Applications of Blockchain in Healthcare

Pranav Desai
*Dwarkadas J. Sanghvi College
of Engineering, India*
Mumbai, India

Rayyan Merchant
*Dwarkadas J. Sanghvi College
of Engineering, India*
Mumbai, India

Varundeep Singh Nagpal
*Dwarkadas J. Sanghvi College
of Engineering, India*
Mumbai, India

Nimish Mayekar
*Dwarkadas J. Sanghvi College
of Engineering, India*
Mumbai, India

Pankaj Sonawane
*Dwarkadas J. Sanghvi College
of Engineering, India*
Mumbai, India

Rajat Parab
*Dwarkadas J. Sanghvi College
of Engineering, India*
Mumbai, India

Abstract—Healthcare is probably the most important service available to mankind. Lately, data has proven to be vital in solving many healthcare challenges throughout the world, whether it is the covid 19 pandemic where accurate data was used to finalize local restrictions or long-term clinical data which are used to determine the effectiveness of vaccines, data has become more or less interlinked with healthcare. Thus the need arises to safely and accurately transfer data over the modern-day internet. Data security and integrity is of utmost importance as it can have a direct impact on human lives. Several solutions have come up short but in this paper we primarily focus on our approach using blockchain which we believe solves this problem in a novel way. We explore how blockchain can be used successfully in healthcare to ensure authenticity of drug supply chains, immutability of health record data and in biomedical engineering.

Keywords—blockchain, decentralized, security, healthcare

Current Healthcare Scenario

The blockchain allows for a decentralized and distributed network of nodes without any central authority. Along with this, it guarantees secure transactions using cryptography. Its first proven use case was Bitcoin and now blockchain with its established traits of transparency, decentralization and anonymization represents a solid use case for a data-driven domain like healthcare. The healthcare domain encompasses different skills required for its functionality and operations, which are quite extensively fulfilled by Blockchain. When it comes to health records they bring up an almost perfect use case for blockchain. They are essential and must not be tampered with so security is paramount in that regard. Along with this, the data must be available ubiquitously to the people who are authorized. Blockchain has proven itself to be secure and virtually impossible to change so it seems to be a perfect solution to the problem at hand. The healthcare sector is also highly dependent on collaboration be it storing patient data with medical professionals or medical institutions for research purposes. This collaboration entails sharing of private data which brings with it a host of issues surrounding data security, maintaining data integrity and finding a way to securely edit and share such sensitive data. Present methods are inefficient and often fail to prove effective. There are many issues such as robbery, theft and privacy issues which hamper the usage of various applications. Blockchain allows us to deal with such issues. As a result, such a situation brings about an occasion to think out of the box and imagine new innovative and unexplored solutions. This is where blockchain can be a perfect candidate solution. Blockchain allows us to edit and use features without the involvement of third parties. Often in such cases, unrealistic ideas and proposals arise so we will investigate and assess all the current developments in blockchain utilization in healthcare. We try to understand the work in this field till now and elaborate on it in the subsequent paragraphs. By doing such a thorough analysis of present methods and progress we can understand the current state of research in this sector. We will explore why the consortium blockchain; which is a partially centralized blockchain, where only a few selected objects can take part and view the protocol; is ideal for health records. We will then proceed to suggest improvements that we think can effectively come closer to solving the problems around sharing and working with sensitive data in the healthcare sector.

The Authentication of a Patient

An often encountered problem in healthcare revolves around determining accurately the identity of a patient as well as maintaining their data. Conventional systems can often be compromised, hacked or stolen from. Mismatched identities due to other innocuous mistakes are also a possibility, Identity theft is a very real issue that we are grappling with. The consequences of these attacks are that patients can be falsely identified and can be given incorrect treatment. In some cases, this can very well be fatal. Patient data and

identity proposes a problem wherein we need secure access to the data such that only the authorized personnel can access it and also we need to ensure that this data is then ubiquitously accessible by authorized personnel from anywhere that it is needed. Here blockchain can come in due to its properties of immutability and security to try and solve this issue we are faced with.

Immutability of the Information

When it comes to patient information there are a few paramount characteristics:-
1. Integrity
2. Security
3. Accessibility
4. Traceability

Patient data does indeed propose a unique problem in the healthcare sector. Here we need to ensure access to only the authorized personnel which can include the patient and their healthcare providers. At the same time, we need this data to be accessible from virtually everywhere. So when security and accessibility both are a requirement we can consider the blockchain as an option to tackle this problem.

