

1.1 What is blockchain? A view through Bitcoin and Ethereum

Bitcoin is the parent of blockchain, blockchain is one of the technology underlining bitcoin.

It's the database that stores transactions. It is the public ledger that contain the list of all transactions that happened. It's a decentralized replicated database.

5 Characteristics of the Bitcoin blockchain

1) open

Anyone can access it, participate on it, and innovate on it without asking full permission

2) borderless

Like the internet, there is no border. It doesn't see distinctions between countries.

3) neutral

It doesn't care if the participant is male or female, old, young or any other characteristics. The protocol doesn't care, it's neutral, it just validate the transaction.

4) Decentralized

There is not central point of control

5) Censorship resistant

Cannot censor or freeze transactions

Characteristics of Ethereum blockchain

Using the public ledger feature of blockchain, instead of money, like in bitcoin, we use it to run computer programs (=decentralized applications) that run everywhere and their results are recorded in a way that's immutable and trustworthy by all participants. It is Global, secure and decentralized computation (it's not money in this case).

It allows you to run smart contracts. The idea is taking contractual arrangements (commercial or transactional law), and encode the relationships and obligations in the software programs.

Normally you would write it in human spoken language, but instead you code it in software language. And then execute that legal program on a global platform. Again, it's not money, but money is part of this system of trust.

Other applications of blockchain

Blockchain can be used to register assets, the ownership of tangible or intangible things such as titles over land, or assets like homes. The point is that once recorded on blockchain, the system of trust stops people from changing it. There is no falsification possible. In the traditional system, if you own land, somebody can make paper falsification (by bribing someone at the local registry office for example) and steal it from you. Blockchain stops that.

Blockchain also offers another registration and access to assets: title of car, boat or plane on the blockchain. For example you can record maintenance records and parts through the blockchain so they cannot be modified. So if planes crash, you can go back to the maintenance record and check if everything was correctly inspected, was the jet engine fine? In paper form, people can change date and time. In blockchain, you cannot. These same mechanism used in this trustless systems, can be used for money or transparency in permanent immutable record.

How does bitcoin blockchain run?

People providing network security are rewarded in bitcoin, the currency. They are the miners. The bitcoin currency is not just a vehicle for transferring value, it also allows the foundation for the security mechanism. This permits the blockchain operation and security by anonymous participants. These participants will claim to provide security in exchange for their energy. So they are running these powerful computer mining programs that cost space, electricity and acquiring cost itself of these electronic devices. Currently based on the mining pools data, it's estimated that around 81% of the network is located in China where electricity cost is low.

So every bitcoin transaction is a very complicated problem (the complexity scales with the number of people mining it, the more people, the harder it gets, therefore better processing power you need) and everyone on the network tries to solve it, and once it's solved you get your reward in bitcoin. It's the confirmation of blocks of transaction. The more confirmations, the more solid the transaction is. The point is that nobody can cheat because somebody will find out with different confirmation of this, people have incentives to do it correctly to gain mining reward in bitcoin. This allows to have a ledger managed by everyone, where no one is in charge.

This system of reward is a mechanism of punishment. If there is no system of punishment, there is no security. Blockchains use a currency because their system of security is based on market

	MINER 2 DISHONEST	MINER 2 HONEST
MINER 1 DISHONEST	0,0	0,12.5
MINER 1 HONEST	12.5,0	12.5,12.5

forces, on game theory.

There is incentive to be honest. Key aspect is rewards are only recognized on the longest chain: meaning that if you somehow cheated your block and it invalidates one of the followers, your

rewards are gone.

Blockchain and common database

The problem is that the traditional institutions want to assign trust another way. For example they chose a specific institution who will have the task to validate every block on the blockchain therefore making it a private blockchain, where they control and assign who has access. In that case it's just business-as-usual, it's all centralized. In order to trust that blockchain, you need to trust these institutions. It is blockchain by name but the trust is centralized.

It's different in bitcoin blockchain where the miners (who take care of trust) are all around the world. You know it's easier to trust because it doesn't rest in the hands of only a few people or

groups but in a wide number all across the globe with different interest (however, many mining plants are in China). This make whole difference between blockchain and database.

1.2 What is Healthcare industry

Healthcare industry consists of all economic products and services that allow curing, preventing, rehabilitating, and palliating patients. Healthcare industry in modern society is divided into many sectors to satisfy people's need in health. It is one of the largest and fastest growing industry in the world.

