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BLOCKCHAIN TECHNOLOGY FOR HEALTHCARE SECTOR

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Bachelor's Thesis
Spring 2020
Information Technology
Oulu University of Applied Sciences

ABSTRACT

Oulu University of Applied Sciences
Information Technology, Option of Internet Services

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Title of the bachelor's thesis: Blockchain Technology for Healthcare Sector
Supervisor: Jaakko Kaski
Term and year of completion: Spring 2020 Number of pages: 40

The aim set for this Bachelor's Thesis was to have a better understanding of the technological methods to increase the quality of public service sector of healthcare by using blockchain and applying its applications.

The research was implemented by persistently searching information and executing the applications. The cryptographic techniques are used in blockchain to achieve high end security of the personal and organizational data as it can be agreed that healthcare data and information are very important to all parties and the confidentiality should always be maintained and evolved as there is always a consistent growth of technology.

Although, there is still a vast amount of information to be researched. Any person reading this thesis report with no past information is provided with enough research information about what the blockchain technology is in non-technical as well as technical terms.

Keywords: Blockchain, Cryptography, Confidential

PREFACE

The basis for this research was originated by realizing how important healthcare is to public as well as government and applying new but proven technological inventions to improve it further. As the world has transformed into digital age, the security of data has to be up to the standard maintaining integrity. It is my passion to investigate new technologies in the modern world and how they can help people improve their lifestyles. The research for the report of this thesis was done at Oulu University of Applied Sciences during January 2020 and February 2020 as part of an academic curriculum.

In truth, I could not have gathered such amount of information from various da-abases without the help of Mr. Tomi Pelkonen who is a member of library at Oulu University of Applied Sciences (OAMK). A special credit goes to my supervisor Mr. Jaakko Kaski who always made sure I am on track, provided guidance on the content of the report and references needed. I would also like to thank our language control faculty member of OAMK, Kaija Posio who throughout the degree programme made sure students meet the standard of language needed in professional career and also very helpful resources on the thesis formatting and standard requirements. Thank you everyone for the unwavering support.

Oulu, 30.03.2020
Sreejesh Bhattarai

CONTENTS

1 INTRODUCTION

The name ‘Blockchain’ has been in the news recently for many reasons, mainly in relation to cryptocurrency ‘Bitcoin’. However, its application ranges in a wide range of fields and one such area could be ‘Healthcare’, if applied in a right way. Many organizations have increasingly benefited from this technology, especially in relation to finance and security. This research was conducted to understand and find the possibilities to implement this technology in the healthcare sector, which is an integral part in life of any individual as well as organizations running it. (figure 1)

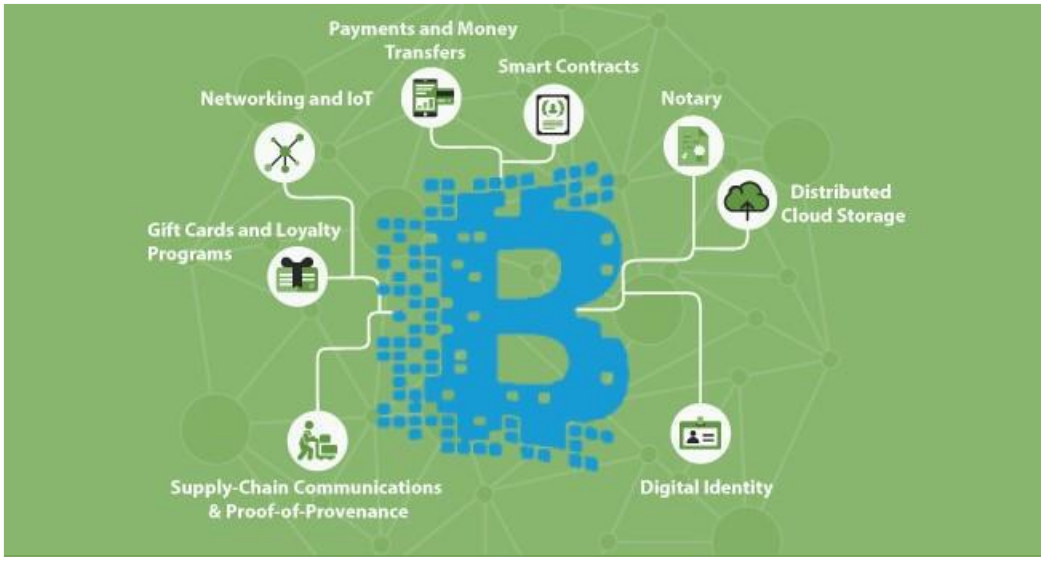

FIGURE 1. Different applications of blockchain technology (1)

Although blockchain will not solve all the problems in healthcare institutions, it will certainly help to minimize significantly some of the major issues within it. Some examples of such issues are mentioned below and they are explained in detail in the following sections. (2)

- Restrictions in sharing real-time data across multiple parties
- Verification of the integrity of data (2)
- Not enough standard of security (2)
- Lack of transparency (2)
- Struggle in integrating Artificial Intelligence into clinical practice (2)

2 BLOCKCHAIN TECHNOLOGY

It is important for one to understand the topic from the root because of which the basic knowledge of what actually is blockchain technology has to be understood.

2.1 Internet Today

The world has moved beyond expectations in terms of technological advancement as the Internet has touched almost all aspects of life impacting the way things are run, work is done, communications are made and education is implemented. Day to day lives have been made convenient with the help of the Internet, such as low-cost communications, running online businesses and providing healthcare information and services. However, it also comes with some major threats associated with it, such as:

- Software viruses
- Online frauds
- Fake news
- Unethical hacking

All above mentioned problems of the Internet today can be related to “trust” if people’s lives are to be revolved around the Internet arising questions, such as:

- Is the person real whom we are talking to?
- Are the services real as promised?
- Are unauthorized people denied access to information and systems?

Major breakthroughs have been made for better security and integrity, such as two factor authentication, biometrics, firewalls and antiviruses as well as CAPTCHAs. However, these mechanisms are not enough and users are still compromised of data, identity and money and the need for more secure and trustworthy internet remains. One such mechanism which could solve such a problem is “Blockchain Technology”.

2.2 Database

Data is an integral part of Blockchain Technology and it is vital to know how traditional and relational databases have been working in today's world where data is stored and managed. Traditionally data has been stored in structured and unstructured ways.

2.2.1 Structured Database

Data in a structured database is stored in rows and columns in tabular format making it easier to find certain data with a unique identifier during the search. Entries in one table of a database could be referenced by another table or database preventing a duplication of data thus making it efficient by making the use of references instead of recreating the data when there is a need for it or it to be updated. (3)

Figure 2 shows an example of this:

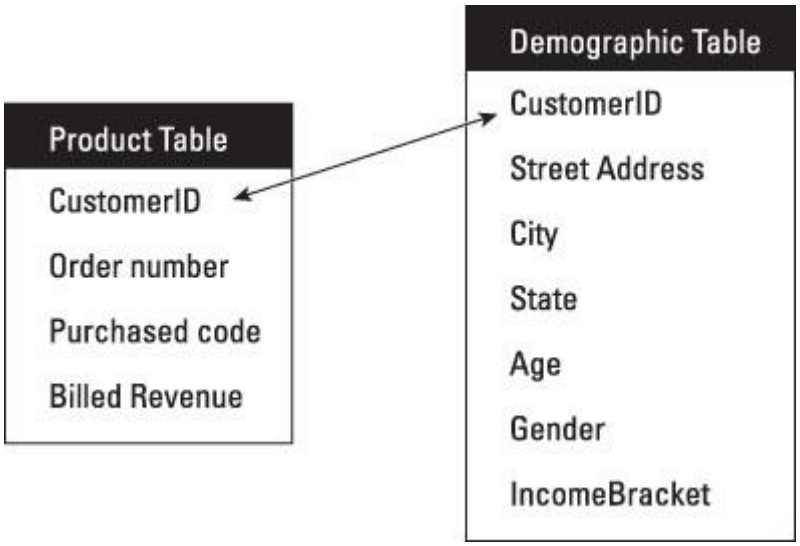

FIGURE 2. Structured database example of invoice (3)

In the figure 2, a structured database is illustrated by giving an example of an invoice of a customer with two tables consisting of purchase information and personal information of the customer referenced by the identifier "CustomerID".