Immutability is a concept that is enshrined in the very ethos of the blockchain. So any attempt at changing or corrupting the data is highly unlikely to be successful. So in these terms, the concerns around integrity and immutability of patient data can be addressed. Also, another issue that pops up around pharmaceutical products, specifically counterfeit drugs. Over the years this problem has grown in size to a point where it needs to be addressed urgently. Several such incidents have been noted where several regulations tend to be skirted during the manufacturing process. Regulators have extensive reports of such incidents and they are increasing in number with every year. Drugs are often found in adulterated forms due to rampant corruption and lawlessness in the various stages of the supply chain. This further compromises the integrity of drugs and erodes the public trust in them. This makes it an even bigger and more serious issue. Pharma companies need a system using which they can track the drug as it's being produced at every stage. This is one of the best ways to prevent any fraud or counterfeiting in the process. The ability to track it at every stage again makes us consider the blockchain as an alternative to the current system. Security is another major concern in the modern world. Nowadays everything is connected and has made our lives much easier but along with it we now have to deal with its implications for security and data breaches. Hackers often motivated by both political and financial reasons find new and innovative ways to breach the security of systems. Often using attacks like social engineering and phishing to gain access to sensitive data.

This is more of an issue in the healthcare sector because of how sensitive it is. In the past decade, there have been a record number of security breaches surrounding healthcare data. Here we will discuss a few to highlight the extreme urgency of this issue.

1. Anthem Blue Cross: In January 2015, Anthem Healthcare revealed a data breach in which sensitive data from 78.8 million patients was compromised and stolen. Sensitive information included names, social security numbers, home addresses, and dates of birth.

2. The UCLA health device introduced an information breach in 2015. Hackers have claimed that they've endangered facts from 4.5 million sufferers. To make subjects worse, this touchy information is unencrypted and will be utilized by hackers for malicious purposes.

3. Applications International Corporation (SAIC) has announced data breaches affecting approximately 4.9 million military clinics and inpatients registered with TRICARE, a federal military healthcare provider. Data was stolen from SAIC employees' cars, and victims were active retired military personnel and their families. Fortunately, no financial data was included, but sensitive information such as social security numbers, phone numbers, home addresses and other personal information was leaked.

4. Excellus discovered a cyberattack in 2015 which demanded the personal information of about 10 million members. After several cyberattacks on health care data in early 2015. Excellus ordered a forensic review of its system. What they found was the third-largest medical data breach in history.

5. Premera Blue Cross has announced a cyberattack that reveals the medical information of 11 million customers. The attack disclosed bank account numbers, dates of birth, damaged information, and more.

Such incidents do prompt us to consider very carefully the implications of insecure highly sensitive data like patient health records. Security is another strong point of blockchain technology and further makes us want to consider it as an alternative to current methods.

Applications of Blockchain in healthcare

Healthcare is a domain that constantly evolves as the diseases, variants and types of issues faced by people grow. It requires technology that is efficient in terms of operations, feasibility and dynamics. Blockchain helps us in a myriad of ways in the dynamic healthcare domain. Since healthcare deals with a lot of patients and their databases, it requires quite a bit of automation in its processes and that can be achieved utilizing blockchain technology.

Additionally, blockchain would provide a single and secure platform where various organizations can update, share and maintain data on medicinal stocks, patient databases and other inventory items.

Many of them are there which include:

1. R&D in the clinical sector:
   Since we have data about the medicines and the supply of different inventory, we'll be able to automate many parts of the sector.
2. Security:
   We can provide more security while using blockchain applications in healthcare. Many of which will streamline the process and make it easier for staff to manage the patient data.
3. Supply chain optimization:
The supply chain is the heart of healthcare. If we have a proper track at different stages of the supply chain which is possible due to blockchain, then we'll be able to handle the sector efficiently.
4. Personal health records:
The health records of different patients can be maintained for ease of future reference. The suitability of medicines and other relevant data can easily be fetched.
5. Electronic data of patients:
We can easily manage patient data through a streamlined process of data management software via blockchain environment architecture.

