Proceedings of the Fifth International Conference on Intelligent Computing and Control Systems (ICICCS 2021)
IEEE Xplore Part Number: CFP21K74-ART; ISBN: 978-0-7381-1327-2

Healthcare System Using Blockchain

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2021 5th International Conference on Intelligent Computing and Control Systems (ICICCS) | 978-1-6654-1272-8/21/$31.00 ©2021 IEEE | DOI: 10.1109/ICICCS51141.2021.9432157

Abstract— Medical data privacy and data protection are crucial issues during medical services. Data security or secure storage of medical data is always a major concern for the majority of the population. An effective and efficient healthcare system requires a technology platform to communicate securely and seamlessly. Blockchain has been emerging technology for a few years now. The key features of blockchain which attract most developers are its immutability, decentralization, transparency, distributed ledger. So, the use of Blockchain in HealthCare systems will make a drastic impact as it can be used to securely store personal medical data. This paper has designed a HealthCare system that securely manages personal medical data and creates interaction between Doctors, Patients, Insurance Companies, and Pharmacy shops or Medical shops. The paper further highlights a comparison between a traditional system and the proposed system, describing the scope of the system, areas of future work.

Keywords— Ethereum, Blockchain, Healthcare, Data-sharing, Distributed ledger technology, Distributed systems, Health information exchange.

INTRODUCTION

As per the situation faced by the world during the COVID-19 pandemic, it was really difficult for Healthcare systems to trace the people who are targeted by coronavirus and what past medical history they had. After some research, it was found that the people who had blood pressure, diabetes, and other diseases were severely affected by the virus. Moreover, it becomes quite difficult for the doctors and hospital facilities to deal with these researches in an efficient way without wasting much time and resources. Also, the lack of transparency in the current system is another issue that affects the efficiency in this situation.

Those patients who have visited more than one hospital are mostly experienced with the same medical examination which was performed by the earlier visited hospital. This is because medical data in a medical institution is always stored in a centralized manner and mainly managed by the medical institutions themselves. Under the traditional data management system, there is no guarantee of data integrity and reliability of patient data. Thus, this data will be vulnerable to different threats such as malicious tampering, hacking or natural disasters, this will lead to issues such as data privacy and data security. Another issue seen in medical institutions is the medical insurance fraud done by few patients to avoid payment. Since there is no peer-to-peer connection between the patient and the medical institution or the medical institution and the insurance company, it is very difficult to handle these situations.

In June 2017, according to a British "Daily Telegraph" report, the Cosmetic Institute in Bondi Junction posted information of patient names, addresses, medical insurance numbers, and medical records online resulting in exposure of patients' data and privacy. In October 2017, approximately 47 GB of medical data stored on Amazon database was accidentally opened to the public, with an estimate of at least 150,000 patients affected. Blockchain has characteristics of decentralization, verifiability, and immutability which are essential in medical history.

The emergence of Blockchain technology brings a new idea to solve these problems. Blockchain could offer an efficient distributed framework to amplify and support the integration of healthcare information across a range of uses and stakeholders. An organized data sharing between healthcare providers results in a higher probability of accurate medical checks and effective as well as timely treatment. Accurate and complete medical data are one valuable asset for patients. This study has designed a healthcare system to securely manage personal medical data on the blockchain storage system. The key contributions of this work are as follows. 1) A healthcare system has been proposed based on blockchain technology to achieve safe storage and a platform to interact between medical institutions, the patient, pharmaceutical stores along with insurance companies. 2)A few modules, which would help with managing data are introduced. 3) The proposed system does not depend on any trusted third party.

EXISTING SYSTEM

Looking at the current situation and all the traditional methods of a healthcare system, once a person visits a hospital, he/she has to perform all the basic procedures such as taking an appointment, form filling and some basic tests. Then after consultation, a prescription consisting of all the necessary medication is provided by the doctor for that particular patient's problem. The next step is payment for the entire consultation and medication. If the patient has medical insurance, then the amount is covered by the insurance company. But integrating this entire process becomes very time consuming and inefficient. Also visiting any new doctor means one has to provide a full description of their past illness where they could forget to mention some minute medications and allergies. Along with that, maintaining this entire information in the form of hard copies is again inefficient and tiresome. It was also seen that

some doctors charged variable fees to patients in the pandemic which is entirely wrong in many ways.