2.2.2 Unstructured Database

Most of the data in the world today is stored in an unstructured format. Almost as high as 80% of all data is stored in unstructured database system e.g. collection of data from social media accounts, email and online documents. (figure 3) Various tools have been created to manage unstructured data efficiently with the increasing demands. (4)

Structured vs Unstructured Database

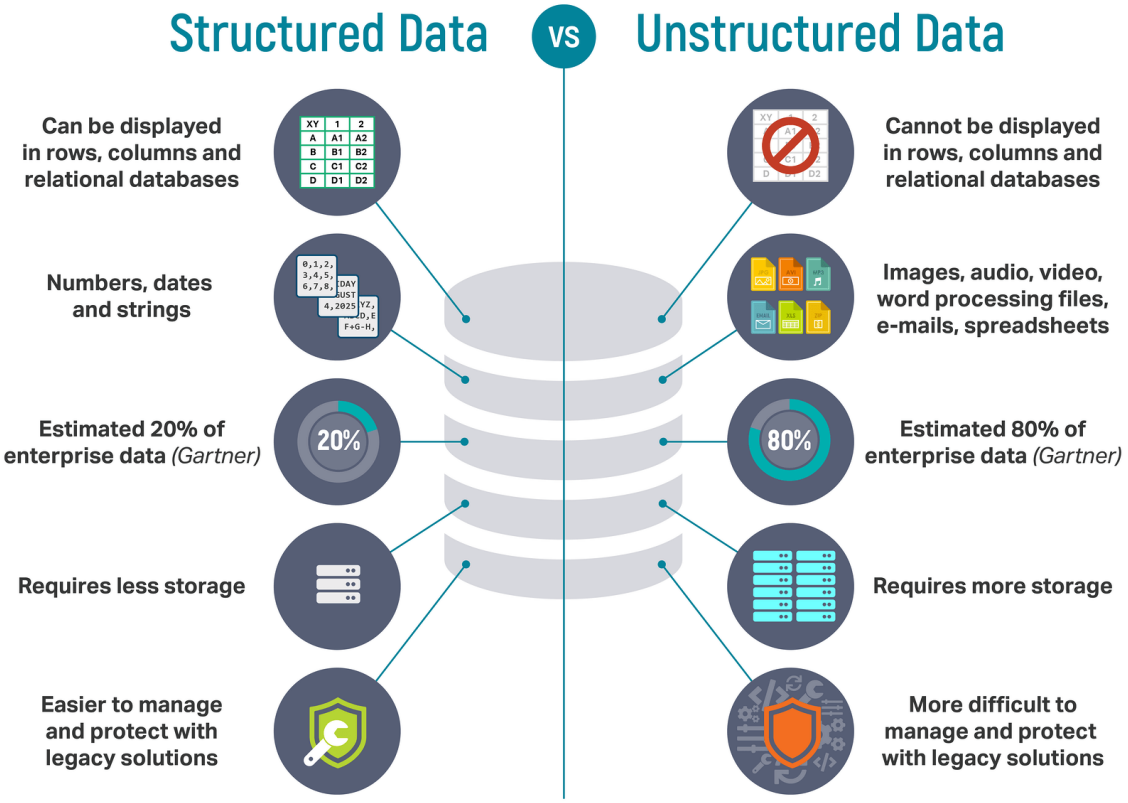

FIGURE 3. Structured vs Unstructured database comparison (4)

2.2.3 Traditional Database Challenges

Traditionally data in a database is typically stored on a server computer or a data centre at a business or a systems provider or in other words, a centralized database. (5) (figure 4)

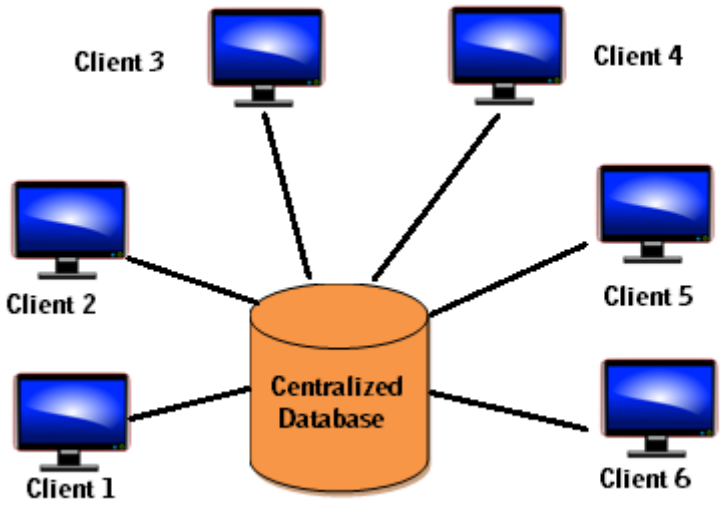

FIGURE 4. Centralized database architecture (5)

In a centralized database structure, data resides in a database which can be accessed by various clients through different devices such as PCs, tablets and smartphones. Many mechanisms are implemented to allow certain people or authority to have access privileges to a database. For example, certain users might only be allowed to view or look up the information on a database but not change or update the data while other users might be given access to add, delete or modify data. In all cases where users are granted certain rights, there exist an authority that grants those rights. In many organizations, this authority is a designated system administrator who has been authorized the right to grant certain rights to users. However, this architecture comes with some security limitations and few examples of them are mentioned below:

- Someone who is not authorized certain rights in a database gains access to a database.

- Security measures could be bypassed and data could be altered in the database

Generally, organizations are served well with this kind of database providing a great value economically. However, there are many risks involved and they are vulnerable to security threats. Blockchain technology can help overcome these challenges giving new opportunities to move from the traditional system of storing a data to new advanced system.