Personal health data management:
In the modern world, there's a dire need for quality health facilities supported by high technologies. For our betterment in healthcare, Blockchain would play an essential role in transforming the dynamic sector. Also, healthcare is progressing towards a more patient-centered approach. The majority of it focuses on appropriate healthcare resources and accessible services. The technology ameliorates healthcare-based organizations to provide sufficient patient care. Additionally, we all have used smart devices like fitness watches, bands and applications. These leverage data which is personal. Like oximeters check your oxygen levels and then keep a track of your blood oxygen. Blockchain technology is currently being used to do a variety of things from securely handling patient data to managing the outbreak of harmful ailments like Covid-19. Some countries with good infrastructure are trying to leverage the technology in these difficult times to have minimal stress while handling the maintenance and operations. They can focus more on patient care and empathy. We can say that health is of utmost importance in today's world as we all have understood after grappling with the pandemic for around 2 years. The quality of services provided in healthcare is essential as it comes to the question of the life of an individual which is paramount. But, traditionally, while maintaining healthcare records of vaccines and medicines, it has been that many spurious medicines are also being circulated. This is quite detrimental to the success of the entire healthcare domain. To ensure the accuracy and efficiency of operations of medicine and vaccine supply, we can use blockchain technology.

Development in the field of biomedical engineering
Biomedical engineering involves the enhancement of healthcare-based engineering devices to ensure better technical integration of various facilities and the health of users. It follows an architecture diagram of the blockchain(refer to figure A) wherein the different layers of the system interact to manage data required for the engineering and management of health records and the development of applications. Different steps are required to perform the procedure of data management:

1. Verification of healthcare permissions.
2. Retrieval of patient data.
3. Request for data for processing.
4. Get the encrypted data using an encrypted data set.
5. Try to decrypt the whole dataset of EHR.
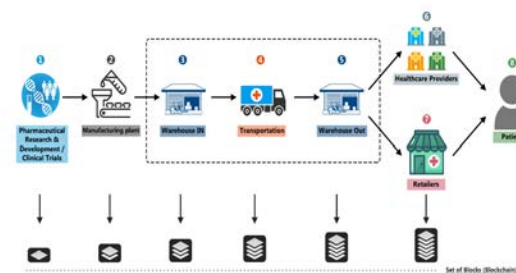
These steps ensure proper data management and efficiency in dealing with different sorts of errors.

Healthcare Bill Management Systems
Different transactions take place in the healthcare domain relating to insurance policies, medicines orders, healthcare operations costs and other such bills. To keep a track of all, it's paramount to have a proper designated system. This system requirement is efficiently fulfilled by blockchain. The Healthcare bill system faces several issues. One of the issues is that the complexity of medical coding can lead to billing inaccuracies and inconsistencies. Blockchain's fully complete form of records helps with proper payment processing. It also assists to show every action and transaction taken. Blockchain-based systems may also help to optimize the billing process when it's combined with computer-based methods. Blockchain can be said as an unchallengeable record of a peer-to-peer transaction group of blocks that are stored in the form of a digital ledger.
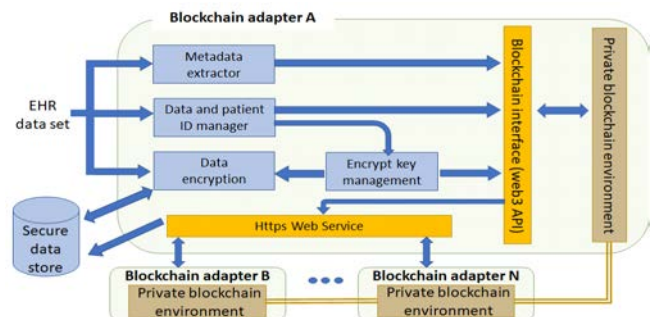
Optimizing Drug Supply Chain

Pharmaceutical distributors form an essential link between the drug manufacturers and end-users, namely hospitals, pharmacies and other pharmaceutical institutions. Indeed, the relationship between the manufacturers and distributors is complex, leading to a substantial amount of counterfeit medications. To overcome the issue, there is a requirement of essential traceability, to determine the current as well as the previous owners of the product. Blockchain is a technology that provides a decentralized, distributed ledger system, thus proving to be a trustworthy and efficient solution for product traceability. Blockchain can aid to optimize the drug supply chain by optimizing the processes involved in the pipeline. This will help to overcome the following shortcomings:

- Improved traceability of health products

The blockchain-based solution will facilitate a better perception of the motion and stakeholders through which the medicines transit in the supply chain. This provides an optimized supply of goods and efficient inventory management.

