Blockchain in Healthcare

Mert Cokelek-21727082 [1]   **Ali Kayadibi-21727432** [1]   **Nese Gamze Uyanik-21627744** [1]   **Kerem Uremez-21627782** [1]
Kaan Beyhan-21627026 [1]

1. Introduction

Healthcare is the touchstone in current research areas since health is in the center of human life. The healthcare industry is trying to follow the new technologies, applications and adopt those technologies in a wide range, however, the applications put in forward for this purpose are generally outdated in terms of security and cost.

1.1. Problems in Current Systems

Despite the Blockchain idea came up in 2008, it is still used mostly in financial systems. So, the current systems in healthcare industry usually do not take advantages of Blockchains.

The companies, governments worldwide make investments on this industry, while the outcomes remain the same. Here are some real life problems:

- Counterfeit Drugs

- Personal Records are Shared to 3rd Parties

- Unreported Clinical Trials

- Data Breaches

- Malpractices

- High Costs

- Time Inefficiency

Some Problems in Healthcare in US

In this figure, you can see three examples of drawbacks of the current healthcare industry. In United States, the cost of data breaches for one record is 408$. Almost half of the clinical trials are not reported and half of the healthcare records have errors/misleading information. Apart from the economic side, more importantly the patients' records are not safe, not always official and not always correct. Like mentioned earlier, healthcare industry is growing slowly compared to the related technologies.

1.2. Blockchain

Blockchain is a distributed, time-stamped collection of records which are secured and linked via cryptographic hash functions. The main idea behind Blockchain is that it is:

- Decentralized,

- Safe,

- Immutable,

- Transparent.

2. How Does Blockchain Advance Healthcare?

First of all, with Blockchain, there will be no need for a third party company/organization to store clinical records, all the

data will be distributed on the chain. This implies most importantly a "Patient-Centric" system, where the patients will have full control on their own data.

The data will be immutable if wanted and verified. So the number of possible problems will drastically decrease. Besides, since the patients will have full control on their data, they can and will limit the accesses of doctors, hospitals, insurance companies, etc. If such party needs an access for some purpose, first it should get permission from the patient with this system.
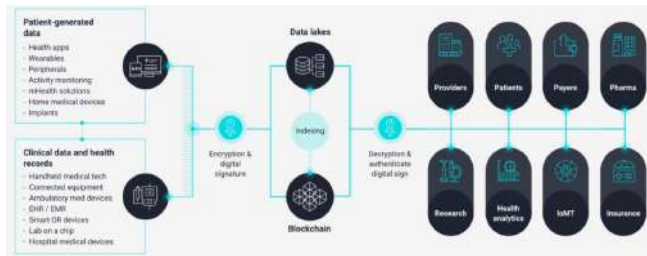
Medical Record Operations with Blockchain

Some use cases of Blockchain in Healthcare are :

- Clinical Trials
- Data Sharing
- EHRs EMRs
- Medical Device Tracking
- Micropayments
- Accelerating Research Development
- Drug Traceability

Now, we will shortly explain these use cases. This part will be an introduction on these use cases. In part 3, we will cover these topics in a detailed manner.

2.1. Blockchain for Clinical Trials

Blockchain creates such an environment that is transparent and self-trusted. This helps the clinical trials to be kept safe and efficient.

Also, Blockchain can reduce audit costs. With the help of "Supply Chain", a safe transfer environment is created. The details of Supply Chain will be explained later.

2.2. Blockchain for Medical Data Sharing

With Blockchain, medical data integrity is provided under global standards between patients and third parties. Besides, with Blockchain, patients are pushed to monitor their own data, this situation reduces costs.

2.3. Blockchain for Electronic Health/Medical Records

Patients will have full control over their own health records. So, they can manage the accesses by third parties such as doctors, laboratories, hospitals, insurance companies.

If such party needs an access to a patient's records, then they need to contact with that patient for permission. The implementation details will be explained in next sections.

2.4. Blockchain for Medical Device Tracking

Blockchain permits follow-up of a process from production to execution until it becomes unusable. Since transactions are time-stamped and verified, throughout the life cycle of a device, the detailed location history will be available.

If a process fails during the entire progress than the verification will fail and operation can be cancelled.

2.5. Micropayments

In healthcare, Blockchain allows the creation of a process traceable by the parties. Therefore, it is used for micropayments without any intervention from a third party.

There are many additional applications for developing rewards programs for patients who benefit from clinical projects and maintain health care plans regularly.

2.6. R & D Acceleration

With Blockchain, research and development can be improved both in terms of success and time. The medical records can be shared by patients, hospitals and more data means better performance in RD. This will also reduce costs in pharmaceutical and medical industry.

2.7. Blockchain for Drug Traceability

The Blockchain app helps prevent the introduction of counterfeit or unapproved medicines.

Processes are time-stamped, adding chain with a pharmaceutical smart contract, pill containers are being processed into the system and an integrated GPS and surveillance chain record ensures complete reliable drug deliveries.

