

APPLICATIONS OF BLOCKCHAIN IN HEALTHCARE

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Abstract: *The word blockchain elicits thoughts of cryptocurrency much of the time, which does disservice to this disruptive new technology. Agreed, bitcoin launched in 2011 was the first large scale implementation of blockchain technology. Also, Bitcoin's success has triggered the establishment of nearly 1000 new cryptocurrencies. This again lead to the delusion that the only application of blockchain technology is for the creation of cryptocurrency. However, the blockchain technology is capable of a lot more than just cryptocurrency creation and may support such things as transactions that require personal identification, peer review, elections and other types of democratic decision-making and audit trails. Blockchain exists with real world implementations beyond cryptocurrencies and these solutions deliver powerful benefits to healthcare organizations, bankers, retailers and consumers among others. One of the areas where blockchain technology can be used effectively is healthcare industry. Proper application of this technology in healthcare will not only save billions of money but also will contribute to the growth in research. This review paper briefly defines blockchain and deals in detail the applications of blockchain in various areas particularly in healthcare industry.*

BLOCKCHAIN – AN INTRODUCTION

Blockchain is a shared, distributed ledger with decentralized control. It is immutable ledger for recording transactions, tracking assets and building trust. A transaction cannot be changed once it is recorded and verified. All parties to the transaction, as well as a significant number of third parties maintain a copy of the ledger (i.e. the blockchain), which means it would be practically impossible to amend every copy of the ledger globally to fake a transaction.

A blockchain consists of ordered records arranged in a block structure. Each data block contains a hash (digital fingerprint or unique identifier), timestamped batches of recent transactions, and a hash of the previous block. With this design, each block is connected in chronological order and the connected blocks are called a blockchain. It is practically impossible to modify one of the blocks in the middle of the chain because all of the blocks after the modified block must be modified at the same time. With this mechanism, the data on the blockchain network are immutable.

KEY ELEMENTS OF A BLOCKCHAIN

Distributed ledger technology: All network participants have access to the distributed ledger and its immutable record of transactions. With this shared ledger, transactions are recorded only once, eliminating the duplication of effort that's typical of traditional business networks.

Records are immutable: No participant can change or tamper with a transaction after it's been recorded to the shared ledger. If a transaction record includes an error, a new transaction must be added to reverse the error, and both transactions are then visible.

Smart contracts: To speed transactions, a set of rules – called a smart contract – is stored on the blockchain and executed automatically. A smart contract can define conditions for corporate bond transfers, include terms for travel insurance to be paid and much more.

TYPES OF BLOCKCHAIN NETWORKS

There are several ways to build a blockchain network. They can be public, private, permissioned, or built by a consortium.

Public blockchain networks: A public blockchain is one that anyone can join and participate in, such as Bitcoin. Drawbacks might include substantial computational power required, little or no privacy for transactions, and weak security.

Permissioned blockchain networks: Businesses who set up a private blockchain, will generally set up a permissioned blockchain network. This places restrictions on who is allowed to participate in the network, and only in certain transactions. Participants need to obtain an invitation or permission to join.

Consortium blockchains: Multiple organizations can share the responsibilities of maintaining a blockchain. These pre-selected organizations determine who may submit transactions or access the data. A consortium blockchain is ideal for business when all participants need to be permissioned and have a shared responsibility for the blockchain.

APPLICATIONS OF BLOCKCHAIN TECHNOLOGY

Blockchain brings in powerful benefits to healthcare organizations, bankers, retailers and consumers among others. Blockchain technology is one of the most important and disruptive technologies in the world. Multiple industries are adopting the blockchain technology to innovate the way they function. One of the industries that are looking to adopt the blockchain is the healthcare industry.

Of course, the most well-known blockchain technologies in production today involve cryptocurrency. There are scores of deployments with Bitcoin as the most popular. Others with unique and valuable properties include Ripple and Ethereum. Ripple has a nice foothold in global finance markets and Ethereum uses smart contracts to replace escrow and for digital identity management and along with other implementations.