- Decreased counterfeiting

The blockchain pharma solution will provide a clear visualization of the healthcare product journey, right from the manufacturer to the end-user with digitized transactions. Thus, it will be able to examine any shortcomings in the supply chain and reduce the chances of fraud and associated costs.

- Improved transparency and trust

All the medicines/drugs can be traced. It is also possible to track the stakeholders involved in the supply chain. Any problem arising in the supply chain can be easily tracked.

- Enhancing the recall management

Blockchain also enables us to track the exact location of the drugs. The batch remainders can be efficiently carried out thereby ensuring the patient's health.

Integrating blockchain into the drug supply chain
In the re-modelled drug supply chain, blockchain can be integrated by identifying each stack of medicines by a unique hash (code). Assuming that each stakeholder has an account of the blockchain network for reviewing the associated transactions. Following is the procedure for the blockchain-based solution:

Step 1: Manufacturers produce the drugs with unique identifiers (hash)
The manufacturers produce the drugs with a unique QR code. The code contains critical information such as, Timestamp, Location, Item name, Manufacturer and Expiry date.

This information is permanently stored in the blockchain, providing transparency to other stakeholders. After the storage of information, a hash id is provided which can be used to track the following transactions.

Step 2: The Distribution phase

Once the drugs are distributed across the globe, the unique hash ID helps the distributors to trace the location of the drugs. The receiving distributors can verify the origin of the drugs, thus confirming their credibility. All the stored information, which was provided by the manufacturer, can be evaluated.

The distributors validate the information, and sign the document digitally, which is eventually added to the blockchain.

Step 3: Validation by the Pharmacies
Similar to the distributors, the pharmacies can also validate the origin and manufacturer of drugs to confirm their authenticity. In case of any fraud/counterfeit medications with a fake hash ID, the transaction is considered invalid because of the fraud information associated with the drug. Once the drugs are accepted by the pharmacies, the corresponding entry is done in the blockchain.

Step 4: Verification by the end-user
The patients themselves can verify whether the medicines purchased are safe or not. Once the user scans the OR code, all the information associated with it can be viewed. This is done by the hash ID which is associated with the OR code. Thus, blockchain provides a clear idea to the user, about the source and quality standards of the drugs.

Case Studies
Numerous corporations around the world in the healthcare domain are implementing blockchain technology to address the ever-increasing challenges faced by them. The strength of blockchain stands in its transparency and unalterable features. Further, blockchain uses public key cryptography to only create attached, time-stamped content. Such blockchain copies can be distributed to any node in the network. Blockchain security is further enhanced by a "Proof of Work" system that reduces tampering.

The medical industry has suffered for a long time, from the ability to share sensitive patient data securely. Considering its potential applications, many healthcare firms are adopting blockchain to solve the challenges.

Following are a few industry projects implementing blockchain technology:
Project Alive is a great application of blockchain in the healthcare world. It aims to create a comprehensive healthcare system that works on the blockchain. The goal is to provide a transparent ecosystem around patient records and efficiently connect all stakeholders in the healthcare industry, including patients, physicians and pharmacies. This project creates decentralized and smooth communication between her Alivents and doctors with a high level of security.

It will provide a human-centric solution to the public with support from the following teams:
1. Teams providing support

2. Medical Costs and Financing
3. Healthcare services
4. R&D in Medicine

The project Alive comprises three modules such as Olive, Olivia and Olaf. This module creates a comprehensive profile of each affected individual. It can be used throughout the life cycle of your data network. This module distributes data across multiple locations and transforms data silos into smaller silos to ensure data transparency. This aids the diseased to comprehend their problems with efficiency and overcomes the obstacles faced by the cultural methods.

Olivia makes use of Machine learning algorithms to facilitate the solutions to the problems faced by the traditional methods. The use of modernized methods such as Deep Learning(DL), machine learning(ML) and AI(Artificial Intelligence) aid in the efficacy of the solutions using human-like learning techniques, commonly known as Heuristic methods.

The MedgiLeder Network:
This Network is essentially a **private permission blockchain-based network** for the healthcare industry, the supply chain usually faces several problems, there is often less clarity in the chain or data that isn't well sorted out. However companies operate under the strict supervision of regulators, hence they have to upload detailed data about their supply chain to centralized database systems which makes interoperability complicated.
The regulations now mandate interoperability in the industry and prescriptions now have to be verified by their product identifier before being resold.