2.8. Excellence in health

Blockchain works with a patient focus on data flow, management, and storage in healthcare. Blockchain solutions try to easily optimize innovation for EMRs and EHRs and shorten your cure. It increases the efficiency of each organization in the health sector both in the working environment and in the economic activity and provides better service conditions for the users.

2.9. Enhanced information security

The more protected the information security, the more protected the patient security. Blockchain guarantees data provenance in healthcare and provides enhanced trust without the need for third parties. Blockchain technology allows you to confirm and keep it confidential and highly secure.

2.10. Interoperability

With Blockchain, unwanted operations on records are prevented. The record sharing process works with seamless coordination between multiple maintenance providers, simplified verification processes, and automatic requests based on constant, complete records with Blockchain.

2.11. Data Integrity

When companies use Blockchain for Electronic Medical/Health Records, they benefit from health data which is improved by using artificial intelligence. It becomes impossible to edit or tamper with health records, clinical trials and their results. Payments are immutable and simultaneously updated on chain, preventing bad behaviors and reducing outgoing money for data monitoring.

3. Which Improvements Can Be Done with Blockchain?

Until now, we expressed Blockchain, the problems in current healthcare systems and the advantages of Blockchain for some cases. In the next part, we will mention these improvements in a more detailed manner. Also, some new solutions that Blockchain puts forward.

3.1. Making Electronic Health Records More Accessible with Blockchain

What is EHR,Taken from [2]

Electronic Health records are digital versions of patients record that contains medical treatment histories of patients , test results , allergies , medications and all other things of patients. Electronic health records are helping patients and doctors because it is fast,reliable and has access to patient medical histories, test result and all other medical things.Some of the hospitals who use this system states that, Electronic health records have helped them by having results of patients so any unnecessary operations are prevented, doctors are reacted better with knowing everything about the patient, they have reduced cost of staying at the hospital .And they also say that if people had access to EHR systems, many deaths from heart attack,cancer and other diseases could be prevented, many costs would be decreased.


What Does EHR Include,Taken from [3]

3.1.1. PROBLEMS IN CURRENT SYSTEMS

But it also has drawback such as physicians who use these systems say that it takes more time to enter the system and access the wanted patients EHR results more than paper medical records and also they say that when a EHR comes from another hospital it is much harder to understand and access patients results.So in the time of urgency this would take so much time to transfer,access your EHR so doctors can be late to do operation on you without knowing your EHR results.This is why we need a better solution that can make EHRs more accessible.And also they are vulnerable to hackers, if one hospital gets hacked, all of the informations of patients would be gone.

3.1.2. HOW CAN BLOCKCHAIN BE USEFUL?
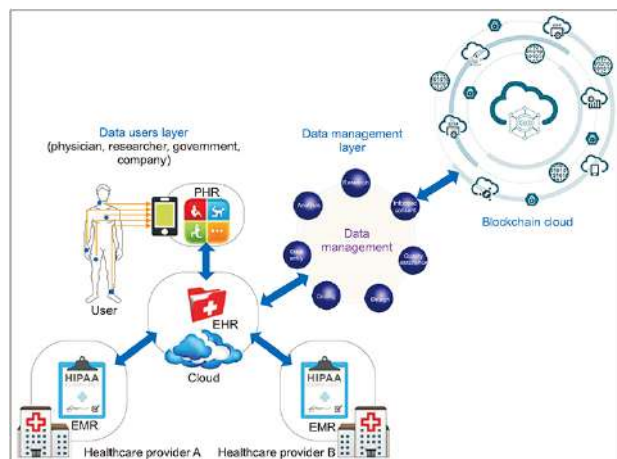
Example EHR System,Taken from [1]

To avoid these unnecessary steps that take too much time, we can use blockchain to keep our medical datas in the chain and the doctors can access our medical informations with your permission which kept private and secure in the blockchain.By using blockchain every patient becomes owner of their data, they can give their results to hospitals with permission safely and securely and this would be much easier, cheaper, faster compared to what we are using today.
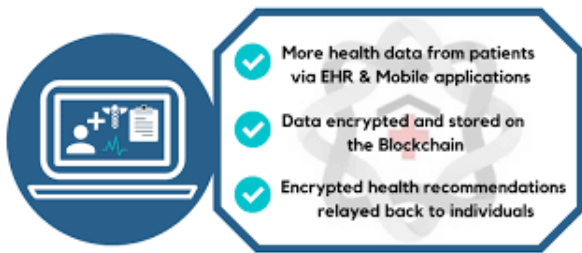
Advantages of EHR Systems,Taken from[4]

3.1.3. IMPLEMENTATION DETAILS

To store EHRs decentralized and permissioned blockchain can be used.Etherium platform and utilized Etherium smart contracts can be used to create representation of medical records stored within Blockchain.With blockchain, patients have full access and control over their EHRs.

3.2. Patient Satisfaction and Healthcare Industry Development

3.2.1. PROBLEMS IN CURRENT SYSTEMS

In current systems in healthcare industry, one of the biggest problems is that organizations hold multiple and partitioned health records about patients. This situation implies:

- Records to be unsafe, wrong,

- Involuntary accesses of 3rd parties,

- a Trust-needed environment.