Most cryptocurrency deployments involve public blockchains allowing anyone to participate. Whereas, most corporate blockchain deployments utilize a private ledger limiting access and authorization. While cryptocurrency's have a valid place in the

blockchain world, they by no means cover the vast possibilities behind this emerging technology.

Financial services have one of the greatest rationales for utilizing blockchain. The inherent security and immutability directly tie into key requirements for banking and insurance. American Express appears to understand these facets and have taken steps in a few different areas of their business to deploy blockchain. American Express joined Ripple's global payment network and launched a blockchain for membership rewards.

APPLICATION OF BLOCKCHAIN IN HEALTHCARE

While we talk more on usage of blockchain in finance, applications of chain in healthcare is gaining momentum. Numerous companies are now providing specific blockchain-focused solutions for healthcare organizations. Below are three major areas which can greatly benefit the advances in blockchain technology.

1) DRUG TRACEABILITY

Drug counterfeiting is a major problem in the pharmaceutical industry. Some metrics revealed by the Health Research Funding Organisation are:

- 10% to 30% of the drugs sold in developing countries are counterfeit
- The counterfeit drug market is worth \$200 billion annually
- Internet sales of counterfeit drugs account for \$75 billion of the total market
- About 60 different Pfizer medicines and products were being counterfeited around the world as of 2014
- WHO estimates that 16% of counterfeit drugs contain the wrong ingredients, while 17% contain the wrong levels of necessarily ingredients.

The main issue with fake drugs isn't the fact that they are fake but rather that they can be very different from the original product in a quantitative and qualitative way. Indeed, many of them don't have the active ingredients they claim they do. This can be particularly dangerous for the patients that take the counterfeit drug since it won't treat the disease it is supposed to treat.

Furthermore, if the ingredients and the dosages are different, the product can trigger unexpected secondary effects that can lead to death.

Application of blockchain in this scenario

The main characteristic of blockchain technology that is useful in drug traceability is security. Each new transaction added to a block is immutable and timestamped, making it easy to track a product and make sure the information cannot be altered.

To insure the authenticity and traceability of the drugs, the companies that register a product on the blockchain have to be trustworthy. Hence, only private blockchains controlled by a central entity are logical to make sure that fake drugs are not registered. A company's access to the "drug blockchain" would therefore be a proof that the drugs they produce are authentic.

When a drug is produced, a hash is generated that contains all the relevant information about the product. Each time the drug moves from an entity to another (eg: from the manufacturer to the distributor), the information is stored on the blockchain, making it easy to track the drug.

If a problem is detected and a batch has to be withdrawn from the market, blockchain technologies make it easier for the company to find their products and hence, avoid any complications.

Blockchain technologies help with two main issues when it comes to drug traceability: first, it allows companies to track their products down the supply chain, creating an airtight circuit, impermeable to counterfeit products. Second, it also allows stakeholders, and especially labs, to take action a posteriori in case of a problem by identifying the exact location of their drugs.

2) CLINICAL TRIALS

In the pharmaceutical industry, clinical trials are designed to test the tolerance and effectiveness of a product on a group of patients in order to validate or invalidate hypotheses. Usually they take several years and the outcomes are critical for the future of the drug.

Pharmaceutical companies and their sponsors can invest billions of dollars and a non-conclusive result could have great financial repercussions. Due to the importance of the results in clinical trials, fraud is not uncommon. However, it is not easy to estimate how frequent it is. Indeed, those committing fraud are not likely to admit what they did and the problem is usually under-reported.

During clinical trials, a considerable amount of data is produced – safety and quality reports, statistics, blood tests, surveys, medical imagery and large groups of people are involved, making it hard to track and control everyone. Hence, mistakes can be committed along the way, some unintentionally and others not.

Fraud usually includes modifying or hiding data that could compromise the advance of the clinical trial and damage the image of an organization among regulatory agencies or patients. Different types of data can be modified or manipulated.

First of all, the trial has to be very precisely designed, in term of hypothesis, research protocols and data keeping methods. This information is not always shared prior to the

beginning of the trial, which allows participants to modify the protocols to favour a positive outcome. Afterwards, all the patients involved in the trial have to sign Informed consent Forms that can be incomplete or even fabricated if the researchers failed to obtain consent.