2.3 What is a Blockchain Technology?

The name “Blockchain” has been derived from the term “chain” of “blocks” containing information where the transactions made on a network are represented by “block” and string of the blocks by “chain”. A new block of transaction is added to the end of an existing chain, which is a list or ledger of transactions validated on the network. (figure 5)

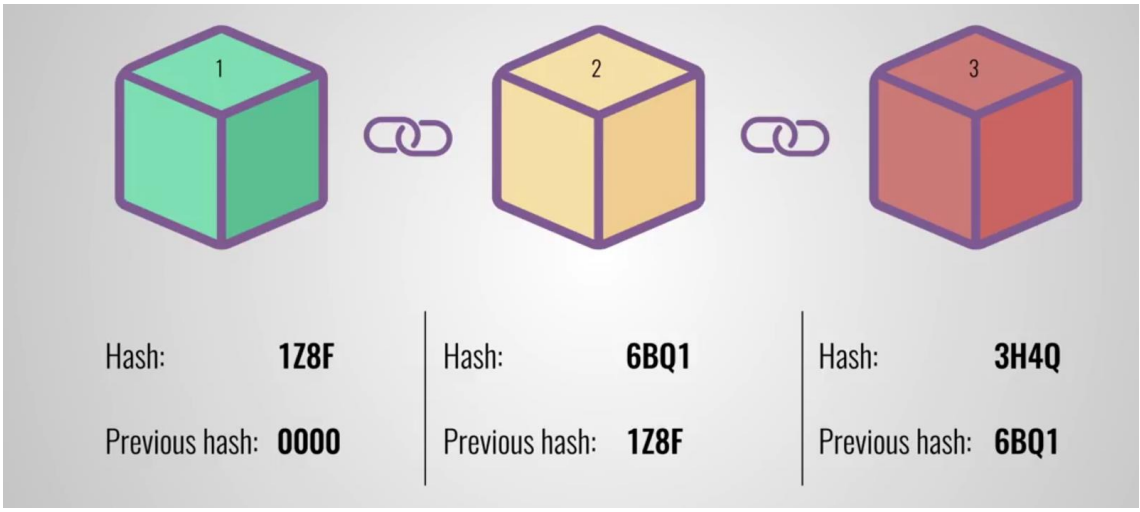

FIGURE 5. Visual representation of a chain of blocks (5)

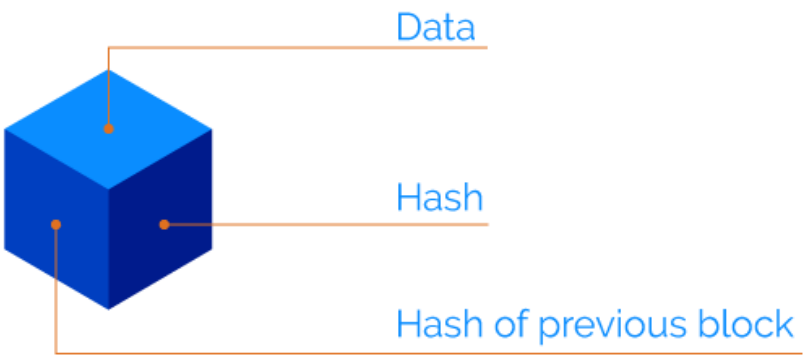

FIGURE 6. Visual representation of each block in a blockchain (5)

When a data is recorded in a blockchain, making changes to it is extremely difficult. Each block in a blockchain contains data, a hash of the block as well as a hash of the previous block. (figure 6)

- **Data**: The data stored is dependent on the type of blockchain. For example, in a Bitcoin blockchain, the data stored consists of the details of the transaction made, which are “Sender”, “Receiver” and “Amount”.
- **Hash**: A block in a blockchain also contains a hash which can also be compared to a fingerprint as it uniquely identifies a block and all the content in it. A hash is calculated when a block is created and any changes to the block will result in a change in the hash.
- **Hash of previous block**: Each block also contains the hash of the previous block creating a chain of blocks which helps each block point to the previous block. The first block in a blockchain cannot point to the previous block as it is the first one, hence it is also named as the “Genesis Block”. When a change is made in a block, the hash is also changed. However, the next block already contains the original hash of the previous block which is changed and do not match anymore. As a result, all the following blocks are invalid. This attribute makes a blockchain very secure to any malicious activity with the data.

As mentioned in the previous section, a traditional database is governed by a central authority where all rights to it are owned by an organization giving different types of access rights to a desired authority. However, various flaws are drawn with it and some of them are discussed below:

- When a central database is relied on by a system, it could result in a single point of failure which means that if a central authority is compromised or backdoor is exposed, the database could be in a huge risk. (6)
- Since all rights and power are held by a central authority, humans remain the final arbiter of the validity of a transaction. It requires a central authority to validate data. For example, a contractual agreement between two entities completed over the Internet, a mortgage where savings are validated by a central authority bank to approve loans and signatures are validated by legal professionals. (6)

Transactions on a database are complex processes requiring time to process and finance. They are vulnerable to external threats, require special skills and error prone. Blockchain Technology could help overcome all these challenges. On the contrary to a traditional database system, a blockchain database is installed on individual computers used by the people using the database. Each copy of the same database is installed on every computer of every user of the database without the need of a database server. All changes on a blockchain database are stored as new blocks making it an immutable database by not allowing changes to the already existing data or block as the blocks rely on each other interconnected in a form of chain.

Often, a blockchain database is referred to as a “distributed ledger” because it helps keep track of changes, such as an accounting ledger where financial transactions are recorded. (7)

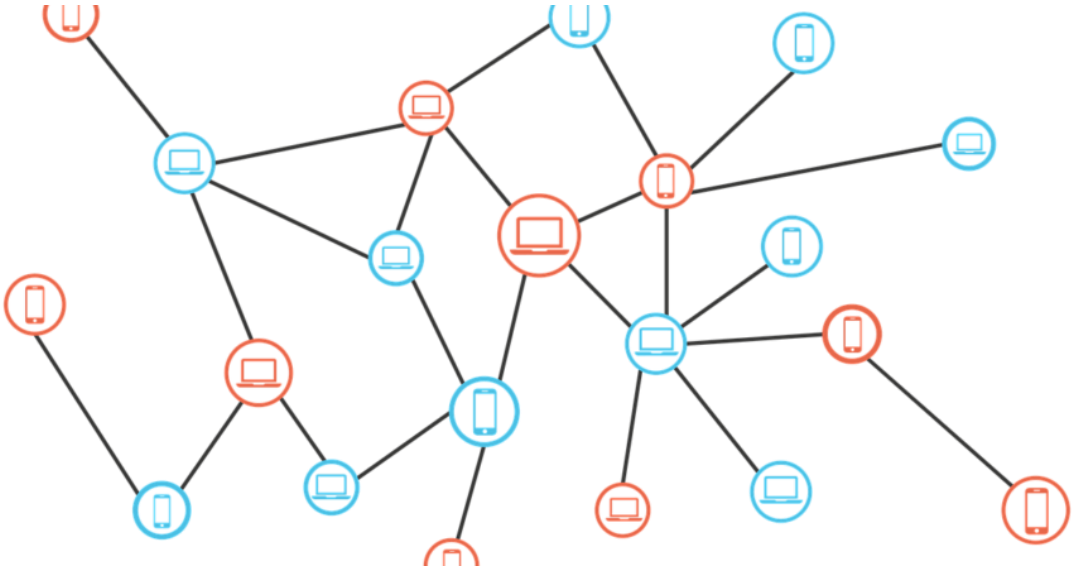

FIGURE 7. Distributed Ledger structure (7)

As illustrated by figure 7, a database is not controlled by a central authority, the power is distributed across all the network of users of the database, not allowing a single person or system to approve the changes or in other words, the power has been decentralized.