These problems can cause mistreatments, or patients to feel uncomfortable.

3.2.2. HOW CAN BLOCKCHAIN BE USEFUL?

This can be solved by storing records and transactions on a distributed network to create a resourceful, safe, efficient, public and compact environment. In this environment, when a third party (Doctor, Insurance Company, etc.) is to access the records of a patient, a smart contract is used for that patient to give limited access to those records.

The possible participants of these smart contracts can be:

- Doctors,

- Hospitals,

- Laboratories,

- Health Insurance Companies,

- Pharmaceutical Companies.

In this context, doctors will add notes about patients, hospitals and laboratories will add scans, trial results, lab results and these will be recorded as transactions. Pharmacies will dispense medication, and the general process of such medications, drugs will be also recorded as transactions on Blockchain. After these steps, patient gives a limited, pre-determined permission to their insurer to access the system and verify the treatment and payments.

3.2.3. PATIENT - DOCTOR, HOSPITAL, LAB INTERACTIONS

With smart contracts, patients can rate doctors based on their medical case reviews, give advices and additional notes to doctors. Doctors will be rated publicly; successful, decent doctors will have higher rates, these rates will indicate how good that doctor is. Under these conditions, good doctors will earn more reputation and more job opportunities. Good behavior will be rewarded, bad behavior will be punished -or not rewarded-. These improvements will create more secure and effective patient-doctor interactions.

3.2.4. PATIENT - INSURER, PHARMACEUTICAL COMPANY INTERACTIONS

Like mentioned earlier, patients will give a limited access to the insurers to their health records, to monitor the general progress. This implies a more secure, efficient and officially right process of healthcare operations. One advantage of patients' to share personal records is that science and healthcare industry can grow faster with these datum. Additionally, patients will earn tokens since they contribute to healthcare industry by sharing such records.

3.2.5. IMPLEMENTATION DETAILS

The things mentioned under this subsection are already covered by a company named "Medical Chain".

With Medical Chain, data can be obtained from wearable devices, smart applications, clinical trials, etc. This data is

verified and updated simultaneously with smart contracts and stored on Blockchain. The rewarding system simply works by these smart applications and in return, patients earn MedToken (1 MTN = 0,02TL).

3.3. Tracking Medical Trials & Drugs

In this section, we present how to improve the safety of the clinical trials process and the supply chain in the pharmaceutical industry using blockchain.

The beginning of this section is the process of drug development. The drug development process is quite complex so it takes time around fifteen years to reach marketing part. After that, we will show a mobile application called "LifeCryper" that can help us to solve safety problems.

A- The drug development process
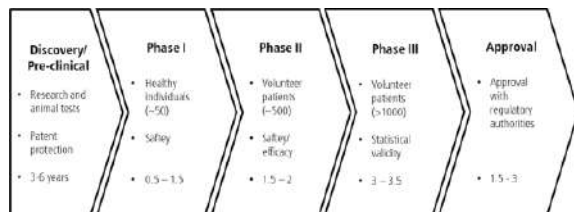
Drug development process scheme Taken from [10]

This process has different phases, from the discovery and pre-clinical testing to patent protection and marketing. Clinical trials start with human testing followed by testing in a large group of patients. The trials consist of three phases which correspond to safety, effectiveness, and efficiency tests. To proceed to the next stage, you need to get positive results from the previous one. Otherwise, the whole process is canceled or suspended. After clinical trials have been successfully completed, companies apply for marketing. The marketing approval in most countries (Turkey is one of them) is given by the relevant ministries. After approval, the sale of the drug begins.

3.3.1. PROBLEMS IN CURRENT SYSTEMS

In order to ensure the safety of the supply chain and the traceability of the medical product, there are laws adopted by each country. Despite the law, we face a lot of problems. Sample problems:

- Parallel Trading is one of them. This situation arises from the price difference in different countries. For example, any drug is 8 TL in Turkey, while in Germany 5 euro. so the drug can be sold on the black market.

- Another is Counterfeit drug. According to the WHO,the volume of counterfeit drug sales worldwide will reach $75 billion and the majority of the supply of drugs will be covered illegally.
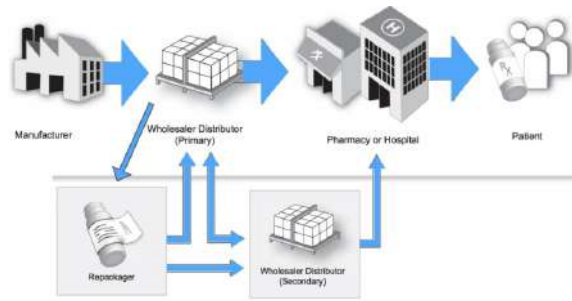
Drug supply chain Taken from [11]

The drugs supply chain is complex as you can see in the figure above. The reason for this complexity is the different packaging, storage, and transport process of the drug from the manufacturer to the consumer. The more these processes, the more difficult it is to maintain the originality of the drug. We encounter security problems in these processes, which cause financial losses and consumer distrust.