The Mediledger Network is based on the blockchain and is a decentralized platform made for the Pharmaceutical industry. The platform helps with regulatory compliance. A company by the name of Chronicle in San Francisco supports this project with the ultimate goal of facilitating an industry-owned network to comply with standards and specifications. With the help of this platform, companies can now access product identifiers through the blockchain which allows only authenticated companies to add products in the categories. The system then assigns a unique serial number to every drug transfer which makes the system better. Also, the platform is very resilient as only accredited companies can edit entries here. As the platform verifies every transaction and edit made false and wrong entries cannot be made easily. It has the ability to:
- Facilitate inter-industry trade between different stakeholders to certify the authenticity of the product and contract.
- Form connections with different stakeholders in the pharmaceutical industry.
- Preserves Business Analytics

   System to monitor

Product Verification System on the MediLedger Network

1) A firm first joins the network, then a private node will be created.
2) The product id then gets added to a directory which is essentially like a phone book which points requests to its location in the repository.
3) The directory is changed and pushed towards the consensus node.
4) We then use the lookup directory to route the verification to the correct private node.
5) It then resells the verified products.
6) The lookup directory is then changed and pushed to all nodes in the network.
7) The GTIN is then verified with no delay or triggering of an investigation.

Blockchain in the covid pandemic
Blockchain has proved itself to be very effective to solve quite a few pain points during the Covid pandemic. Among the several uses its main utility has been shown around managing, adding and creating new vaccine certificates. Blockchain came front and center to manage this development because of its inherent features that make it the most suitable for this task. These features include:-
Traceability(end-to-end): The powerful domain can facilitate the live visibility of vaccine supply chains, thus resulting in the elimination of the unavailability of data points essential for analysis and decision making.

Reduction of Risk: Detection and proactively notifying supply chain issues, ill effects, malpractices, spoilage and other issues to help deliver the vaccines ready to go.

Safety and efficacy assurance: The effective monitoring of transport and storage conditions as well as traceability will help in ensuring safety and efficacy.

One solution is to create a pharmaceutical network. A permissioned data exchange platform will help to unite diverse vaccine management strategies into a single view, to enable participants to use the preferred systems.
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A perfect example of this practice was when the Maharashtra government onboards blockchain technology for issuing COVID-19 test certificates. This has then gone on to prove to be a resilient and sustainable way of managing and adding new vaccine certificates while all the

while making sure that security and integrity are maintained. Such applications of blockchain further solidify the fact that its uses in healthcare are abundant and still many solutions are yet to be discovered. More research in this area will surely pay dividends in the future.

Conclusion And Future Scope

In addition to the problems listed above, the healthcare industry in this chapter has a lot of problems that can be fixed if blockchain technology is adopted globally. Since there is little evidence of legality, the majority of the population does not receive medical care because they do not yet have legal status for their identities. Therefore, if the demographic is provided with evidence of the blockchain health network's ongoing identity, they will be a better, more moral, and more prosperous segment of society.

Access to progressive medications is limited in poor nations, particularly in those with the lowest per capita income. Unfortunately, alternatives to or lower-quality drugs can be found in these nations. Each year, these cruel con games kill more than 250,000 newborns globally. Registered candidate members can validate the complete supply in the healthcare supply chain. Additionally, blockchain may be eligible for international financing and contribution initiatives for medical societies and healthcare systems in impoverished nations. Blockchain facilitates the distribution of donations to those in need. Blockchain technology has the potential to completely revolutionize and disrupt the healthcare industry. The healthcare sector is one of the most important ones. To raise the calibre of the services they offer, many businesses are making significant investments in blockchain. To improve health, there have been substantial advances in continuous medical care. Nevertheless, the switch from conventional systems to new platforms needs to be managed without endangering the patient and his data. By integrating the important components of persistence, anonymity, and decentralization into conventional healthcare systems, it is demonstrating its strength. The usage of blockchain lowers the operating costs of the entire healthcare system. You can minimize the prevalence of counterfeiters in the healthcare industry in addition to protecting your data. Distributed ledgers significantly reduce processing time. Even though blockchain may be a new technology to the healthcare sector, it will soon improve public health. Acceptance within the healthcare ecosystem is necessary for such possibilities. We advocate the appropriate use of high standards of performance and openness in early clinical trials. As a result, the blockchain will become the industry's main pillar. Blockchain may have some drawbacks and unanswered questions regarding its compatibility with current healthcare infrastructures and cultural support, but it will likely become more significant shortly.

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