Traditionally, the payment procedure in any sector works with the help of third parties. Currently, third party applications such as PhonePe, Google Pay, Paytm, and Amazon Pay, dominate the UPI ecosystem, controlling a majority of the transactions. Even in medical sector, when a payment for a particular appointment or drugs are made, some amount is deducted by banks or other online payment system. The use of Blockchain in this case completely avoids the involvement of these third parties. The transaction amount becomes minimal, and the procedure gets efficient. Another problem seen in traditional system is the transaction time. This is also solved by the introduction of Blockchain as Blockchain is a peer-to-peer system which makes every transaction easier and expeditious.

LITERATURE SURVEY

Title of Paper	**Journal/ Conference Name**	**Year of Publication**	**Author Names**
Blockchain-Based Medical Records Secure Storage and Medical	Journal of Medical Systems, Springer Science+Business Media, LLC	Nov 2019	Yi Chen, Shuai Ding, Zheng Xu
Service Framework Opportunities for Use of Blockchain Technology in Medicine	Springer Nature Switzerland AG	18 July 2018	Igor Radanović, Robert Likić
A systematic review of blockchain	Southwestern University of Finance and Economics, Chengdu, China	May 2019	Min Xu, Gang Kou
Towards Using Blockchain Technology for eHealth Data Access Management	Fourth International Conference on Advances in Biomedical Engineering	Nov 2017	Elie Rachkidi, Tripoli, Nada C Taher
Applications of Blockchain towards Healthcare	Philips Research North America, Cambridge, MA, United States	Dec 2018	Sandeep Pandey, Gajendra K

I. Blockchain-Based Medical Records Secure Storage and Medical

Medical data [1] is scattered throughout various medical institutions and the data standards are different for different medical institutions resulting in low level of interoperability of medical information between the institutions. All of these causes the exchange and sharing of medical data to be very difficult.

In June 2017, according to a British "Daily Telegraph" report, the Cosmetic Institute in Bondi Junction posted information of patient names, address, medical insurance numbers and medical records online resulting in exposure of patients' data and privacy. In October 2017, approximately 47 GB of medical data stored on Amazon database was accidentally opened to the public, with an estimate of at least 150,000 patients affected. The Blockchain is viewed as a storage supply chain in which every transaction/operation may be verified. Blockchain has characteristics of decentralization, verifiability and immutability which are essential in medical history.

II. Service Framework Opportunities for Use of Blockchain Technology in Medicine

Blockchain [2] is a new and emerging technology which is currently in its early stages. Blockchain offers great potential in healthcare systems as the main advantage of blockchain is data security. In a survey conducted by HSBC, 59% of consumers said that they had never heard of the term blockchain, and even if they had heard 80% of them don't know what actually blockchain is?

III. A systematic review of blockchain

This paper [3] is based on five themes "economic benefit," "blockchain technology," "initial coin offerings," "fintech revolution," and "sharing economy." It also explains how blockchain has evolved over years and its various versions. This paper also explains how business can be benefited from blockchain use and how it can become an advantage for a business. Paper also gives us an idea of various fields in which blockchain technology can be implemented and how it can prove to be an advantage over existing technology.

IV. Towards Using Blockchain Technology for eHealth Data Access Management

This paper [4] focuses on how the huge amount of crucial data of patients can be stored securely in a decentralized way. It is the ease of medical data access using blockchain, the use of this data for research matters, and the advantage of using this technology to prevent counterfeit and fraud, along with some

Blockchain applications for healthcare. They have proposed a system which would have a smart contract deployed in blockchain in order to secure doctor-patient relations. In order to maintain data security, patients have the power to choose who can view the data. This data is stored in IPFS system which is a powerful decentralized Database system as the data from live monitoring systems like heart rate monitoring system, ECG sensors cannot be connected with blockchain directly. After the data from sensors is stored in IPFS its hash is generated and can be used to access the data. This system can be used with cloud computing to solve the high computational power problem of mining.

