Blockchain Technologies in Healthcare: Patient Access Records

1. Introduction

The US healthcare sector alone loses out on more than 300 billion dollars every year through poor data integration (Donato, 2016). The issue is related to fragmented, slow access to medical data; system interoperability; patient agency; improved data quality and quantity for medical research. Emerging technologies could be used to enhance the profitability and efficiency of this industry. These issues are explained by a case study white paper of 2016. This case study, named MedRec, delves into the utilization of blockchain for managing access and permissions in medical data. We will analyse this paper through three dimensions: accessibility (fragmentation and interoperability), security, and scalability. In addition, we will consider the context of the Estonian healthcare system and examine how it addresses these dimensions. We will then give recommendations and critically review how to implement these changes, drawing insights from both the MedRec case study and the Estonian healthcare system.

2. Accessibility

The national library of medicine defines three diverse types of interoperability: foundational, where one system can receive data without interpreting it; structural, allowing data exchange with interpretation at the data field level; and semantic, the highest level enabling meaningful use of exchanged information between two or more systems (Reisman, 2017).

The integration of blockchain technologies into Electronic Health Records (EHR) presents numerous advantages over traditional methods, particularly in facilitating data sharing across healthcare providers. Interoperability is recognised as a critical aspect of EHR for several reasons, including ensuring prompt and smooth access to patient information, preventing manual errors, improving the efficiency of healthcare providers, and reducing national healthcare costs (Yates, 2020). However, achieving interoperability is inherently complex.

The existence of hundreds of governments certified EHR products, each with distinct specifications, complicates the establishment of a standard interoperability format. Most of the time, EHR systems are tailored to suit an organization's preferences. This leads to problems because even systems built on the same platform face interoperability issues due to customization based on organizational preferences (Reisman, 2017). In response to these challenges, healthcare providers resort to outsourcing systems to use on the blockchain to create more decentralised platforms for data sharing locally (e-Estonia, 2017).

For instance, Estonia and its neighbouring country, Finland, utilise the X-Road trust federation, an open-source software solution ensuring unified and secure data exchange between organisations. This collaborative approach emphasises the significance of interoperability in healthcare systems, enabling seamless data sharing across borders (Observatory of Public Sector Innovation, n.d.). Moreover, MedRec employs a modular design that integrates with providers' existing local data storage solutions, enhancing interoperability and making the system convenient and adaptable (Ekblaw et al., 2016). This approach reflects a commitment to addressing the challenges of data sharing and promoting interoperability in healthcare.

3. Security

MedRec is based on the distributed ledger characteristics of blockchain, which endow it with a robust failover capability, especially in addressing the issue of single-point failures. However, this does not imply that MedRec is perfect in terms of security. Below, we will analyse the advantages, challenges, solutions, and feasibility of MedRec.

As MedRec's mining proposed by Ekblaw et al. (2016), MedRec involves medical researchers and healthcare stakeholders in the system as miners. They receive requests from patients and senders/providers, granting access, and in return, they receive anonymous medical data as mining rewards. MedRec provides a sustainable approach for blockchain in the healthcare sector. On one hand, it can attract a considerable number of miners. For example, in the United States in 2023, there are over 20,500 healthcare organizations and programs, including 6,129 hospitals and 919,649 hospital staff, as well as large organizations like International professional societies, which have around 40,000 healthcare executives (Phillips, 2023; American Hospital Association, 2023). On the other hand, it positively benefits medical researchers and healthcare stakeholders by providing them with real and trustworthy medical data, helping them achieve precise and targeted medical research.

However, this paper questions the decision to limit the list of miners to only medical researchers and healthcare stakeholders, which indirectly restricts the number of miners and has a negative impact on the decentralisation and security of the MedRec blockchain. Since mining rewards are in the form of anonymous medical data rather than direct token rewards, and the obtained medical data is subject to external regulations (such as HIPAA), miners should only copy or access the minimum necessary information. This indirectly reduces the commercial value of the data, further diminishing the interest of individuals in the role of MedRec miners. For blockchain, the number of miners is an important criterion for assessing the security of the chain. Additionally, considering the reality that healthcare institutions are typically divided into private and public sectors, for example, in the UK, the ratio of private to public hospitals is approximately 1:4.27 (Soffe, 2023). Centralised institutions (such as the NHS) control around 81% of hospitals, which implies that MedRec is vulnerable to a 51% attack.