3.3.2. HOW CAN BLOCKCHAIN BE USEFUL?

Blockchain is an opportunity to avoid these problems. With using blockchain, traceability of the supply chain can be increased and pharmaceutical products can be supplied from the manufacturer to the consumer while maintaining their originality.

Solution Proposal: We give each drug a uniqueID. These unique ids are redefined for the current location at each stage in delivering the drug to the consumer. Only trusted parties are allowed for doing this process. And the process is processed into the blockchain. This process, which will be updated in real-time, can easily identify problems that may occur. Frankfurt School has developed an application for these problems.

3.3.3. IMPLEMENTATION DETAILS

B- LifeCrypter

The purpose of this application that developed in Frankfurt school is to increase security and traceability in the supply chain using blockchain, thus creating a more secure process. My opinion will be a practice that will eliminate the problem of counterfeit drugs.

Tracking Supply Chain of a Drug Taken from [11]

According to the research, the number of deaths caused by counterfeit drugs in one year is around 100000. Also, it has great financial damage to the global market. According to the same research, pharmaceutical companies are losing around $ 200 billion in a year on the global market due to counterfeit drugs. The operating principle of the application is verified at each checkpoint that the drugs arrive and delivered safely to the consumer. The operating principle of the application is as follows: To verify the incoming drugs at each checkpoint and process this process into the blockchain in real-time. In this way, to reduce the damage to human health and eliminate financial damage.

3.4. Storing & Tracking Medical Credentials

3.4.1. PROBLEMS IN CURRENT SYSTEMS

In current systems, medical credentialing is usually inefficient financially and in terms of time. These operations are conducted with phone calls or e-mails. Some possible drawbacks of the current systems are the insecurity of personal information and a need for a third-party storage unit such as a company, or a database. If the company or the database that holds these records encounters a fail situation then there can be irreversible consequences about the records.

3.4.2. HOW CAN BLOCKCHAIN BE USEFUL?

The main advantages of Blockchain in this situation are that it is a distributed, immutable, cryptographically secured ledger. These advantages imply credentials to be verified and the chain to be updated efficiently. With public-private key pairs, the database can be secured with access limitations. The contributors, participants can get permission to view or change the records or such operations can be restricted.

3.4.3. IMPLEMENTATION DETAILS

Credentialing can be done by "Smart Contracts". The participants (hospital-company managers, storage officers) agree on a smart contract. In this context, the credentialing records are inserted, viewed, updated, removed within a single

database with access provided by the participants in the contract. The access granted by the participants and the record to be processed is only available for a short pre-determined time. At the end of the day, the winnings both in terms of time and cost are inevitible, especially when considering tens and hundreds of credential storage operations.

3.5. Counterfeit Drugs

3.5.1. PROBLEMS IN CURRENT SYSTEMS

Counterfeit medicines are fake medicines.They may contain less or no active ingredient.Which may have no or little effect on consumers.They can even cause harmful effects on consumers.Counterfeit medicines are illegal and they may be harmful to consumers health.

Taken from [5]

They are becoming more popular around the world especially in the undeveloped countries and they are causing over one million death a year.The World Health Organization states that, we have %10 percent chance to use or see or buy a counterfeit medicine and this chance increases(triples) if you are living in underdeveloped countries.This is due to cost of original medicine compared to cost of counterfeit medicine.This can also mean the risk of fraud in the drugs we take. https://www.oecd.org/ states that this industry is worth near $200bn and the drug trade around the world is near $246bn

Counterfeit Drugs Effects on Industry,Taken from [9]

During 2011-2014 the increase of counterfeit medicines

was so high that Interpol has reported x9 increase in the number of the counterfeit medicines.This is a real threat and we must find a way to prevent this from increasing more and more.For this, blockchain technology can help us. Because of the immutability of blockchain, we can use this to track the movement of medicines and we can verify every step from production of medicine to selling the medicine.This is a must because the counterfeit medicines are nearly identical to original medicines.Even doctors and patients may not separate them.Partnership for Safe Medicines states that counterfeit medicines may contain less or no active ingredient.Which may have no or little effect on consumers.They can even cause harmful effects on consumers.By doing that they are decreasing the cost.Many of the consumers are unaware of these dangers and they are buying the cheaper option without knowing the risk of counterfeit medicines.According to drugfree.org nearly thirty-six million consumers have bought drugs on internet without any validation that confirms the origin of medicine.All these weakness' cause counterfeit medicines to slip through the system and cause danger within the consumers.