V. Applications of Blockchain towards Healthcare

[5]A few issues in healthcare stem from the complex organization of mediators and the need of traceability of exchanges. To say some: healthcare information is divided over a few silos negatively influencing investigation and administrations, around half of the clinical trials are never detailed, the cost of sedate disclosure is ever expanding, and substandard and fake solutions are still a tremendous problem. Blockchain has the potential to illuminate these issues because it gives belief without any intermediaries, has traceability as a default highlight, and guarantees unused trade models by empowering novel incentive structures. Due to its potential, blockchain has assembled noteworthy intrigue within the healthcare industry.

Patient information is scattered over distinctive substances within the esteem chain of the healthcare industry alluded to as information silos and sharing of information is inclined to a multi-level handle of consent control. Due to this, pivotal information is not accessible and accessible at the time of critical necessity. Blockchain can illuminate this issue with wellbeing data exchange (HIE) by serving as a premise for a trusted decentralized database. It can enable one-stop access to the complete medical history of persistent overall healthcare suppliers. Get to control framework built utilizing belief on blockchain puts patients in control of their information; they can allow assent and get to rights to outside parties like analysts to have get to all or subset of their restorative records. This includes pleasantly with the patient-centric show of healthcare where blockchain can act as a catalyst actuating belief. The Data composed on the blockchain cannot be changed or erased. On a monetary note, blockchain might save hundreds of billions for the pharmaceutical industry by defining a chain-of-custody within the supply chain.

Hence, Blockchain can empower healthcare arrangements; and as a motivating force, it can empower novel commerce models that may lead to an unused energy among different healthcare partners like patients and suppliers. For illustration, a patient-centric healthcare show and a worldwide HIE may be realized by the ethicality of blockchain empowered decentralized trust and motivating force structures. So also, blockchain based decentralized network/services may minimize merchant lock-in problems in healthcare.

VI. Blockchain Technology Use Cases in Healthcare

Although blockchain technology is emerging we are already seeing its implementation in everyday life particularly in banking and financial sector.

Blockchain [6] eases the dependence on a centralized specialist to certify data judgment and proprietorship, as well as intervene exchanges and trade of computerized resources, whereas empowering secure and pseudo-anonymous exchanges beside understanding straightforwardly between collaboration parties. It has key properties, such as unchanging nature, decentralization, and straightforwardness, that possibly address squeezing issues in healthcare, such as inadequate records at point of care and troublesome get to patients possessing wellbeing data. A proficient and effective healthcare framework requires interoperability, which permits computer program apps and innovation stages to communicate safely and consistently, trade information, and utilize the traded information over wellbeing organizations and app sellers.

Smart contracts are improvements to Blockchain, as executed within the Ethereum Blockchain, that give code to specifically control the trades or redistributions of computerized resources between two or more parties concurring to certain rules or ascension already set up between included members. Keen contracts can store information objects and characterize operations on the information, empowering advancement of DApps to be associated with Blockchains and give consistent administrations to the application clients. Within the domain of healthcare, savvy contracts can be connected to form secure and compelling specialized foundations to improve care coordination and quality and in this way progress the prosperity of people and communities. In a perfect world, computer program apps and innovation stages in an interoperable healthcare environment ought to be able to communicate safely, trade information, and utilize the traded information over wellbeing organizations and app vendors.

An interoperable design would without a doubt play a noteworthy part all through numerous healthcare use cases that confront comparative information sharing and communication challenges. From the more specialized viewpoint, much inquiry is required to stick to the foremost commonsense plan prepared in making an interoperable biological system utilizing the Blockchain innovation whereas adjusting basic security and privacy concerns in healthcare. Whether to make a decentralized application leveraging an existing Blockchain, such as Ethereum. In a few cases, a modern Blockchain network may be more appropriate than the existing Blockchains; subsequently, another course may be examining

expansions of an existing Blockchain or making a healthcare Blockchain that solely gives health-related administrations.

