maintained on Blockchain, Guardtime (Mettler, 2017) a data security firm located in Netherland in sponsor with the government of Estonia created this system to keep the identities of patients on Blockchain.

In this paper, we propose an interoperable healthcare system based on Blockchain technology which can address interoperability issues and allows healthcare system stakeholders to share data with each other with privacy and secrecy. To prove the proposed concept of healthcare system on Blockchain, a prototype system is developed so that the user acceptability and usability can be tested.

We organize the rest of the paper as follows. We provide brief details on the proposed system in Section 2 and its implementation and Testing in Section 3. In Section 4, we provide the related literature and finally conclude in Section 5.

2. PROPOSED SYSTEM

Our proposed system design has three layers, which integrates different healthcare systems with the help of Blockchain layer. Before we describe the proposed system in detail let's have a look on following high-level structure of proposed system which will help us to understand proposed system easily.

(Fig 1) shows the high level structure of proposed system, description of each component is given below

Independent System. This component is an independent healthcare system which can request registration server to add to Blockchain server and authorize it to access data on Blockchain server. Independent systems are hospitals and medical care centers which are allowed to create and add patient's records in their local databases and only required sharable part of data is updated on Blockchain.

Registration server. The job of registration server is to receive requests from any authorized independent healthcare systems to create and add patients' records on Blockchain server. Registration server will check the registration certificate of authorized node before writing the data on Blockchain.

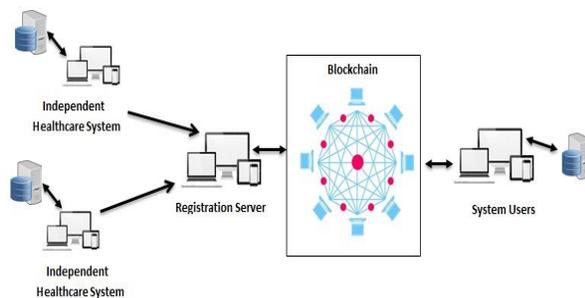


Fig 1. High-level Architecture of Proposed System

Blockchain server. In proposed system, Hyper ledger fabric is used for Blockchain server which allows independent systems to read and write data. This will allow independent system to share / access healthcare data across different systems.

Systems users. These are the users using different devices like personal computers, laptops, tablets and smartphones to access and use healthcare information of patients. System users like laboratories and doctors etc can also maintain their own local databases for different purposes. To understand request and response flow consider (Fig 2).

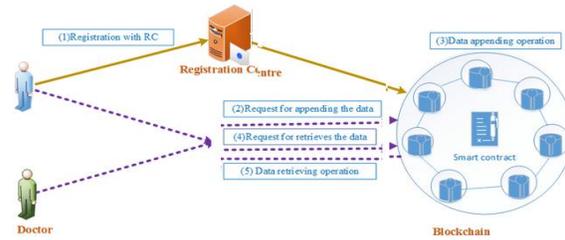


Fig 2. Request Response flow of proposed system

In (Fig 2). There are 5 steps of request and response to add and access data by different users of systems.

System user of independent system will send request to registration server which checks the authorization of requester, once request is accepted by the Blockchain server then the requester sends the data to Blockchain and Blockchain servers appends the information on to various Blockchain servers which then replicates the data across all Blockchain servers with the help of smart contracts.

Users like doctors and patients etc request the information from Blockchain server using the application designed for them. Patients will be able to access to their information with the help hash key provided to them and doctors will be able to access the information of patients on the bases on hash key provided by the patients and they can also append new information on the blocks if they have authorization to append the data.

We adopt the client-server architecture along with peer to peer architecture for this healthcare system. Thus, the independent system can interact with the Blockchain server through the Internet. The Blockchain servers, on the other hand, use the peer to peer architecture, to replicate the information across different server so that replicas can be created and users across the network can access data. The concept of Blockchain depends on peer to peer architecture to avoid centralization of data; this system takes the advantage of this concept and uses Blockchain for healthcare systems. The implementation of this concept is provided in implementation section.

3. RELATED WORK

In this section, we provide some of the related work on healthcare systems and Blockchain based health care systems.