Moreover, throughout the trials, patients undergo biological tests and complete surveys to track the evolution of their condition. However, the data that is collected from the patient and the one reported on standardized forms can be different. Usually, the reports are compared between the participating centers to spot inconsistent data but this type of fraud is not rare especially in trials that occur in only one centre.

Application of Blockchain in this scenario

Blockchain can provide proof-of-existence for any document and allow anyone to verify the authenticity of said document. In order to add new data in the form of transactions, the majority of nodes have to agree that it is valid and coherent with the blockchain history. Hence, modifying existing information would require changing the records of the majority of the computers in the network.

This characteristic of blockchain is very powerful when applied to clinical trials. Indeed, as mentioned above, data is often altered or modified because there is currently no system that prevents it.

A study conducted by Dr. Irving and Dr. Holden looked at how exactly blockchain can be used to provide proof-of-existence for clinical trial data and allow anyone to verify it. In order to be stored on the blockchain, data from the trial goes through an SHA256 calculator that provides a hash, which is a unique code, specific to the content of the document (trial protocol, biological results, Informed Consent Forms, etc.). Even a small change in the original file could result in a completely different hash. Using a bitcoin wallet, public and private keys are provided.

The public key proves that a certain document was registered on the blockchain at a certain time. If during the trial, someone has doubts about the authenticity of data they encounter, they can verify that information they have is similar to the original information stored on the blockchain.

To do so, the person would have to run the data they have through the SHA256 calculator and compare the public and private keys that are generated. If the newly created keys are identical to the original ones on the blockchain, this means that the data has not been altered.

3) PATIENT DATA MANAGEMENT

When it comes to patient data management, there are two main issues in the healthcare industry. First, each patient is unique therefore there is no such thing as a common disease or common treatment strategy. What works on a patient might not work on the other due

to inter-individual variability. Hence, access to complete medical records is essential in order to adapt the treatment and provide personalised care. Healthcare is becoming more-and-more patient-centred. Second, sharing information among the medical community is a major challenge.

Still today, doctors use social networks to communicate and share patient data. This type of medical data is sensitive and should always go through secured networks when divulged. Moreover, the lack of secure structure to share data is an important obstacle for scientific advances. Indeed, medical records are kept in very different locations, and there is no common database. Allowing the researchers to access the data could heavily contribute to scientific advances worldwide especially when it comes to rare diseases or minorities.

Application of blockchain in this scenario

Blockchain can provide a structure for data sharing as well as security. Healthcare providers collect information from the patient such as name, date of birth, procedures performed and prescriptions. The data is stored in the organisation's existing databases and/or on cloud computing systems. A hash is created from each source of data and is redirected to the blockchain along with the patient's public ID. Smart contracts are used to manage patient data access.

Through an API, healthcare stakeholders can query the blockchain that provides the location where the data can be found without revealing patient identity.

If needed, the patient can share his full medical record (with or without identifiable data) to any stakeholder. For instance, he could share identifiable data with his doctors and non-identifiable data with Big Pharmas. The patient can decide to whom he gives access to and on which conditions. Once accessed, data can be analysed and shared by the medical community and researchers.

One of the main advantages of this technology, is that it allows the patient to control the access he gives to his medical records. The patient defines through a smart contract the condition on which his data can be accessed on the blockchain. In fact, all this will be done through an API and the patient will set the conditions on his profile.

When the patient is conscious, the combination of the patient's and the provider's private keys unlocks the access to the data. If the patient isn't conscious, one or more third parties, picked by the patient, need to give their permission before the healthcare provider accesses the data. Either way, the patient has full control over his medical information and can decide whom to share it with.

Furthermore, medical records are not the only source of data related to a patient. Indeed, as IoT develops, wearables become an important source of information. This type of data could be used in the patient's interest to track his activity, set goals and adapt treatments.

All this can be done through smart contracts. Indeed, the patient and his GP can define the clauses of the contract and set objectives and consequences if the patient succeeds or fails to reach them.