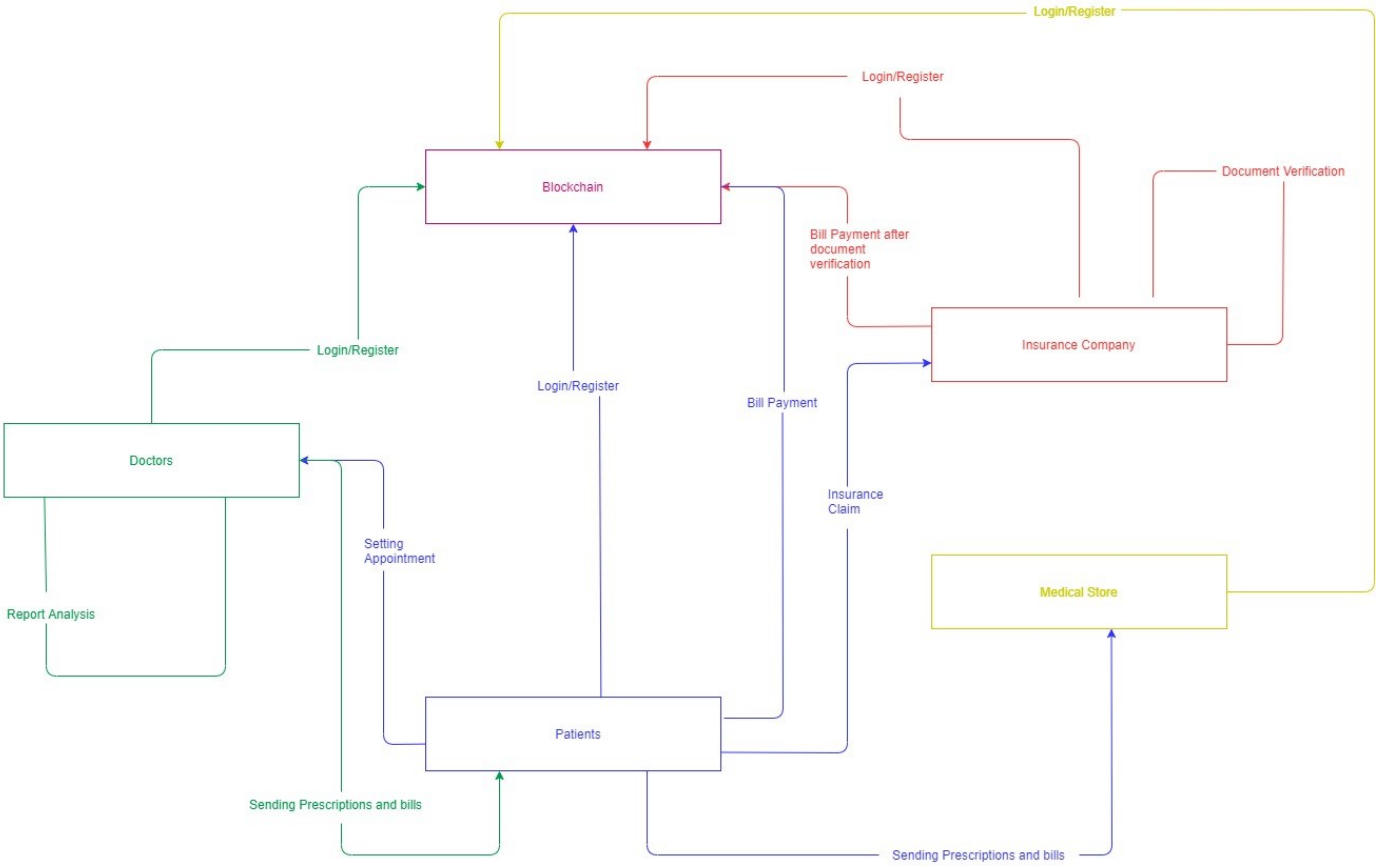

Fig.1 Communication Diagram

PROPOSED SYSTEM

According to the problem statement, this solution mainly focuses on data security of individual entities of the system. Using the concept of private blockchain, it is an efficient way to revolutionize data storage in a healthcare system. Private blockchain for every patient would have all the details of doctors, insurance companies with whom they have ever interacted. This will not only connect them but also will store the medical history, transaction and insurance details using smart contracts. The system has modules which are classified by stakeholders of the system, that are to be addressed separately and further integrate them accordingly.