2.3.1 Origin of Blockchain in Bitcoin

Bitcoin is a new form of peer-to-peer digital currency which was first mentioned in a paper written in 2008 by the mysterious and pseudonymous developer Satoshi Nakamoto, whose true identity has yet to be verified with speculation of the name referring to a group of writers and not a single person. Later in 2009, the emergence of Bitcoin occurred as an open-sourced software allowing anyone to inspect, modify and enhance it. A digital currency was enabled with Bitcoin software which could be used without any intermediaries or governing authority allowing the flow of currency from person to person without the need for a bank or any other third party intermediary. (9)

FIGURE 8. Bitcoin logo (8)

Bitcoin (figure 8) is also known as cryptocurrency because the history of a transaction can be seen by everyone but the contents are only known to the people making and receiving each individual transaction. Bitcoin's existence does not occur in a physical form as there are no coins or paper notes but it lives natively on the internet. (figure 9)

FIGURE 9. *Bitcoin transaction example (9)*

When a transaction is made on a bitcoin network, the computers of participants using Bitcoin specifically validate the transaction and record it in a distributed

ledger which is the “Blockchain”. There has to be a limit on supply to have a value of a particular thing, similar to Gold, Silver, diamonds and others whose value is dependent on the level of scarcity and how expensive it is to mine. Some of the characteristics of Bitcoin are given below: (9)

- Bitcoins are also made available in a limited amount. The original creator stipulated that there would only be 21 million bitcoins.
- A unique type of mining is required to acquire a new bitcoin in contrast to an existing tradable bitcoin. To keep in simple words, new bitcoins are provided as rewards to a blockchain participant who solve complex mathematical puzzles every time a blockchain transaction has taken place and usually referred to this participant as a “miner”. A considerable amount of computing power is required for this process resulting in a very high and expensive value of a new bitcoin which can be traded openly on the global bitcoin exchange. After this process, the value is calculated according to supply and demand on the market.

  Figure 10 illustrates the surge in Bitcoin price in the last few years as a result of high demand of miners

  .

FIGURE 10. Bitcoin price index (10)

- An electronic wallet is required on the user's computer or device to receive and spend bitcoins, it could also be an app. It is not required to be a miner to own a bitcoin as it can be easily bought on a bitcoin currency exchange in exchange for a local currency. (10)
- A transaction which is initiated from the electronic wallet is added to the queue, validated by all other bitcoin users and if approved, added to the distributed ledger which is a blockchain. (10)

The activity of miners is required to add a block which helps in validation of the transactions eliminating the risk of fraudulent activity because a hacker would need all the processing and electrical power of the miners to fake adding a block to the blockchain. This process also gives "Proof of Work" in the transaction because miners are required to validate adding blocks to the chain. There is a huge opportunity and endless possibilities for organizations of various fields to implement digital currencies using blockchain technology which would eliminate the need of central authority, such as banks, and securely move money around the Internet with a low cost.

2.3.2 Opportunities with Blockchain Technology

As described in previous chapters, this technology supports immutable transactions and currency movements more securely and undisputed without the need of central authority. They are only modifiable by agreement from all participants. Following the similar concepts as Bitcoin, stocktrades, bonds and other financial assets can be managed with Blockchain Technology. However, blockchain is not limited to only a financial transaction but has wider possibilities which need to be experimented and explored. Some examples are given below:

- Blockchain Technology can help overcome the challenges of proving an ownership of a digital products, such as photos and music, by registering the products in a blockchain. If digital products, such as photos and music, are registered on a blockchain by the owner, it would be almost impossible for someone else to claim the ownership of that product as the ownership records are stored on the blockchain and it is almost

impossible to change it. However, making it a lot easier to change the ownership if all participants are on agreement. (10)

- Shipping business can have huge benefits if blockchain technology is used as a lot of time is spent on paper work in shipping or trading businesses with processes, such as signing papers, stamping, many people and checkpoints involved for validation and confirmation, e.g. customs, tax officials and inspectors. Apart from time, the paper work could also be vulnerable to tampering allowing criminal activities off the product. Blockchain technology can help overcome these problems by making all the transactions digital and all changes on the blockchain making it impossible to tamper by including digital signatures and an immutable history of every step of the journey of the product during the shipping. IBM and Maersk have already partnered to form a blockchain powered platform to facilitate international trading. (10)
- Blockchain technology can also establish trust in digital world with a highly secure identity verification as everything on the Internet today relies on the identity of the user but yet it is one of the most vulnerable aspects of web. Passwords or other credentials could easily be stolen and compromised. By using blockchain technology, identities could be stored as a block and having it universally accepted for authentication purposes. These identities could be e.g. passwords, identity cards, driver's licenses and certificates. (10)
- Having secure and trustworthy online identities could also open opportunities to online voting, which would enable all citizens to vote in an election easily even with the smartphones. (10)

At present, this technology is still in an experimental phase. However, possibilities are endless, and many organizations and institutions have already started to implement it in a hope to increase their productivity and data security.

2.4 How does Blockchain Technology work?

2.4.1 Technologies Involved in Blockchain

Cryptography

There are various technologies involved in working of blockchain and one of the most important technologies used by blockchain is “Cryptography” using public and private keys. The term “Cryptography” is derived from Greek words “kryptós”, which means “hidden”, and “graphein”, which means “writing”. In other words, cryptography can be said as secret writing. It is a process of sending a message from one person to another without making it accessible to unauthorized users.

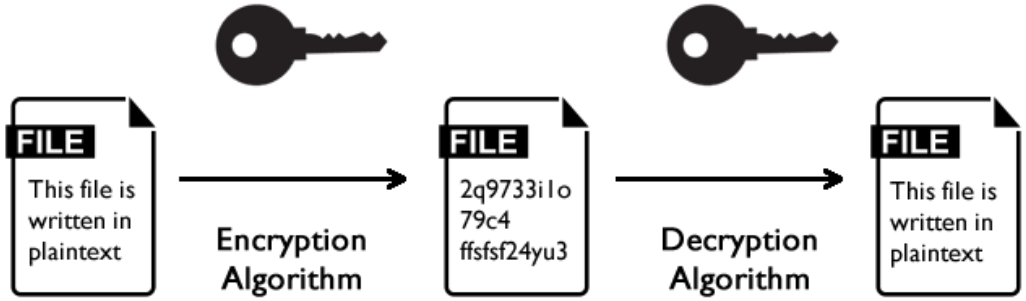

FIGURE 11. Simple Cryptography example (11)

When a message is sent over the network and cryptography is implemented, the sent message cannot be seen by others as it goes from a state of plain text, which can be read, to the state of cipher text using an encryption algorithm and this process is called “encryption”. When the message is received by the user, it has to be in plain text to be readable again and the process of decryption is applied for it. (figure 11)

Public and Private Keys

One of the many forms of cryptography is called PKI which means the Public Key Infrastructure and it involves two keys, a “public key” and a “private key”.

The Public key can be seen by everyone whereas the private key can only be seen by the user owning it and it must be kept in secret.

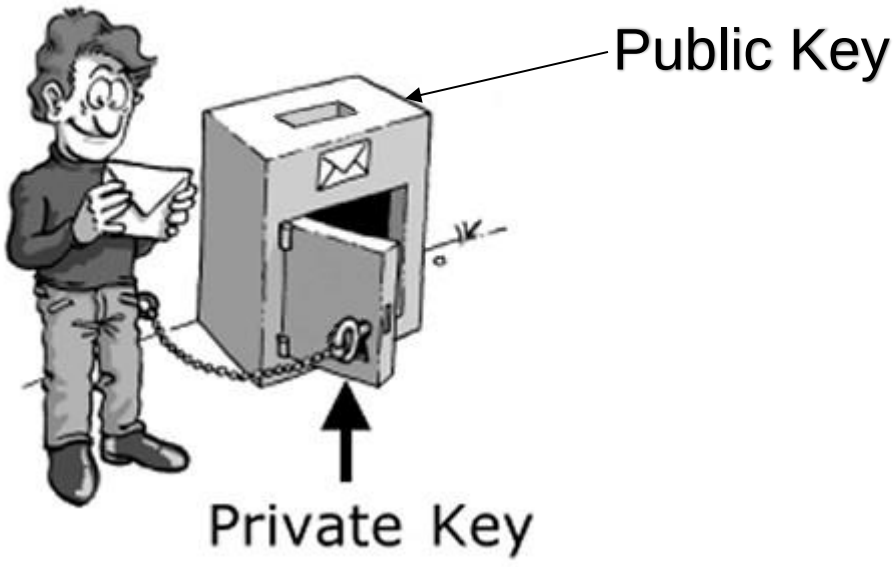

FIGURE 12. Public key and Private key comparison to mailbox (12)

The Public key and private key can be compared to the mailbox of a person in which the public key is the address of the mailbox where any person can insert a message or money into it but cannot retrieve from it. Only the private key, which in this case is the key to open the box, can help retrieve a message or money from the mailbox and is secured unless anyone have access to the private key. (12) (figure 12)

PKI in cryptography involves the first step of generating a private key which is basically a random mix of letters (A through F) and some numbers. When a private key is generated, its pair is also created using a complex algorithmic process which is called the public key. Even though the public key is generated from the private key, it is extremely difficult to figure out the private key from the public key and for this reason it is basically one directional in creation.