The United Nations categorizes healthcare industry into followings:

1. Hospital activities
2. Medical and dental practice activities
3. Other human health activities (nurses, physiotherapists, scientific or diagnostic laboratories, or any other health professions)

Healthcare industry also involves healthcare equipment, pharmaceuticals, biotechnology and related life sciences. It is possible to include any related business such as education and training of professionals, related laws, and insurance. Everyday there are millions of people purchasing these products and services directly or indirectly and the amount of data generated from these activities are enormous but the data exchange between practices are still very limited.

2.1 Blockchain in healthcare industry

Future potential of blockchain technology in healthcare industry is huge. Currently the revenue of such industry is approximately calculated to be \$34 million and professionals predict the value to jump to \$1415 million by 2024. Many suggest the importance and potential of blockchain in healthcare industry and here are the factors why it makes such industry promising in present and future society.

Blockchain characteristic applied to healthcare industry

1. Decentralized system

Decentralized system of block chain offers healthcare industry data to be almost immune to hacking and the data stored in the system are prevented from being compromised. Once servers and computers are registered in this decentralized system, it will eliminate all human-made errors and unavoidable disasters that were inevitable previously by providing foolproof security. The system also allows the researchers and laboratory workers to gather bigger size of data to make more accurate and convoluted calculations to help finding cures and drugs, leading into finding the optimal treatment for diseases and disorders that were regarded as incurable.

2. Monitor and access of data for 24/7

Blockchain for healthcare can be used to record personal health level with using wearable equipment to have same effect of having 24-hour nursery in care units by storing and updating data such as blood pressure and sugar level. It will allow the patients to have remote watch from the doctors and alert patients when are at high risk and assist promptly and fast in emergency.

3. Cost effectiveness

Blockchain technology completely substitutes the need of third party or mediator systems who collect and transfer data in current system. Healthcare industry will be more cost effective by eliminating this middle step of the system.

4. Consistent rules through smart contract

By adapting blockchain technology, healthcare industry is also allowed with smart contracts where computer protocol and algorithms assist verifying, facilitating and enforcing negotiations between different parties. In healthcare industry, development of a consistent rule-based process for various organizations will assist in accessing patient's data more promptly.

2.2 What is healthcare data management?

Healthcare data management is the process of storing, protecting, and analyzing data pulled from diverse sources. Managing the wealth of available healthcare data allows health systems to create holistic views of patients, personalize treatments, improve communication, and enhance health outcomes.

The healthcare sector is a problem-driven, data- and personnel-intensive domain where the ability to access, edit and trust the data emerging from its activities are critical for the operations of the sector as a whole. If we divide the operations within the healthcare sector into triage, health problem-solving, clinical decision-making, realization and assessment of knowledge-based care, then achieving the desired health outcomes hinges on engaging a multidisciplinary team of health personnel that apply the most appropriate knowledge, technologies and skills when dealing with the patient. Improved healthcare data management will hugely support that purpose.

To both maintain the patient's privacy and exchange data with other institutions in the healthcare ecosystem, access control, data integrity and interoperability are crucial. The traditional way of achieving access control commonly assumes trust between the owner of the data and the entities storing them. These entities are often servers fully entrusted for defining and enforcing access control policies. Healthcare institutions currently experience an increased demand of real-world data from industry and research organizations. At the same time, unauthorized sharing, and highly publicized break-ins and robbery of sensitive data constantly erode the public trust in healthcare institutions.

2.3 Why Blockchain fits Healthcare data management?

There's a very complex ecosystem that exists in healthcare, and you've got competition where you really need transparency, where data is thought of as currency, and you've got a lot of cybersecurity issues. Healthcare industry would benefit from blockchain—creating complete and portable medical records that connect all the disparate pieces in a patient's health history. A patient's health record today is often incomplete, divided into pieces sitting in doctor's offices and hospitals whose computer systems don't speak with each other. In theory, blockchain could be used to keep track of where those pieces of the health record are, so patients and doctors with permission could easily access them and have a full view of the patient's history.

The use of blockchain technology in healthcare is also advantageous because maintaining a typical healthcare information system involves many different types of operations such as, among many others, having recovery mechanisms in place, ability to do backup storage services, and continuously updated information's. Blockchain ensure these operations efficiently. When looking inside a blockchain, data is distributed all across the network, therefore there is no single

point of failure which would require backup mechanism. In addition, once the blockchain is smoothly connected and running, all the data is continuously updated. Another important point is finally patient can control their data access, anonymity and security in a more efficient way. They can also gain ownership on this precious data if they own their private key. They can also benefit from reward mechanisms built-in the blockchain.