First module describes the system as a platform for patients (every individual of the country) to store their personal information i.e., all the medical documents. The patients can add as well as update their documents but cannot remove it as long as the system exists. Every patient would have an account linked to Aadhar number to maintain uniqueness. Apart from keeping track of documents, patients can consult or book an appointment with doctors. Patients can provide their private key to a particular doctor which would assist them and go through previous medical history and get familiar with the patient's body structure and medications. Furthermore, one can pay bills i.e., consulting fees and medical store amount in form of ether which is a cryptocurrency (no third-party intervention).

Second module elaborates the solution from the point of view of the doctor/hospital organization. In this, doctors are given a platform to go through (read only) the medical history of a patient who has provided his/her private key and examine accordingly. After proper analysis, prescription and medication will be uploaded by doctors. Other reports such as blood reports, X-ray reports, MRI reports will be made available by the organization on the patient's block.

Third module deals with insurance companies. If the patients apply for insurance, then he/she has to share a private key for document verification and further process will be carried by the insurance firm as done now-a-days. This will prevent the unwanted fraud done during this process.

Last module is associated with the medical store facility. As per the prescription given, one can buy medicines from the store and that information will also be stored in the system. If

this is done, it would work in the form of a supply chain of medicines and provide an ease to track any of them.

The concept of private blockchain would revolutionize the way health care systems work and store data. A private blockchain for every patient would have all the doctors, insurance companies with whom they have interacted previously. This would not only connect them but also the blocks in the blockchain will have all the previous medical history. So, comparing this with the existing system, the existing system only has the medical records of the patients who are admitted in that particular hospital. So, while admission of the patient, the system would use his/her public id which will be generated at the time of his/her registration with the system, and it will also use the UID (Aadhar number) for their verification.

After the treatment the bill generated will be directly linked with the system. The main benefit of this facility is for the payments as the bill is available on the block, so it would be visible to the insurance companies as well. The patient can choose the mode of payment. Patients can also pay with the help of Ether (which is a cryptocurrency). Ether is nothing but a type of currency that uses the concept of blockchain. Patients can also opt-out for insurance if he/she is eligible for it. Generally, in the current system, most of the frauds are done in the payments section. As the system is transparent, any kind of malpractices cannot occur under any circumstances.

All the reports and records are maintained in a single block so it would also help in research later. On willingness of a patient, he/she can share their part of records which would be helpful for research work as all the data is stored in a centralized manner (i.e., all the previous medical records are stored in a single block).