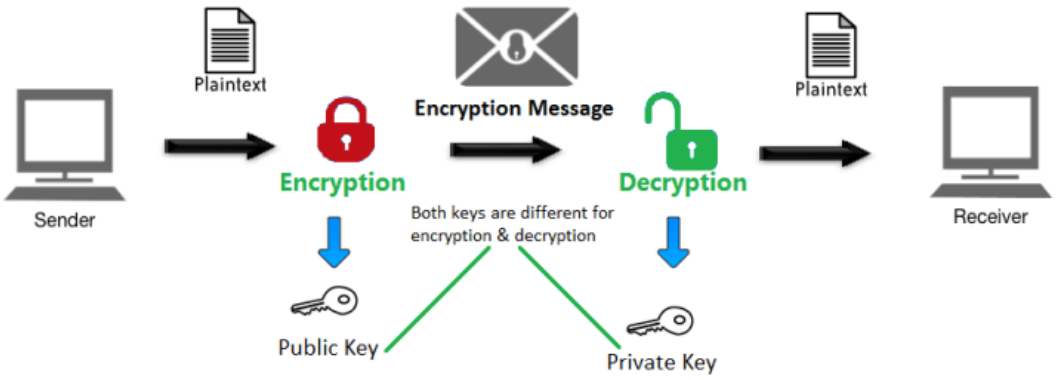

FIGURE 13. Sending message with PKI using private and public keys (13)

When something secret is sent between users, first, the public key of receiver needs to be sent to the sender who locks the message with the receiver's public key and sends the message. Then, the message is opened by the receiver using the private key. The message will be in a locked state if it is intercepted by a third party as it requires the private key to unlock which only the receiver has. In this way cryptography is enabled by PKI. (figure 13)

Digital Signature with PKI

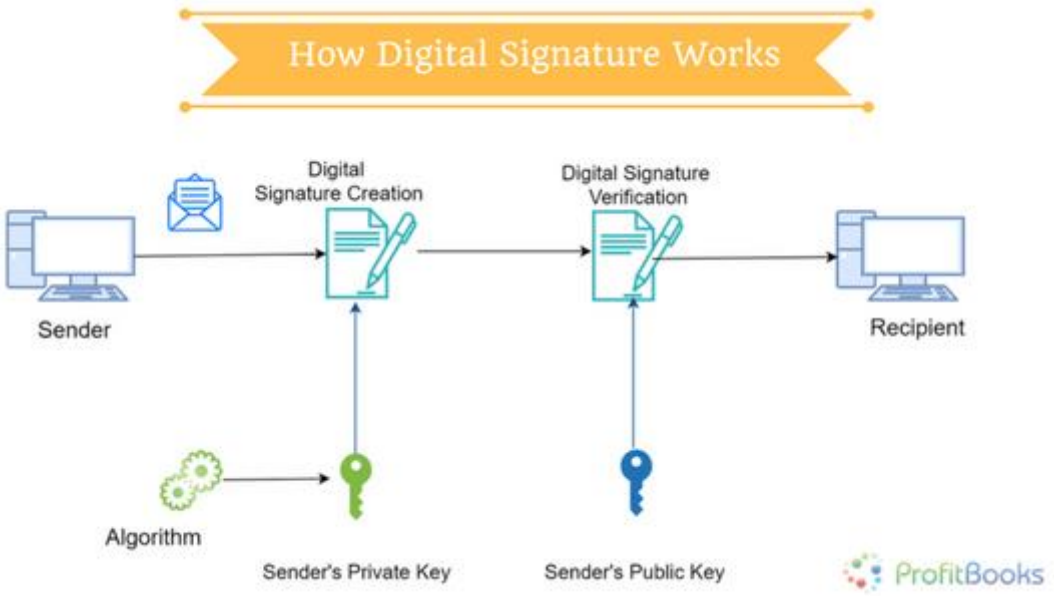

FIGURE 14. PKI based digital signature process (14)

PKI can also be used to enable the proof of authenticity which helps the receiver to identify specifically who the sender is and a digital signature is used for it. In ancient times, documents and letters were sent enclosed in envelopes which were often sealed with wax and a unique stamp on it. This would help the receiver identify that the document is sent from a trusted source and not been tampered with on its journey. Similarly, a digital signature is the digital version of the wax seal and stamp. Public and private key pairs are used to function as digital signatures. When an electronic message is sent, it is first signed with the private key of the sender and since the receiver has the sender's public key, it verifies that the signature was created with the private key pair of the sender. This PKI based digital signature helps authenticate that the sender is who they say they are as the public key of the sender needs a successful pairing with the sender's private key to verify. (figure 14)

Nonce

Nonce is defined as a number that is used only once for a specific purpose and never used again. One of its important uses is for digital transmission to reduce duplicate transactions which could be very dangerous and have negative consequences. When it comes to dealing with big data, there is always a high probability that the data entered into a database might have the same identifier and for this purpose, adding a nonce to some identifier makes it more unique, making it harder for an accidental duplication and helping transactions to be approved for adding to a blockchain database. (figure 15)

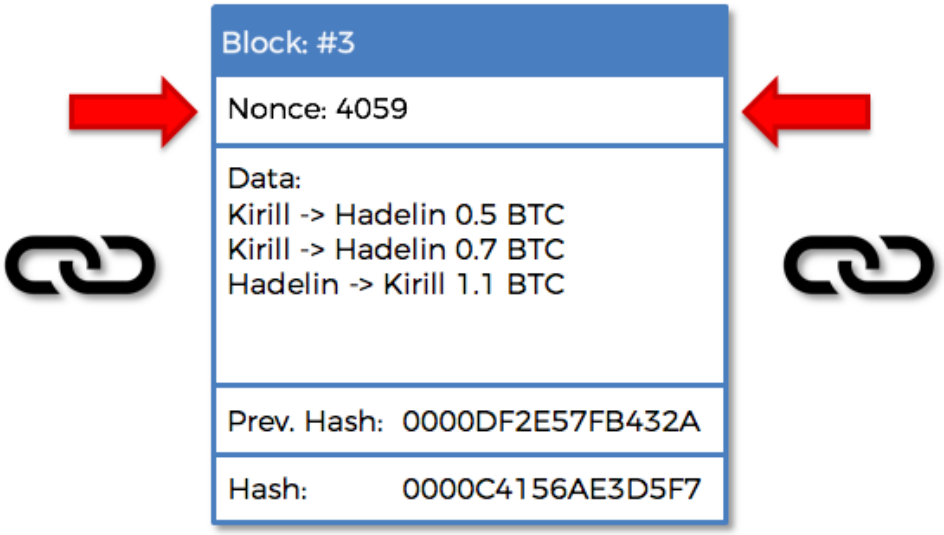

FIGURE 15. Example of nonce in a block of a blockchain (15)

Hash Functions

Hash functions are one of the most popular techniques used and it is basically a mathematical process in which it performs an operation on the data of any size and returns the hash, which is a fixed sized data. The returning hash is the same size regardless of the size of the original data. In other words, hashing is also known as the process of converting a string to a signature. It is one directional and thus, it is used for encryption as a hash function can take any length of string and return a fixed length output. However, the fixed length output cannot be taken to recreate the string. This process significantly helps in keeping a database small by storing only hash outputs in the database and reducing space requirements.