Comparison of Original and Counterfeit Drugs,Taken from [6]

3.5.2. How Can Blockchain Be Useful?

With using Blockchain we can track the movement of medicines, we can verify the origin of the medicine in each step from production to selling.If it fails to verify in any of the steps that means this drug is not original we can not verify the origin of that drug. This situation provides the delivery information without doubt. At each state we verify the origin and we can add transactions between sender and receiver.
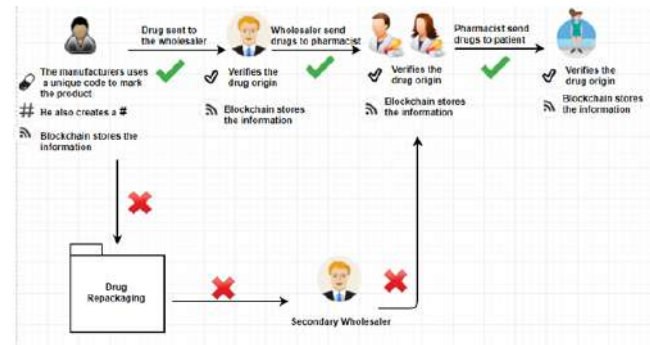
Detect of Counterfeit Drug System,Taken from [7]

First manufacturers uses a unique code to mark the product they also create a hash and they store that in the Blockchain. Than drug is sent to wholesaler , wholesaler verifies the drug origin , stores the information on Blockchain, wholesaler sends to pharmacist, pharmacist verifies the drug origin, stores the information on Blockchain , pharmacist sends drug to patient, patient verifies the drug origin , blockchain stores the information.If it fails to verify in any of the steps that means that drug is counterfeit and we can cancel the process or maybe call the cops. We have learned Blockchain as a cryptocurrency to earn money from air but the usage of Blockchain in industries are increasing.We are using Blockchain to track the movement of products, secure the safety of products, prove the origin of the products.In one survey it shows that %83 of the 120 officials believes that they will adopt blockchain and %68 of them believes that blockchain would be very useful.

Supply Chain From Manufacturer to Patient,Taken from [8]

3.5.3. Implementation Details

There are many organizations and government bodies who use Blockchain technology to detect counterfeit medicines.For example MediLedger is an open , decentralized network for storing transactions from manufacturer to wholesalers,from wholesalers to pharmacist,from pharmacist to consumers on supply chain.They store data on seperate servers which makes the manipulation of the data

almost impossible.Even if one of servers got hacked, thanks to Blockchain technology they will not manipulate data across between the other servers.Blockchain technology also ensures patient privacy and safety of medicines without revealing any of the personal data. Also the US have begun using a software which aims to provide history of drugs to track drug shipments.They tag the products with description of product, story of drug and they validate that in each step and keep track of them using multiple systems.

3.5.4. SUPPRESSING THE THREAT

With the grow of counterfeit medicine industry, the Blockchain technology will also be used more and more in the industry to limit and also to block increase of counterfeit medicine industry.Because of the proof of origins, time stamps, transactions stored online on networks, immutability, assurance,security provided by Blockchain, in the future it will be more popular and it will help us to save countless lives,money,ingredients all around the world.

3.6. Reducing Costs and Improving Medical Record Access

3.6.1. PROBLEMS IN CURRENT SYSTEMS

Nowadays, a healthcare provider can't reach the patient's health history without communicating with another healthcare provider. Currently, according to Gem, moving data from one healthcare provider to another in health care costs $ 8 and no other industry transport is rate does not live.

The amount of data produced in the last two years in the world is equivalent to the sum of the last 5,000 years. Despite the increase in information and processing speed with the advancement of technology, we still face several obstacles in accessing and analyzing data. We were able to analyze a very small portion of the data in our hands.

3.6.2. HOW CAN BLOCKCHAIN BE USEFUL?

Blockchain can be used to update patients' clinical trial results, or medications in chronological order. Furthermore, with the help of IoT and wearable devices, the information about blood levels are sent to the system as transactions. It instantly helps patients report their condition to doctors in an easy way.

With Blockchain, it is possible to store all of these records in one place instead of being fragmented and stored in different health care providers. One of the biggest advantages of this is that time and extra-economic expenses can be saved by avoiding the recurrence of unnecessary medical tests in different health care facilities in a short period. Another advantage is that the storage of the information in one place will ensure efficiency in terms of storage space and the costs associated with the maintenance of these records will be

eliminated. In the light of all this information, a report by BIS Research indicated that the use of blockchain in the field of health would save the health sector up to $ 125 billion in costs associated with data breaches by 2025. There will be no need.To give an example for the United States, HIPAA and each supplier are allowed to charge a legal fee for sharing a copy of their data records.

The advantage of the interoperability of healthcare institutions with other healthcare organizations using the blockchain will also restore the time and energy that doctors will spend on unnecessary repetitive activities. Assuming that the diagnosis and the positive results are added to the Blockchain Treatment Chain. Blockchain has the right medical control and the possibility of effective and timely treatment in other words. It can even prevent misdiagnosis.

Some of the other advantages of using Blockchain technologies can be listed as follows: Users will not need to rely on insurance companies to protect their health information. It brings transparency to financial transactions and eliminates the third party (banks etc.). Thus, it reduces the transaction fee. Because the method of creating records in one place by reducing the costs of transactions lies in the blockchain. To give an example of this problem, when a doctor conducts clinical research and needs to find people who potentially have the disease, it is possible to find them easily via the blockchain network.