3 Blockchain for HDM : A View through entrepreneur eyes

We saw that blockchain seems to be a good a good idea for HDM because it can solve some issue about data sharing and data transparency most notably. We can assume there is a problem to solve and a demand for that problem to be solved. Now let's take a more in-depth analysis of how will that idea fit the realm of entrepreneurship: Who's involved and what are the benefits of blockchain compared to the traditional database?

3.1 Stakeholder's analysis

Hospital: They are gathering this data through the patient coming to the hospital. They are also consulting this data to keep track of patient evolution or see their background. They want to have as much data access as possible and they might be willing to share the data depending on different factors such as hospital ownership (public or private) or the linkage with a university (research and education purpose) for example.

Researchers: They are using the data for research purpose, they will benefit from easier data access. They are working for different parties, like universities or pharmaceutical companies.

Pharmacy: When people come to the pharmacy, the medicines they are buying and all measures related to it are gathered. They also want access to the data, and might want to share it depending on the context. One of the purpose is optimization of inventory.

Doctors and health professionals: They are consulting this individual patient data to see the progression or to get information before taking action. They are also gathering some data every time they record what patient are saying and the reasons of their venue. They desire as much access as possible and are willing to share it, especially to other doctor's. The usage of the data is aimed to improve quality of treatment for patient and as a way to keep track of their evolution.

Pharmaceutical company: They are analyzing the data for R&D purpose, to see the effectiveness of a certain treatment and for assessing market trends (by seeing which medication, or which medical problem people are subject to). They again want as much access as possible but they don't want to share this data to other competitors. Monetary cost and benefits of the data is an important factor. They are one of the central stakeholder because they are the ones who need the biggest amount of data, and most recent one as well. The benefits of data is difficult to quantify but it's pretty huge because more data, and especially recent and updated patient data really make the difference in terms of competition against other companies. You can think about the development of the covid-19 vaccine: pharmaceutical companies with the very latest data concerning covid-19 patient have a tremendous advantage over other companies.

Data Analyst Company: These companies are either purchasing or collecting the data to refine it, analyze it and resell it. They benefit from a wider access but their business model would be threatened by the openness of the blockchain and they would need improve their competitive

advantage in terms of data analysis. They are also a big player because the nature of their business model require a lot of data, and that data must continuously be fresh and new.

Insurance company: They use healthcare data to model the pricing of their services when it comes to healthcare insurance. They greatly benefit from easy access to healthcare data.

Patients: The data is directly based on their health status and their behavior. They have concerns concerning its privacy. They are willing to give this data to the people who need it to help them. Blockchain database could allow them to gain the ownership of their data, and even sell it under certain circumstances and set rules and regulations. They also have to configure through their own wearable what is gathered and/or shared.

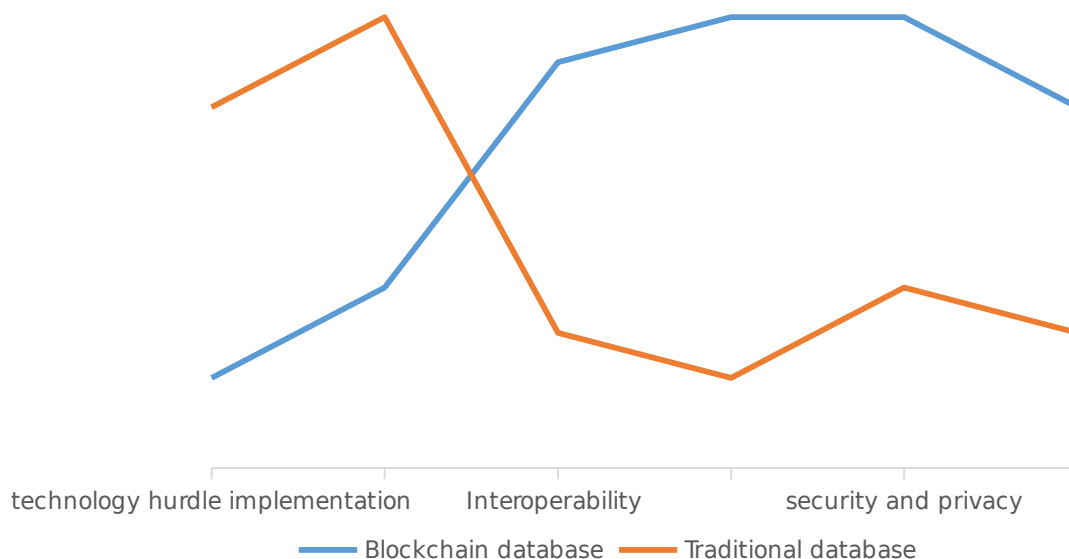
Companies selling wearables: These companies would play a role in the blockchain database if they connect their devices to the blockchain ecosystem.