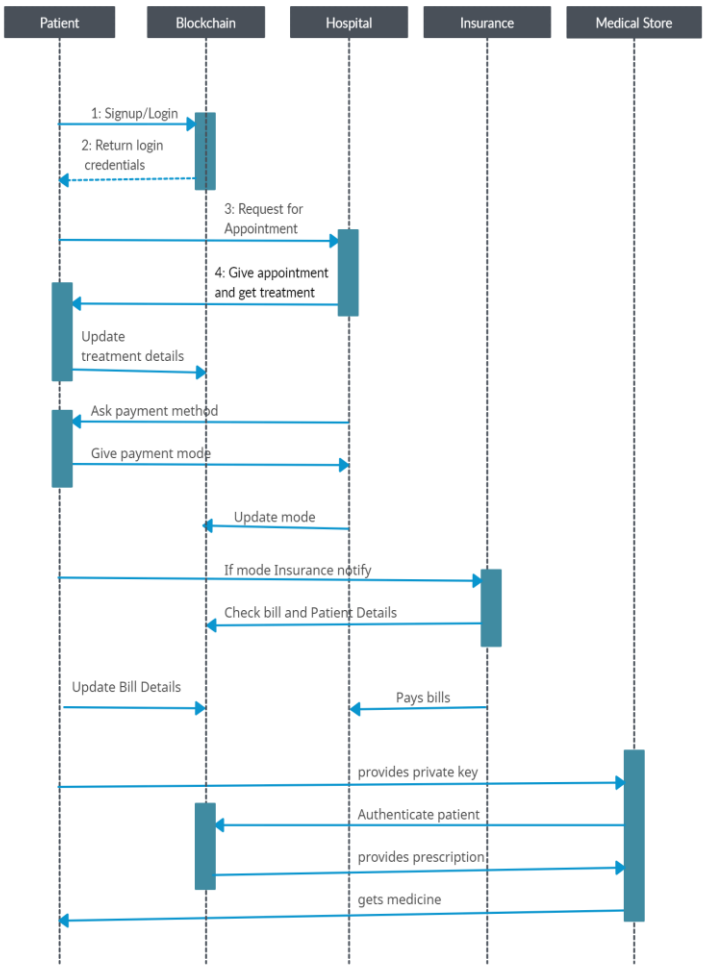

Fig.2 Sequence diagram

The above sequence diagram explains the overall flow of the system. Let us take an example, suppose we have some characters, Ram as in patient, Dr. Shyam and ABC insurance company. Ram will register himself providing some basic details and UID number for verification. Then he has to login to the system and have a look at doctors and their availability, he wants to book appointments for. Suppose Ram books an appointment for Dr. Shyam, then Ram has provided the private key to Dr. Shyam to get access to his medical data. Once the doctor is done with the diagnosis and treatment, he will provide a detailed prescription and bill also. Now it totally depends on Ram whether to claim insurance from ABC or not. If he opts for insurance, then he will request the same and provide necessary documents. ABC will verify documents and if all goes correct then insurance will be approved, and ABC will pay bills to Dr. Shyam using ether. Or else if Ram does not want to claim insurance, he will directly pay bills using ether. Similar condition goes with a medical store. Again, it depends on Ram which prescription to share with the medical store and to do so he has to provide a private key to the medical store. Further Ram will get verified by the medical store owner using blockchain and once Ram gets verified, he will receive prescribed medicines.

SCOPE

The system could reinvent the way patient's electronic health records are shared and stored by providing safer mechanisms for health information exchange of medical data in the healthcare industry, by securing it over a decentralized network. Precise and consummate Medical Data are one valuable asset for patients.

Medical Indemnification Fraud done by few patients to evade payment could be eschewed by keeping a peer-to-peer connection between the patient, the medical institution and the indemnification company. The distributed connection between the Medical Institution and the Indemnification Company avails to evade frauds and bring transparency in contract execution and a near authentic-time settlement for claims.
The system facilitates expeditious, secure, low-cost payment processing accommodations through the utilization of encrypted distributed ledgers that provide trusted authentic-time verification of transactions without the desideratum for intermediaries. Utilization of Ethereum framework significantly truncates transaction costs and makes the transactions more expeditious as compared to other payment methods. Payment utilizing Ether could avail the patient preservation both time as well as extra cost charged by a third party making the payment efficient and secure.

The medical records uploaded by the patients can also be used for medical research purposes. With the permission of the patients these documents can be made available to them. This will help them get genuine and accurate data for research.