ADVANTAGES OF MEDICAL HEALTHCARE BLOCKCHAIN

- Since the blockchain is Immutable and traceable, patients can easily send records to anyone without the fear of data corruption or tampering.
- Similarly, a medical record that has been generated and added to the blockchain will be completely secure.
- The patient can have some control over how their medical data gets used and shared by the institutes. Any party which is looking to get the medical data about a patient could check with the blockchain to get the necessary permission.
- The patient can also be incentivized for good behaviour via a reward mechanism. Eg. they can get tokens for following a care plan or for staying healthy. Also, they can be rewarded by tokens for giving their data for clinical trials and research
- Pharma companies need to have an extremely secure supply chain because of the kind of product they carry. Pharma drugs are consistently stolen from the supply chain to be sold illegally to various consumers. Also, counterfeit drugs alone cost these companies, nearly \$200 billion annually. A transparent blockchain will help these companies to enable close tracking of drugs to their point of origin and thus help eliminate falsified medication.
- Various medical institutes around the world conduct their own research and clinical trials on various new drugs and medications. A blockchain will help create a single global database to collect all this data and put them in one place.
- Insurance fraud is a major problem that is affecting the healthcare industry. This happens when dishonest providers and patients submit false claims/information to receive payable benefits. According to Boyd Insurance, Medicare fraud in the U.S. alone costs about \$68 billion a year.

ISSUES IN USING BLOCKCHAIN IN HEALTHCARE

Public Blockchains

The blocks in bitcoin and ethereum have a storage issue. Bitcoin has a little over 1mb of space per block which is simply not enough to run the kind of transactions and store the kind of data that healthcare institutes require.

Further, Public blockchains, especially the ones that follow the proof-of-work protocol like Bitcoin require an immense amount of computational power to solve hard puzzles. As such,

it is really impractical for these institutes to spend so much money on consensus mechanisms.

Moreover, public blockchains are open chains, which in itself is another detriment. Normally, healthcare institutes are averse to interact with each other in a network where anyone can come in and become a part of it. Medical institutes deal with highly-classified and sensitive data. Naturally, they do not want anyone outside their circles to interact with it.

Private Blockchains

For the above reasons, Public chains are impractical for healthcare institutions. Private blockchains on the otherhand are more practical.

Unlike public blockchains, Private chains aren't open to everyone. As a result, people who want to participate in the private chain must gain permission to be a part of this network. This is the reason why private chains are also called "permissioned blockchains."

Because of this, there are restrictions to the kind of people who can actually take part in the consensus. Access for new participants could be given by a) The existing participants who are taking part in the ecosystem b) A regulated authority & c) A consortium.

Once an entity has joined the ecosystem, they can play a role in network maintenance. The Linux Foundation's Hyperledger Fabric is an example of a permissioned blockchain framework implementation and one of the Hyperledger projects hosted by The Linux Foundation.

The private chains have been specifically designed for enterprise needs and offer a lot of features like a) Fast transactions b) Privacy & c) High security

CONCLUSION

There are various advantages that the blockchain can potentially impart to the healthcare industry. Various institutes and spaces have already started experimenting and working with the blockchain technology.

This space has no lack of money. The following statistics indicates it:

- The funding of digital health startups reached an all-time high in the first quarter of 2018.
- Global annual health spending surpassed \$7 trillion dollars in 2015.
- By 2020, the global annual health spending is expected to have ballooned to over \$8.734 trillion.

According to a report by BIS research, by 2025, the healthcare industry can save up to \$100 billion per year by 2025 in data breach-related costs, IT costs, operations costs, support function and personnel costs, counterfeit-related frauds and insurance frauds if they incorporate the blockchain technology.

The report also states that the use of

“a global blockchain in the healthcare market is expected grow at a CAGR of 63.85% from 2018 to 2025, to reach a value of \$5.61 billion by 2025. The use of blockchain for healthcare data exchange will contribute the largest market share throughout the forecast period, reaching a value of \$1.89 billion by 2025, owing to the use of blockchain to solve the most widespread problem in healthcare information systems related to interoperability and non-standardization that has created data silos in the industry.”

According to the report and the way the blockchain is being adopted by various sectors, it definitely looks like the future of the healthcare industry is indeed decentralized.

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