Government: They are setting the rules for what's allowed or not in terms of data gathering and sharing between external parties. These rules can be different in function of the country where the data is gathered. They also want as much access as possible, especially concerning their own population. Blockchain database would be heavily influenced by government decision concerning privacy. One example is the right to be forgotten in General Data Protection Regulation (GDPR) from European Union. Fortunately, it is considered that 'private blockchains', for example, Enterprise Blockchain can easily comply with government directives since the transactions of the digital records of the stored information can be changed and erased by private entities or authorities who can own and control this platform, using a particular class of consensus algorithm. These private blockchains are run by a single company or organization, but they grant

access to users, typically organizations, that fulfill certain pre-established credentials or criteria in order to fix this issue.

3.2 Value curve analysis

We can compare traditional database systems, with blockchain based database, using value curve comparison in the healthcare data management. This will allow us to see the advantages and costs of blockchain based database.



Technology hurdle implementation: Blockchain based database is a recent technology and require some knowledge and specific people to set it up. As of 2020, more and more professional are able to design and configure them but it's still harder to find blockchain related professional compared to regular database professional. And even if implementation itself is sometime easier, conservative parties can still be reluctant because is still a relatively new technology. Speaking about diffusion of innovation, we still didn't pass the early adopter phase.

Wide ecosystem requirement: Unlike traditional database which doesn't require specific ecosystem, blockchain benefits cannot fully express themselves without it. The more people adopt the blockchain database, the bigger will its content and possibility will be. However this require a lot of collaboration between all the stakeholders, they would need to work together in the same direction even they are competitors (in case of pharmaceutical companies for example). There is also the central access permission question, who can access and at which price?

Interoperability: Interoperability is the ability to freely share information across blockchain systems. In a fully interoperable environment, if a user from another blockchain sends you something on your blockchain, you will be able to easily read, comprehend, and interact with or respond to it with little effort. Interoperability enable endless possibilities where synergies can be found for the benefits of both parties exchanging data. An example could be insurance companies and healthcare companies sharing their data. Interoperability is much more costly in the case of traditional database.

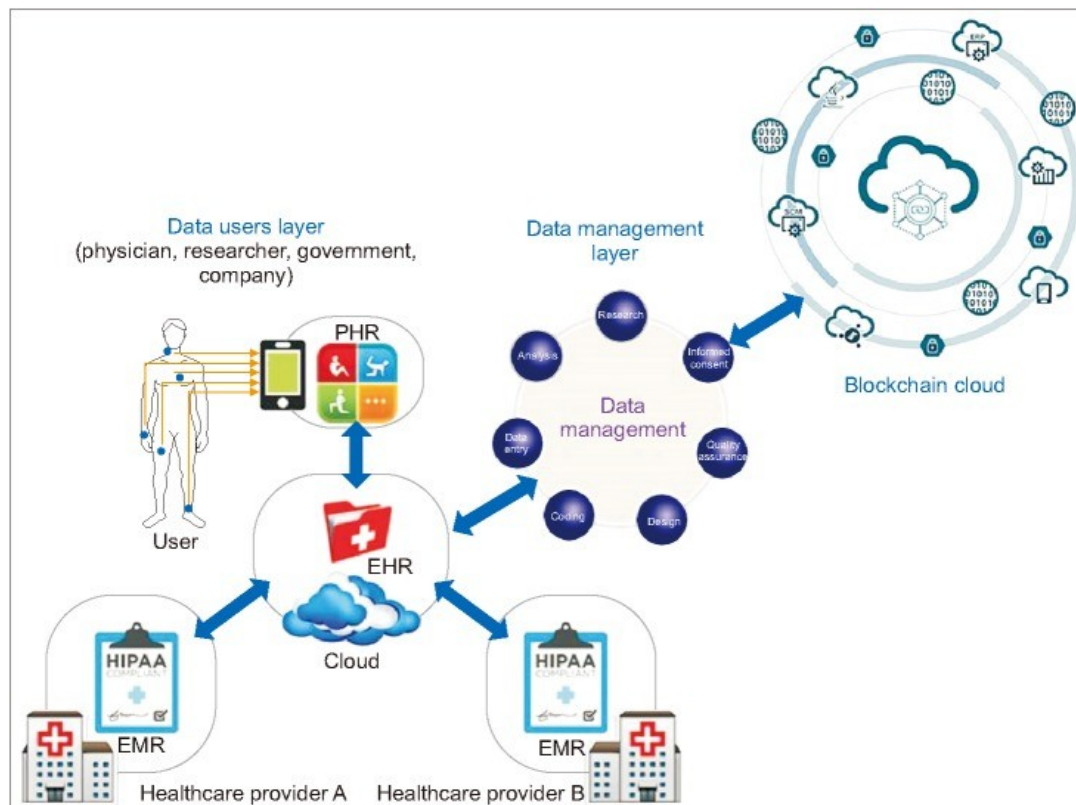
Transparent and immutable record: it's one of Blockchain database main strength. Availability of data is ensured and there is preservation and continuous availability of records. Data provenance can also be transparently shown. These parameters can be adjusted in function of the rules and regulations of the countries or industry. In addition blockchains enable data provenance: This add some value to the data going through the blockchain compared to non-blockchain data as it's reliable and you can legitimately see where it comes from. The origins of the assets are traceable (for example the sources of the data and records can be confirmed), increasing the reusability of verified data. On the other hand, traditional database can be easily modified without anyone knowing and data provenance is either missing or can't be reliably trusted.