One of the biggest problems in the pharmaceutical sector is to prevent the entry of counterfeit drugs into the market. To prevent this, if the information indicating the source of the drug is kept for every enterprise involved in the drug distribution process, it will be impossible to put counterfeit drugs on the market.

3.6.3. SECURITY & CONTROL OF HEALTHCARE TRANSACTIONS

As the popularity of Internet-connected devices and remote patient monitoring systems grows, we begin to encounter some security problems. These safety problems in the health sector are critical. Blockchain should also be used to eliminate these security problems. In this section we will explain why the blockchain is necessary for healthcare transactions and what benefits it will have.
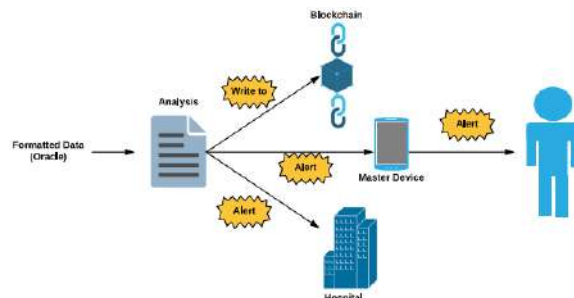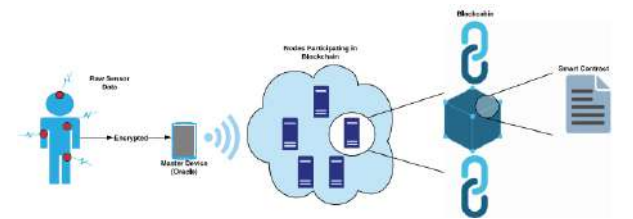
Taken from [10]

Using the Ethereum protocol, a system that calls smart contracts from smart devices and records every health process it performs provides us with a safer environment. According to the search, more than 7.1 million patients worldwide used the remote monitoring system in 2016 and this number is estimated to reach 50.000.000 in 5 years. Therefore, increasing security and control in health care is our most important issue. Our health data is targeted by thieves and hackers. Obtaining this data brings along great gains. Therefore, patient privacy should be protected and health procedures should be fast, easy and safe.

Block chain technology is used in many fields as well as increasing the safety and control of health transactions. Blokchain gives us the opportunity to record an unchanged log of events from the beginning to the end of a topic. Blockchain also uses smart contracts. We can use these smart contracts in every healthcare process. For example, health tests from the patient and monitoring the treatment process.

Blockchain Processing by the Smart Contract Taken from [11]

The system shown in the figure above illustrates how smart contracts can be used in healthcare transactions. Confidentiality is important in this system and blockchain technology is used for the verifiability of records. But it is not open to the public like bitcoin. Trusted parties are authorized and available only to those parties. The patient can follow his / her own treatment process and procedures. This feature increases the transparency of the system and is encouraging.

3.7. Improving Medical Record Keeping

Advances in technology affect all areas of human life. Technology is also finding new ways of progressing in the health sector. The key benefits of advancing technology include improving safety, user experience, and other aspects of the healthcare industry. These benefits are provided by the Electronic Health/Medical Record systems.
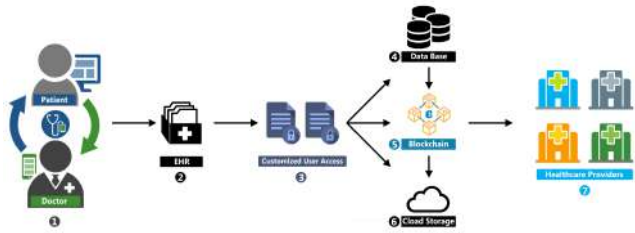
Healthcare data management in blockchain. Taken from [21]

However, the safety of patient records, data integrity, and such some problems are faced with. These problems can be solved by using blockchain. Blockchain aims to provide a secure platform for storing medical records.Before the development of technology, patient records were kept in a non-digital system. This system was inefficient, and unsafe. Same medical records are made in all institutions where the patient goes, so problems of repetition and redundancy occur. The health sector is turning to EHR systems designed to combine these two systems. These systems were used to keep laboratory results and patient information.It is aimed at keeping records more secure by preventing errors and facilitating access to information. The purpose of EHR systems is to solve the problems of the paper system and to provide a more effective system in the health sector.

3.8. Blockchain for Relief Efforts

There are approximately 68 million refugees in the world. These refugees must have a valid identity to receive assistance from government or international donors. These identities are very important in helping refugees access the aid supply chain. Blockchain stores this data on multiple computer nodes. Each node contains an identical copy protected by an encryption technique called hash, and the control is decentralized. This block chain strategy ensures that the funds allocated for assistance reach their intended recipients. These practices will provide visibility to social community organizations, non-profit organizations, host country stakeholders and other charities. A single system that provides information to everyone involved will solve many problems.