One of the related study to ours is from (Mannaro, 2018). OpenCare is a global telemedicine platform that directly connects patients to physicians for medical care anywhere in the world. It's a Blockchain based decentralized application which uses Ethereum smart contracts, IPFS for decentralized cloud storage and client-side encryption for medical information. A qualitative study (interviews and questionnaires) were conducted from the dermatologists and practitioners to improve the quality of system.(Peterson, 2016) proposed an algorithms for storing data in Block and adding those Blocks to Blockchain network. They also proposed an algorithm for medical data encryption before writing data to Blockchain, (Sharma, 2017) also proposed architecture named Block-VN, for smart city using proposed architecture. Data sharing can be done using Blockchain in proposed architecture; various smart city hypothetical scenarios are discussed by the authors to justify their proposed architecture.

(Yue, 2016)proposed a model named HDG-centric health ecosystem; this model has three levels, data usage layer, data management layer and secure data storage layer. Data usage layer is responsible for providing data to end users; data management layer is providing service or translation in between data usage and data storage layer and data storage layer stores data on the cloud based block chain in proposed model. Authors also developed an Android application for end users for accessing and controlling of their own data from the Blockchain based cloud.

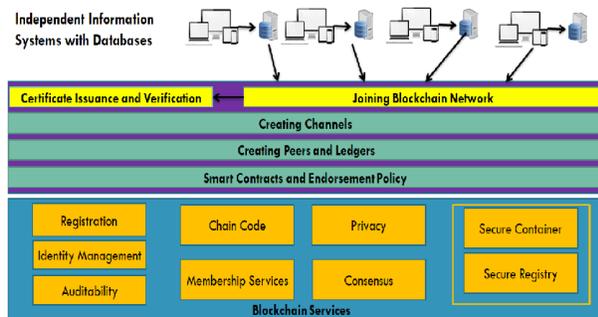


Fig 3.Internal levels of proposed system

4. IMPLEMENTATION AND TESTING

In this section we will discuss the implementation of proposed system in detail. The proposed system has three layers named *independent system*, *registration and authorization services*, *Blockchain service* as (Fig 3).

Independent system. This layer handles the joining of any new independent system like hospitals, Medicare centers and basic health units etc. we have developed two independent systems, one of them is designed and

developed in Node JS and other is designed in Java. These independent systems have their own databases in My SQL and MS access respectively and are connected on same Blockchain network to share information. The interfaces of these systems are shown in (Fig 4). Once user is logged in into system user can create patients records or append data in patients existing records. These systems are designed in different technologies to prove that the system developed in heterogeneous technologies can communicate and share data using Blockchain services.



Fig 4. Independent systems' interfaces

Registration and Authorization services. This layer is responsible for creating the Blockchain network after the verification from the certificate issuance layer. This is done by the administrator of the network administrator of the Blockchain network creator is someone who creates the network for the first time and other nodes only join the network to share the information. To understand the creation of network, issuance of certificate, creating of ledgers and working of smart contracts are shown in (Fig 5).

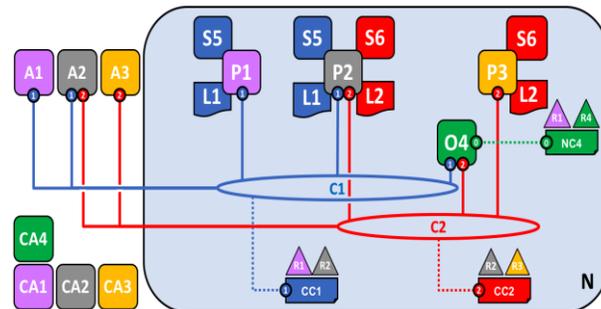


Fig.5. Independent systems' interfaces

In Fig 5, A1, A2 and A3 are independent hospital systems that have created channel C1 and C2. Now these hospitals using S5 and S6 smart contracts are able to read and append data in ledgers L1 and L2. Only authorized hospitals can join the network, once the certificate authority is verified and network is joined hospitals can join channels to append and read data on ledgers.(Fig. 6) shows how the data will be read and append on the ledgers. It also shows the originating address of blocks and the address of the next block connecting to them. It shows that the blocks are connected to each other with the hash addresses of blocks in next and previous fields, which will help in

accessing complete history of records of any patients. As shown in Fig 6, a records in added first block and then patients address is modified from Mirpukhas to Hyderabad in third block but audit trail is maintained by the Blockchain itself and history can be traversed by visiting next and previous blocks. Moreover, the patient will be able to see her data as shown in table 1, without knowing the complexities of managing it.