Security and privacy: data is encrypted in blockchains and can only be decrypted with the patient's private key. Even if the network is infiltrated by a malicious party, there is no practical way to read patient data. Security breach can otherwise often happen in traditional database since that data is worth a lot of money and there is incentive to steal it.

Decentralization: Blockchains enable decentralized management; they are suitable for applications where healthcare stakeholders (e.g., hospitals, patients, payers, etc.) wish to collaborate with one another without the control of a central management intermediary. This will reduce costs for stakeholders and can speed up the sharing process. In the other case there must be an intermediary to ensure trust.

3.3 hurdles and viability of blockchain HDM in entrepreneurship

All means of data collection (hospitals, health professional, pharmacies, wearable, etc...) would



be linked to a cloud database and the data would be first be centralized there in order to be connected to blockchain cloud through a data management layer. It's important to note that the data wouldn't be on the blockchain directly. We talk about commitment to the data which is a cryptographic term. It refers to the idea of having loads of data that you can compress into a short string that will bind to the data, you will find that string on the blockchain, but not the data itself. There is different ways to reward users sharing their data. One way is Federated learning: everybody keep their own data locally but there is a protocol running all among us that use our federated data to produce a machine learning model. With federated learning, people can be rewarded with the difference in result between two learning model, one with all the data, and one with all the data except their own, the bigger the difference, the better the reward. The more valuable my data is for the machine learning algorithm, the more I get compensated. Therefore individuals could benefits from and data collecting companies would have incentives to share their data and be greatly rewarded for it.

Hurdles

As said before the main problem is finding common ground and collaborating between stakeholders so that everyone can find incentive in using the blockchain instead of staying away from it, missing on some of the value. Who will have permission of access? At which cost? There is also a need to set rules for modifying or not the data, or under which circumstance that can be done. There is many technical aspects on how the blockchain is used and connected into the ecosystem. As of now, in the healthcare industry, there are no established rules that guide the usage of blockchain technology. Furthermore, with the privacy regulations such as HIPAA act, it's uncertain how the new rules & regulations will be incorporated. One of the biggest problem blockchain based healthcare data business would face is starting to get the data. They only

become attractive to other stakeholders once they have a lot of data to sell or share as big amounts of data are exponentially more powerful and useful compared to small amounts. The biggest hurdle could be that starting point where they need to convince the stakeholders who have or produce data to be part of this project. But once they have more hospitals, Data Companies, etc... being part of the ecosystem, the value proposition becomes more attractive to other external parties.

Business model: how to incentivize people to use Blockchain base healthcare data?

There would be 2 tokens: 1 for monetary purpose (moneytoken) and 1 other for all the services linked to the data itself (datatoken). You need to get moneytoken in order to buy datatoken which will enable you data access. Each patient will be rewarded in datatoken based on their contribution to the network through wearable data gathering for example. Medical practitioner will also be rewarded with datatoken when creating medical records. Same goes for hospitals and pharmacies who can add their data to the network. These datatoken can be used to get more data, or they can be exchanged against moneytoken in order to be sold for real money. Bigger data companies can also supply data and be rewarded as long there is demand for this data from other stakeholders. Data provenance and data reliability is well ensured when it comes from patient directly, or also hospital, pharmacy and health professionals. On the other hand data companies would need to provide warranty that their data is reliable in term of data provenance. So this business model would start very slowly but once it's running and has gathered a lot of data, it can be dominant thanks to the characteristic of the blockchain, such as interoperability and data transparency.

Source:

<https://www.youtube.com/watch?v=uFIJ6OEJ1Qs>

<https://www.youtube.com/watch?v=i9nUMvpT2rM>

<https://www.youtube.com/watch?v=h5gBfXbN4CE>

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