Taken from [22]

Blockchain enables us to review processes and to uncover

the power of cooperation. Sometimes we find potential in areas we have not thought of before. A shared system of record can significantly reduce complexity and streamline interactions between multiple parties. But who runs the underlying system, who owns the data, who pays for it and how does it work. With Blockchain, independent systems are combined, using a decentralized network without a need for a third party.

3.8.1. EXAMPLE OF USING BLOCKCHAIN FOR RELIEF EFFORTS

Imagine the following situation. The United Nations launched an internationals disaster relief mission just after an island has been struck by an earthquake.France, The United States and the Red Cross established relief camps all over the island. Each provides specific resources. France brings medical support, Red Cross helps drinking water, and the United States provides helicopters. The block chain acts as a single source and provides transparency on needs. Several doctors who should fly to the other side of the island then enters the request in the application published to all mission participants through the blockchain. All other participants can instantly see the request and respond. All parties have agreed to a smart contract with a simple, open algorithm that keeps everyone bound by common rules. Ones an offer matches the request its automatically accepted.Help can be provided without delay and no other party needed.
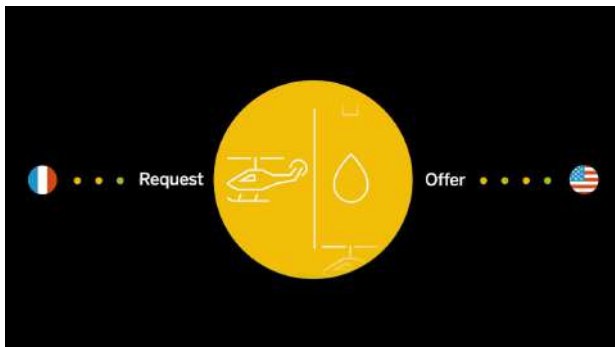

Image from a sample application Taken from [23]

The ability to collaborate directly on a business process across organizations is one of the key elements almost all blockchain use cases have in common. Blockchain guarantees autonomy from intermediaries and ensures transparency and data sovereignty for each party. Everyone covers it own costs while all can benefit from the efficiency of the distributed system. Blockchain service will provide easy access to the full toolkit to establish and run such a system integrated with your solutions and place and connected to an open ecosystem of participants .

4. Our Model Proposal, "LIFE ON CHAIN"

Healthcare is the touchstone of research areas, hence it is the main Investment point, as expected. There are already many Blockchain-based establishments, companies set up for this purpose. However, they are generally independent foundations from each other. Our idea is to combine the "Improvements" into a single model, which results in a more complete ecosystem. "Life on Chain" is not just a union of previous ideas/methods.

4.1. What Does "Life on Chain" Put Forward?

With "Life on Chain":

- Record Keeping
  - Medical records
  - Patient, Doctor, Insurer, Hospital records

- Tracking - Supply Chain
  - Drugs, Equipments
  - Clinical Trials

- Patient-Doctor, Insurer, Hospital interactions
  - Ranking, voting
  - Rewarding good behavior, punishing bad behavior

- A universal currency that is produced and used in this system

4.2. The Innovation Coming with "Life on Chain":

"Life on Coin" united all the improvements mentioned earlier into one piece. However, this proposal model should include new ideas/solutions. **This innovation is: A Blockchain that contains a "Pool of Unresolved/Resolved Treatments, Cures".**

The main idea behind this innovation is to speed up the progress in finding new treatments for new health problems. In this context, a pool of unresolved treatments in the medical industry will take place. Also, the verified treatments will be publicly available so that people will transparently see what kind of treatments should/will be applied to them. This can solve the problem of "Malpractice". A pool contains such treatments, publicly.

4.3. How Does the System Work?

If a new health problem comes up, first check if that problem is cured by looking at the "Solved Treatments Pool". If not cured, it is added to the "Unresolved Treatments Pool". For a health problem;

1. A doctor/scientist thinks that he/she came up with a new treatment and announces that idea to the chain,

2. If 50% + 1 of the system of doctors-scientists agree with this treatment, that treatment is proposed officially with authorized systems. The rest of this process is not abou t Blockchain.

   - That doctor/scientist gets his overall point (rank) increased.
   - The majority of voters' ranks are also increased.
   - The minority voters' ranks are decreased.

As seen, a ranking system is used. With this system:

- Participants can convert their ranks(points) into "LifeOnCoin" (LOC).

- The ranks of the participants indicate the reliability and quality of them, so the doctors with higher ranks will have more reputation and more job opportunities.

These points imply the participants to act well.

4.4. Conclusions on "Life on Chain"

Advantages

- **Speed and Simplicity:** Healthcare operations are merged under one roof.

- **Useful-Correct:** On-chain, only correct and useful information, records will take place.

- **Far from Bad Behaviors:** Verified records are immutable. Good behaviors are rewarded with currency and ranking system. Bad behaviors are punished - not taken into account.

Disadvantages

Disadvantages of general Blockchain systems. (Computing power, transaction speed, storage..)