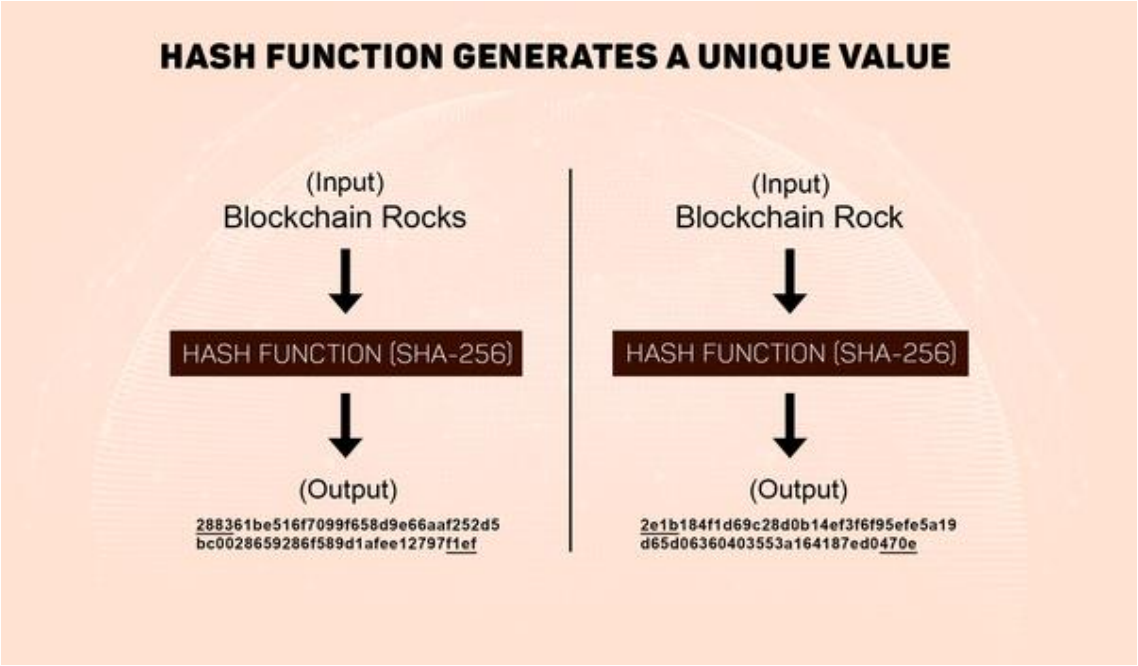

FIGURE 16. Example of hash function process with same input (16)

Hashing can be implemented for many purposes and one of them is that it creates a unique identifier. A hash with 64 characters and numbers create a very large number of combinations making it almost impossible to have a chance of duplication and for that reason hashes are used as identifiers for blocks, transactions and addresses in a blockchain. The hashing algorithms used in a blockchain are called SHA-256, in which SHA stands for Secure Hash Algorithm and generates a unique fixed sized 256-bit hash. (figure 16)

Mining

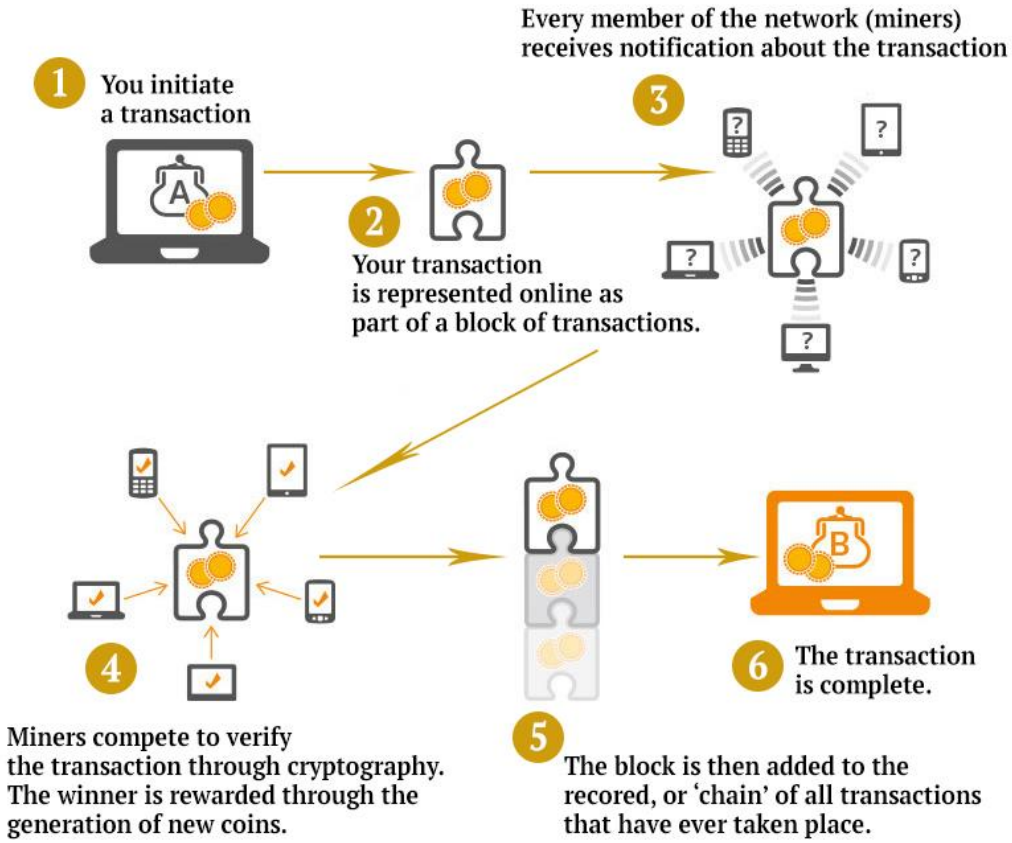

FIGURE 17. Mining process in a blockchain (17)

Traditionally, mining is the process of extracting valuable items, such as gold, coal or diamond and it requires a significant amount of resources in terms of money, tools, manpower and time. The value of the items depends on how hard they are to extract and process. Similarly, in a computer context, mining can be called as the process of solving complex mathematical problems for some reward by using the processing power of the computer consuming electricity to harvest the result. The more valuable the reward is, the more time and power is required to process data. (figure 17)

3 HEALTHCARE SYSTEM

3.1 Introduction

A healthcare system is a process of organizing healthcare in terms of finance, security, ease of access, data storage and retrieval. A healthcare system is dependent on available resources and the needs of public. A typical healthcare system comprises of the following bodies as illustrated in the diagram (figure 18) below:

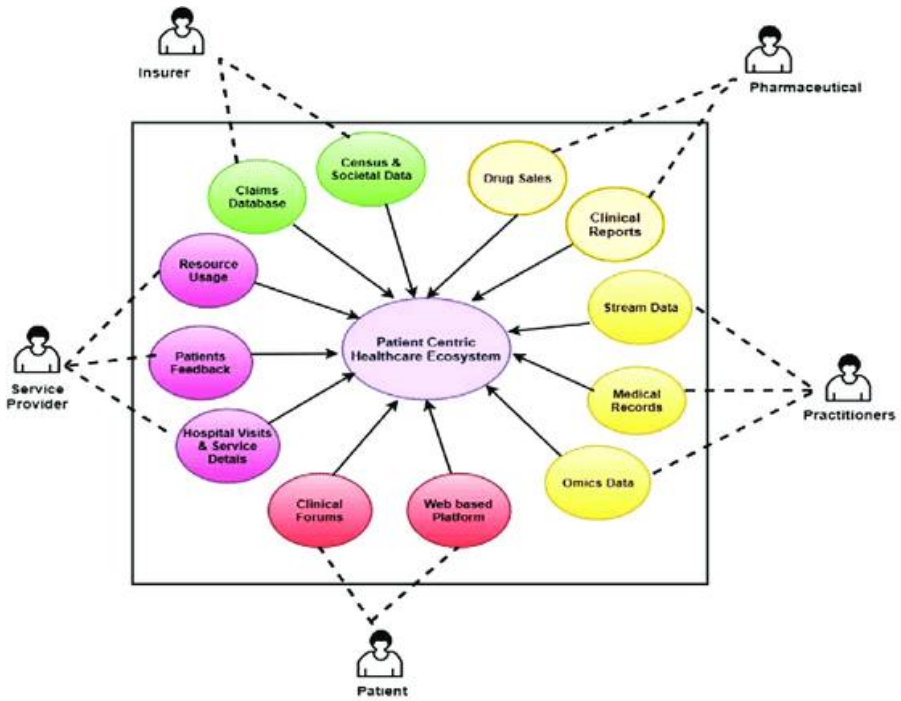

FIGURE 18. A typical healthcare ecosystem in terms of data (18)

- **Providers**: Providers in healthcare industry are generally the institutions and staff who serve to public. Doctors, nurses, hospitals, clinics and pharmacies are few examples of healthcare providers.
- **Patients**: Patients are the end users in healthcare industry and take advantage of the services provided in the public or private sector.
- **Insurers**: The modern healthcare system consists of insuring companies making payments on behalf of the patients covering various or limited costs to expenditures involved in healthcare.

- **Employers**: Generally, health insurance for an employed person is covered by his/her employer either as a small part of the salary or benefit from the work itself.

The primary goal of any healthcare system has always been maintaining a healthy population in the most effective way. A healthcare system is basically dependent on various factors, such as country's level of development, cultures and society. Some are more focused on preventing diseases whereas some put more emphasis on the care or cure of the diseases.

3.2 Public vs Private Healthcare

3.2.1 Public Healthcare System

FIGURE 19. Public Healthcare Services (19)

- Public healthcare is funded by the government and makes sure that everyone has access to basic health services.

- The providers of public healthcare system are not motivated by the profit generation but are driven by patient care and job satisfaction.
- Medical costs are highly subsidised.
- The health status of the public is monitored to identify and solve community health issues. (figure 19)
- Health policies are developed and planned to make the community health more efficient and hazard free. (figure 19)
- Data is used for researching new and innovative solutions to public health problems.
- Depending on the health issue of the patient, the treatment is distinguished either in a primary or specialised health care.

3.2.2 Private Healthcare System

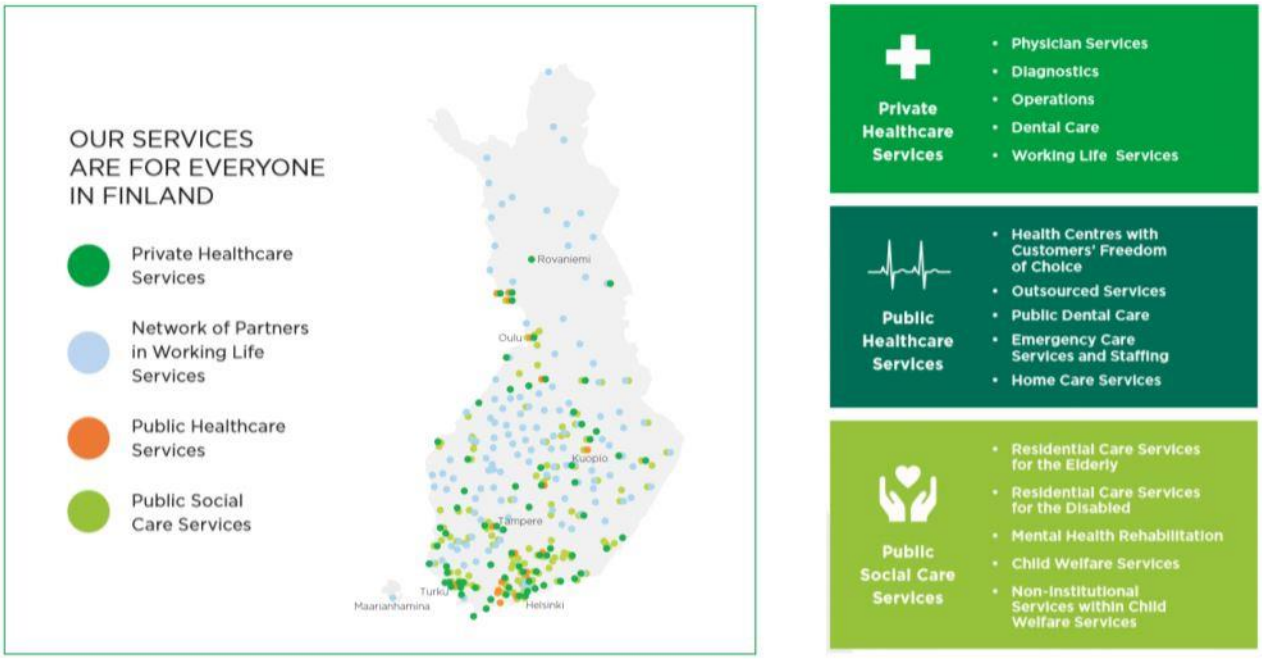

FIGURE 20. Private Healthcare Services comparison (20)

- Private healthcare supplements the public services.
- Services could be sold to municipalities, authorities or directly to patients.
- Covers estimated 25% of the healthcare services.
- Most services are carried out in urban areas. (figure 20)

- More expensive than public healthcare services.
- Greater choice of treatment for patients.
- Some portion of the medical expenses could be reimbursed by social organizations, e.g. Kela in Finland.
- Some common examples: physiotherapy services, consultations with doctors, dentists and occupational therapists. (figure 20)

3.3 Financing

Generally, a healthcare system is financed by two sources which are municipalities fund and the National Health Insurance (NHI). Municipalities fund is used to finance primary healthcare services to the public. They are based on taxes. Municipalities also possess rights to collect fees and receive state subsidies.

NHI on the other hand is based on mandatory fees and primarily used to fund private healthcare services, occupational therapies and sickness allowance. It includes the coverage of family benefits, housing benefits, financial aid for students and state guaranteed pensions. (21)

3.4 Information Technology in Healthcare

Information technology has been an integral part of various organizations in different fields and healthcare is no different. The technological advancement has come leaps and bounds than what it was few centuries ago. This section particularly describes current situation in healthcare industry regarding use of information technology across computerized systems to make sure health information are exchanged between consumers, providers and payers securely. (22)

3.4.1 Electronic Health Record (EHR)

Introduction

Electronic Health Record or EHR can be defined as the electronically storage of an individual's healthcare information in a digital format. This information could be e.g. patient's general healthcare information, signs and symptoms, diseases from the past and present. Each EHR of a patient could contain vital information such as an overview of patient's general health, administrative information and legal documents. (figure 21)

FIGURE 21. EHR illustration (23)

- **Health Information**
  Various clinical information of patient such as medication lists, pathology reports, surgical reports, hospital reports and progress reports, could be stored electronically in EHR making it simple and efficient to update, remove or add the records.