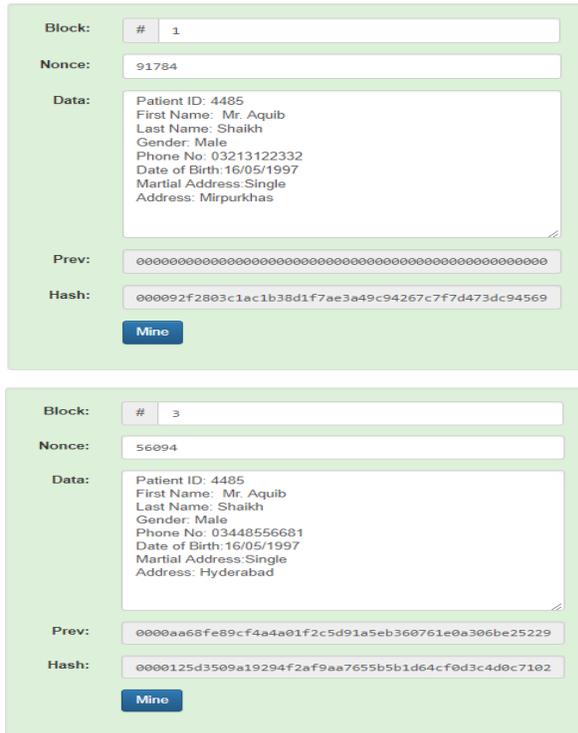


Fig.6.Data in ledgers

Table 1 – Data in tabular form

Pati ent ID	First Name	Last Name	Gende r	Phon e No	DOB	Marit al Status	Address
4485	Aqib	Shaikh	Male	0344 8556	16/05/1 997	single	Hydera bad

Blockchain services. This layer is responsible for handling the services of Blockchain server. We have used Hydper Ledger blockchain by IBM which is deployed on HP Core i7 Machine on Ubuntu operating system. Chaincode is used to write program in GO, Node.js languages which helps independ systems to read & append data on hydper ledger and to run chaincode we have used docker container. Other services like membership service provider (MSP) assures the athencity of members in domain, Privacy service help channels to provide transaction privacy and confidentiality for specific subsets of network members. Consensus protocol provides irrefutable system of contractamong various devices across a distributed network and user authentication and authorizations are

managed by registration services of the Hyper Ledger Blockchain.

5. CONCLUSION

In this paper, we have proposed an interoperable health care system based on Blockchain technology. Interoperability is big concern while sharing the health care data among different systems, to provide interoperability among healthcare system we have propsoed a system which can be helpful while sharing the healthcare data of patients. To test and check its results we also developed different independent healthcare systems using Node JS and Java and connected them on Hyper Ledger Blockchain so that they can share data with privacy and security. This system can be used as reference to address interoperability issues in various domain like land record keeping system, criminal record keeping systems and sharing of information among different security agencies in secure and well-organized.

REFERENCES:

Alonso, S. G.-C. (2019). Proposing New Blockchain Challenges in eHealth. Journal of medical systems, 64.

Ekblaw, A. A. (2016). A Case Study for Blockchain in Healthcare:“MedRec” prototype for electronic health records and medical research dat. Proceedings of IEEE open & big data conference (p. 13). IEEE.

Linn, L. A. (2016). Use of Blockchain for Healthcare and Research Workshop. Gaithersburg, Maryland, United States:.

Mannaro, K. A. (2018). A blockchain approach applied to a teledermatology platform in the Sardinian region (Italy). Information, 44.

McGhin, T. A.K. (2019). Blockchain in healthcare applications: Research challenges and opportunities. Journal of Network and Computer Applications.

Mettler, M. (2017). Blockchain technology in healthcare: The revolution starts here. 2017 IEEE 18th International Conference on e-Health Networking, Applications and Services (Healthcom), 1--3.

Peterson, K. A. (2016). A blockchain-based approach to health information exchange networks. Proc. NIST Workshop Blockchain Healthcare.

Sharma, P. K. (2017). Block-VN: A Distributed Blockchain Based Vehicular Network Architecture in Smart City. JIPS, 184-195.

Shubbar, S. (2017). Ultrasound Medical Imaging Systems Using Telemedicine and Blockchain for Remote Monitoring of Responses to Neoadjuvant Chemotherapy in Women’s Breast Cancer. Kent State University.

Yue, X. A. (2016). Healthcare data gateways: found healthcare intelligence on blockchain with novel privacy risk control. Journal of medical systems, 218Pp.