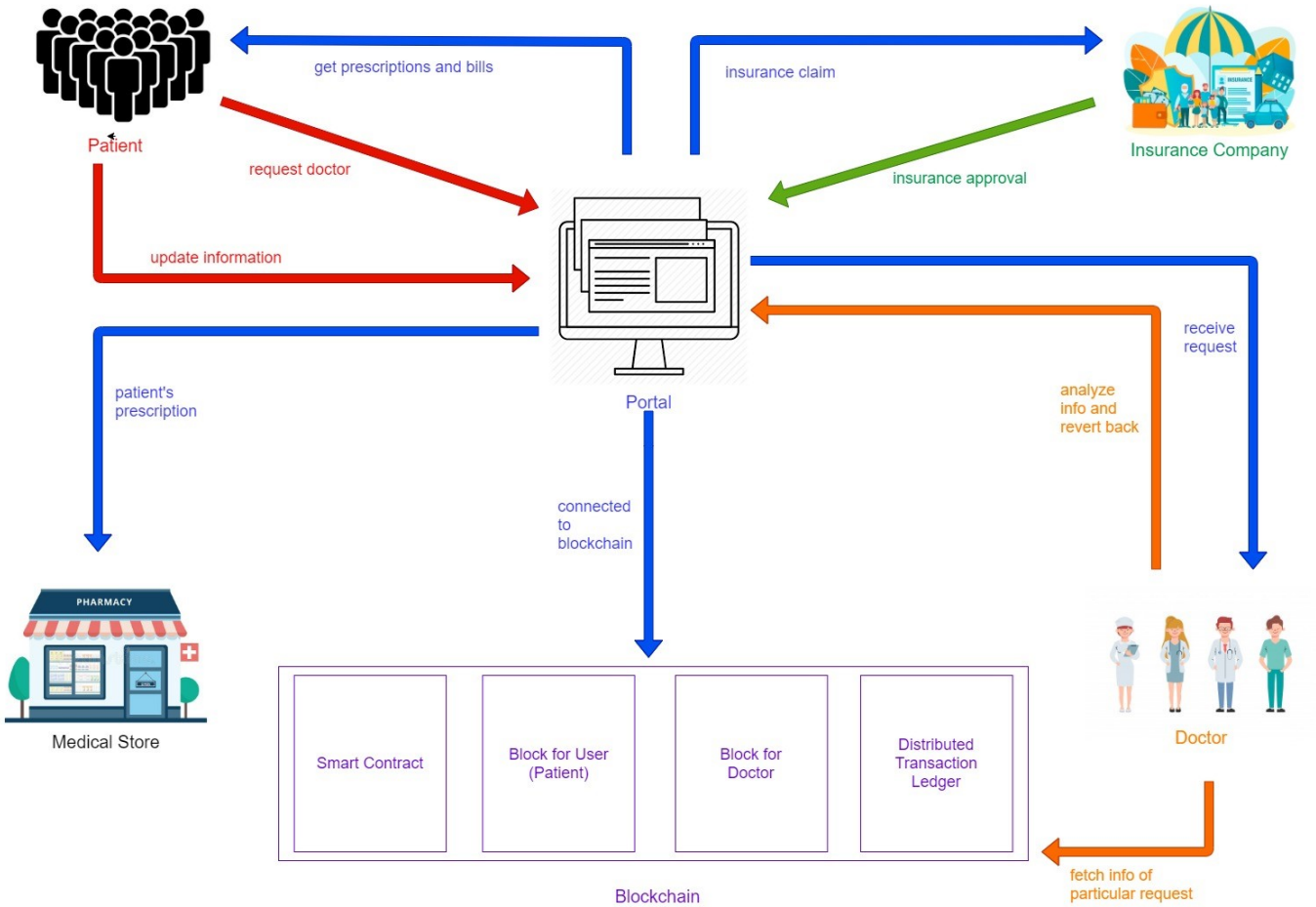

Fig.3 Dataflow Diagram

SYSTEM DESIGN

The system is completely based on blockchain technology. The system is mainly divided into modules such as patient module, doctor module, medical store module and insurance agency module. The implementation is done using private blockchain and ganache which is a personal blockchain for Ethereum and corda distributed application development. This helps to develop, deploy and test overall dApps. Truffle Suite is a development framework for Ethereum. It fully manages the lifecycle of smart contracts including custom deployments, library linking and complex Ethereum applications. Meta Mask is used to login, create account, and do payments using cryptocurrency in the dApp. For storing all the large files and documents IPFS system is used. The reason for using IPFS is that it is a peer-to-peer network for storing data in distributed manner and it's easy to store the hash generated in blockchain. The front end of the system is built using reactJS. The Smart contracts are written in solidity language, built and tested on remix online compiler for solidity.