- **Administrative Information**
  Administration information of a patient is also an important information required for present as well as future diagnosis or treatments. Patient Information Form (PIF), insurance information, billing address, appointment history and contact information are few examples.
- **Legal Documents**
  An EHR also contains information regarding legal documents, such as consent agreements, authorization forms and records release.

Documenters

Documenters of the medical records are the authorized individuals who are responsible for inputting the information into systems. Over the years, the role has changed and at present, the main people responsible for such an important task are:

- Doctors or Physicians who treat patients
- Medical assistants
- Medical billers
- Receptionists

Ownership

The ownership of EHR is defined as the rights of an individual to own the medical information. Typically, the medical records are owned by the authority or organization who created them whereas physicians own the physical record. However, a patient can also have access to his or her medical records as a copy. They could also be charged some administrative fees.

Drawbacks of EHR Systems

EHR is a costly system to implement and adopt as it involves various expenses, such as maintenance cost, purchasing and installing hardware and software and training cost too. Even though setup and installation costs have

dramatically decreased over the years, it is still a costly procedure to implement and maintain. EHR can have a bad effect on productivity as it could disrupt workflows of staff and service providers as they need to be trained beforehand and the first few months could have some loss in revenue.

Privacy of patients information is also an issue of concern with the use of EHR systems as data is electronically exchanged in a wide range. Because of this, many legislations have been introduced for safe access of data and strict penalties for staff and providers who inappropriately use them. A medical error is also a great possibility as data is stored, updated or deleted regularly by staff and providers which increase the chance of error in the database. Doctors and physicians could find it difficult when making decisions on tests and medications as EHR systems might limit their autonomy in decision making concerning the patients.

Implementation time could also be a disadvantage as the whole procedure of setup and initiation could consume a significant amount of time and energy. Patients' health records might not be available if a different EHR system is used by the hospital than that of patient's primary care physicians or vice versa. A data breach is also a major issue of concern when the EHR system is used because an unauthorized user or hacker could gain access to the database resulting fatal consequences with patient's privacy and identity. The data breach could also occur unintentionally if a staff loses or misplaces an electronic device resulting data to be transmitted over an unsecured network. A system failure, although occurs rarely, could have a potentially dangerous outcome halting operations of the organization. Cloud backups are normally the solution for the data loss and system failure but also doors are opened for hackers to gain access.

4 HEALTHCARE SYSTEM AND BLOCKCHAIN TECHNOLOGY

4.1 Blockchain in use at Healthcare

Blockchain Technology has already been applied to some of the areas of medical field and in a particular region though the implementation has to be worldwide to make sure that the connectivity and data retrieval is as efficient and secure as possible. Some of the blockchain implementation already in use in varying medical systems are mentioned below:

- Medicine related data is already being stored with a blockchain making it more secure.
- Various software providers have been involved in the healthcare market.
- Some of the medicine manufacturing processes and controls already use the blockchain technology by recording and storing the parameters and delivering products and shipment with automated decisions.
- Use of Smart Contracts is already in place to determine the stability of the medical product by logging the temperature history of the products by tracking it throughout the supply chain across warehouse, shipment and dispensing.
- File transfers during medical trials.
- Patient data storage and maintenance with a blockchain network.

Although, the above mentioned applications of blockchain applied in healthcare industry in the current situation are limited, there needs to be a wide use of this technology, and with collaboration amongst many healthcare systems across the globe, to bring out the full potential of this ever growing technology. (24)

4.2 Prospects of Blockchain Technology in Healthcare

Several start-up companies have been working and studying on the possibility of applying a blockchain technology in healthcare industry. This indicates that the future of this technology is growing and recognised. It is essential to make sure that it is applied in a wide scale and not just in a certain system. However, cloud technology has vastly improved over the years and it has come as a good news to blockchain enthusiasts as a blockchain requires a vast amount of electricity to operate and a high-end cloud infrastructure can help eliminate this limitation of blockchain in the future.

The administrative burden could be minimized in terms of consent management of the patients by storing data exchange and privacy preferences on the blockchain making it possible for all medical personnel to access from any place. Micropayments through a blockchain provide a universal interface to patients during several stages of the diagnosis to make sure that data and transactions are co-related, which would minimize the burden of healthcare staff. Many companies have already started working on a simple to use programming interface and hiding the blockchain complexity, which would significantly increase the transaction speed. More stakeholders have been educated about advantages and disadvantages of the blockchain and its applications. This would increase the chance of blockchain implementation in a large scale in the future. (25)

4.3 COVID-19 Global Pandemic

Since this thesis concerns healthcare industry and considering the current situation with coronavirus pandemic across the world, some of the ideas to help this industry, staffs, governing bodies and Police have been mentioned in this section which may or may not be related to the thesis topic completely.

4.3.1 Mobile Application for Public

Note: During the writing process, similar application have been in discussion in countries like Germany and some sort of implementation are already in action in Singapore and South Korea.

A simple mobile application for both Android and iOS could be developed for general public in collaboration with Finnish Institute for Health and Welfare (THL) as well as government. The purpose of this application would be to let people know about their surrounding situation concerning COVID-19 through real time location tracking and check the health status of people around from ease of the phone although the identity and personal information would not be visible to other users. This would make people get involved in resolving current situation or at least minimize and not just look at the stats of contracted and deceased people.

Features:

- User is logged in with his/her Social Security Number to prevent duplication.
- User is able to update his/her current health status with suitable emoji (Example: Confirmed Tested Positive / Confirmed Tested Negative / Mild Symptoms / Moderate Symptoms / Serious Symptoms / Post Recovery Quarantine / Precautionary Quarantine)

- The maps API would be used to track the real time location of all users with a map interface on the application showing other users nearby and their health status.
- The location history of the user is stored using a blockchain which is not changeable, and this would help Health Administrators or Police to track the previous location of a newly tested positive patient and other users with whom the patient was in close contact with. At the moment, this is done manually. This gives a lot of burden to hardworking officials and it is time consuming as well.
- This app would also help public distance themselves from other vulnerable users by checking the status just as a precautionary measure.

A global pandemic is not a new thing for this world and it has been coming occasionally for several thousand years and some minor in every decades. This kind of application could be made unavailable when the pandemic ends completely and again be in use in the future in similar situations with improvements and people's safety in mind. Though, blockchain technology implementation in developing this product gives assured security, e.g. immutability of data and tracking right from the first block within a chain. It is difficult to develop it during a pandemic as it requires a vast amount of resources, manpower and some form of transparency which seem to be not approved by officials. So, for this reason, this application could also be developed in traditional database systems with far less technical staff and resources with a quick delivery.

5 CONCLUSION

The blockchain technology has always been in hype but never excelled with many different reasons and restrictions to make systems decentralized. General public are only aware of “Bitcoin” as an application of blockchain but this technology has far more capabilities to enhance every sector or industry and healthcare is one of the most important service sector for any country.

Not only the clear picture of problems in healthcare are understood through this research but also new terms and technological advancements and what they can do for the public and avoid crimes by not giving opportunities to exploit.

When a new invention or technology comes, there is certainly a hesitation to use it, so for this purpose this research has been made to know exactly how this technology works, its applications and what dangerous threats it can abolish in healthcare.

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