5. General Conclusion on Blockchain in Healthcare

The healthcare industry has several problems with safety, efficiency, trust. These problems have important consequences such as malpractices, counterfeit drugs, faults in medical equipment, negative relationships between patients and services. Blockchain provides safety with storing medical records, credentials, tracking informations in a distributed, verified, transparent, cryptographically secured, time-stamped database. This safety will reduce trust problems. Also since it contains verified records, malpractices

and incorrect applications. With Blockchain, medical device tracking, record keeping-accessing, credentialing is done efficiently in terms of time and money with smart contracts.

Advantages

- Patients have control over their data. With Blockchain being immutable and encrypted, patients can send their personal records to third parties safely.

- Medical records stored on the blockchain will be verified, safe, and immutable if wanted.

- The medical history of data (trial, operation, drug) is complete, consistent, timely accurate, and easily distributed.

- Patients are incentivized for sharing their records, joining trials. If they do so, they will earn tokens.

- The agreements on healthcare opertaions can be reached without a third party.

- Changes on the Blockchain are public to all participants of the system, and all data insertions are immutable. So, involuntary operations are prevented.

Disadvantages

- Participants of the smart contracts must be aware of the laws. According to the "https://www.oecd.org privacy guideline", patients have the right to delete their records. This contradicts the logic of Blockchain.

- Financial transactions do not require large storage space, however, medical records are very large compared to financial ones. Storing all the records in the Blockchain will be costly. In order to deal with this problem, off-chain storage of data is suggested. However; if data is kept outside of Blockchain, but the hashes of the data are stored in the blockchain, this is a good solution if the healthcare data is stored off-chain and secured, corrected, and erased as desired.

6. References

1. Shahnaz, Ayesha Qamar, Usman Khalid, Dr. (2019). Using Blockchain for Electronic Health Records. IEEE Access. PP. 1-1. 10.1109/ACCESS.2019.2946373.

2. https://www.researchgate.net/publication/336393649

3. https://openledger.info/insights/blockchain-healthcare-use-cases

4. https://www.sciencedaily.com/releases/2019/04/190415154651.htm

5. https://www.supplychaindive.com/news/blockchain-curtail-counterfeit-medicine/546658/

6. https://www.researchgate.net/publication/331729440

7. https://www.fairwarning.com/insights/blog/ephi-security-why-monitor-more-than-your-ehr

8. https://www.healthysimulation.com/18379/free-electronic-medical-records-training-online/

9. https://www.researchgate.net/publication/330113931

10. https://www.economist.com/node/16943895/comments

11. https://www.pharmaceutical-technology.com/features/blockchain-pharma-opportunities-supply-chain/

12. https://medium.com/techracers/how-blockchain-contributes-to-drug-supply-chain-management-8a1a67ac02ef

13. https://digital.hbs.edu/platform-rctom/submission/can-blockchain-help-solve-the-problem-of-counterfeit-drugs/

14. https://www.arjo-solutions.com/en/2016/02/16/how-to-fight-against-falsified-medicines/

15. https://www.researchgate.net/publication/325605811

16. http://explore-ip.com/2017_Blockchain-Technology-in-the-Pharmaceutical-Industry.pdf

17. https://www.mdpi.com/2076-3417/9/9/1736/htm

18. https://medium.com/@focus_invest/can-bitcoin-and-blockchain-bring-transparency-to-relief-efforts-5f7b7dd6c662

19. https://news.sap.com/2017/11/blockchain-disaster-relief/

20. http://blokzincir.gtu.edu.tr/saglik-ve-ilac-sektorunde-iot-ve-blockchain-kullanimi/

21. https://link.springer.com/article/10.1007/s10916-018-1025-3

22. https://www.computer.org/publications/tech-news/research/blockchain-health-medical-records-cloud-security

23. https://journals.sagepub.com/doi/full/10.1177/1460458219866350

24. https://synapse.koreamed.org/search.php?where=aviewid=10.4258/hir.2019.25.1.51code=1088HIRvmode=PUBREADER

25. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6764776/

26. https://www.nsmedicaldevices.com/analysis/blockchain-technology-healthcare/

27. https://www.cbinsights.com/research/report/blockchain-technology-healthcare-disruption/

28. https://www.beckershospitalreview.com/healthcare-information-technology/new-blockchain-platform-aims-to-cut-prescription-costs-4-notes.html

29. https://www.digitalauthority.me/resources/blockchain-in-healthcare/

30. https://www.wsj.com/articles/how-blockchain-could-help-lower-health-costs-1527559440

31. https://www.ntu.org/foundation/detail/reducing-health-care-transaction-cost-through-blockchain

32. https://yourstory.com/2018/02/blockchain-decrease-cost-healthcare/

33. https://hitinfrastructure.com/news/healthcare-blockchain-could-save-industry-100b-annually-by-2025

34. https://www.nordicwi.com/blog/how-could-blockchain-reduce-costs-for-your-healthcare-organization

35. https://www.peerbits.com/blog/blockchain-technology-on-healthcare-industry.html