MATHEMATICAL MODEL

S = {I, O, Q0, T, Qn, Success, Failure}
Where

I – Input to system
I = {I1, I2}
I1 = {I1`, I2`}
I1` = It includes all the previous medical records of patient
I2` = Input key which will be entered at the Hospital's portal for patient's admission.
I2 = Input key for insurance companies for initiating the billed amount.
O – Output of the system.
O = {O1, O2}
O1 = All the patient's previous medical data.
O2 = Output from the system i.e., the billed amount which will be added to the patient's block as well as Insurance company's block.
Q0 – Initial state which is registration of Patients, Hospitals and Insurance Companies.

Qn – Final state of system which includes updating of each and every block which were used from patient's admission to discharge.
Success = {S1, S2}
S1 = If the system is able to output the correct information to the patient. The information must include all the previous medical history, test reports.
S2 = If the system is successful in making payments via Ether with no third parties involved.
Failure -
Accessing Invalid Document/ block will result in an error message
T - Transition function
T = {F1, F_2, F_3, F_4}
F_1 = Validate public key on the portal.
F_2 = Storing and retrieving all medical records.
F_3 = After treatment uploading all bills and documents on the network.
F_4 = Initiating the payments (Only if done using Ether).

UNIQUENESS

The system points out some of the unique concepts which are highlighted in this section.
Since all over the industry is moving towards digitalization, there is immense need for authentication and verification and unique accounts for everyone. To provide a unique account, every account will be linked with UID (Aadhar Number).
Till the current time there has been no such system that can be found which integrates most of the subsystems under the medical department. Starting from a patient to doctors to hospitals to insurance to research work and moving towards drug's supply chain. Single system consists of every possible aspect of the healthcare system.

FUTURE WORK

The proposed system tries to integrate all types of medical related work which happens in day-to-day life. Beyond that there are some more advanced levels of process that can be included in the system. These additional features will enrich the system and increase the market potential also.

Some of the features are inclusion of supply chain methods for tracing the drugs flow and delivery. This will enable the government body to keep track of medicines and drugs from point of production to the farthest end point i.e., till it reaches the patient. Adding to this, expiry date of product(medicines) can be easily tracked and malpractices regarding the same can be avoided at large scale.

Another feature that can be included in the proposed system is concern with research work. Medical institutions/bodies can seek permission from a particular patient to use their data for research work without disclosing anyone's identity. For this patient has to provide access for all sorts of documents by giving a private key.

LIMITATIONS

The main need of any Blockchain Technology is the Internet. Therefore, all the stakeholders need to have a stable internet connection to access the system. The patient must have the necessary hardware along with the connection to access it. Hardware here consists of mobile phones or laptops to interact with the system.

Another roadblock in the system is regarding the previous patient history of the user. It is necessary for the patients to have their past health records and upload it on the system. Patient's medical history may include all the health issues the person has or had and the prescribed medicines he/she used to take. For the doctor, it becomes easier to access the patient's problem using this. However, if the patient fails to upload these details, the doctor has to take a detailed checkup all over again to understand the issue. This could be time consuming and could have been avoided if the patient had provided the details.

CONCLUSION

Healthcare system is one of the most complex systems with many interconnected entities. In healthcare, there are critical challenges for information exchange and dissemination. Doctors, service providers, and patients are required to have combined secured data exchange technologies. Digitalization of medical records would further create opportunities for analyzing medical trends and evaluation of the quality of care, reducing insurance frauds and false information. The proposed system would also help in faster admission for patients, and patients would no longer require carrying hard copies of previous medical reports. The patient will no longer require carrying hard copies of prescriptions at medical stores or pharmaceutical shops.

Digitization of records is easy to maintain and difficult to destroy or edit in blockchain and only visible to people in the private blockchain keeping it hidden from others. The stored data on the willingness of patients could be shared for research purposes. This is a rapidly evolving field, and we will see a lot of changes and positive impact of blockchain in healthcare in the future.

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