Furthermore, even though all medical data is anonymous, observers can still infer the geographic location, patient status, and even identity of an entity by analysing network traffic and frequency of interactions with another network entity. While Ekblaw et al. (2016) proposed an improvement using a "permissioned" blockchain structure where only pre-approved whitelist members have the right to read and access the ledger, reducing the potential for malicious observers to analyse the data, it also moves the blockchain towards centralisation and increased opacity.

4. Scalability

One of the significant challenges in the blockchain realm is scalability, as an increasing number of participants contribute to a higher influx of information on the network. This leads to potential slowdowns and inefficiencies because of the network being slow and inefficient due to the high computational requirements needed to validate transactions. (Marr, 2023). In the healthcare sector, where daily generation of data, including patient records and diagnostic results, is prevalent, leveraging a blockchain-based system raises questions about how to optimise transaction processing speed and efficiency. This becomes crucial as the healthcare industry heavily relies on real-time data, and scalability challenges may impede processing times as the network expands over time.

MedRec provides a solution by implementing a Database Gatekeeper. This resolution involves accessing the local database of the node off-chain, with permissions regulated by the information stored on the blockchain. Off-chain transactions offer a significant layer on top of existing blockchains which simply improves the scalability while reducing transaction costs (Qin and Gervais, 2019). Apart from their speed, off-chain transactions also offer security by keeping transaction information confidential until it is finalised on the main chain. The Database Gatekeeper check if the data entered by the issuer matches the specifications outlined by the Patient Provider Contract (PPR). This contractual agreement would be between two nodes, which could be a patient and the doctor. It would give detail about the access permissions of the user. If these were to be executed on the provider's database, data about the patient would be returned. In this case, there would be two types of transactions. Data storage in the store (off-chain) and retrieval is considered as one type of transaction, and providing access to data for users or services is another type of transaction. (Jayabalan and N, 2022).

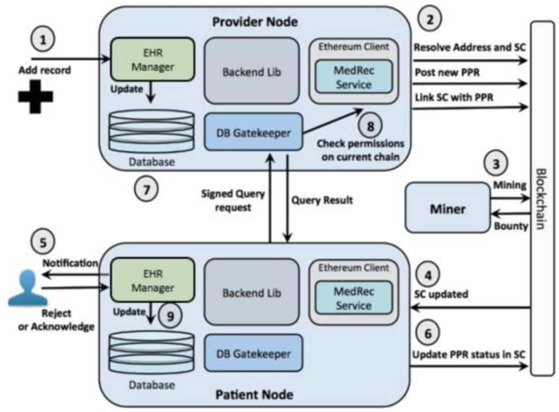

Figure 1, MedRec's implementation of blockchain in healthcare (Ekblaw et al., 2016)

In addition to being very scalable, it would therefore be possible to build APIs through this blockchain system to incorporate many various healthcare systems. Existing health systems all over the world are different due to the different combinations of components that can be considered for their establishment (Schütte, Marin Acevedo and Flahault, 2018). Given the global variance in healthcare frameworks adopted by different countries, utilising this blockchain infrastructure could enable the incorporation of diverse healthcare systems worldwide, promoting a more extensive and globally accessible network.

5. Recommendations

Both Estonia and MedRec, as proposed by Heston et al (2017) and Ekblaw et al (2016), present solutions for managing patient records on the blockchain. However, there is substantial room for improvement, particularly given the scale and critical nature of the database involved. Handling millions of data entries and adding to the dataset simultaneously can lead to conflicts. In addressing this scalability challenge, Praveen et al (2020) recommend employing horizontal partitioning of the database, commonly referred to as sharding. This approach aims to enhance scalability by distributing data across multiple nodes and reducing data volume. While sharding provides a significant advantage in addressing blockchain scalability issues, there are concerns related to accessing user data dispersed across multiple nodes. To mitigate this, master nodes can utilize techniques such as mapping and hashing to organise data into the relevant shard, thereby improving accessibility and minimising conflicts, as shown in figure 1.

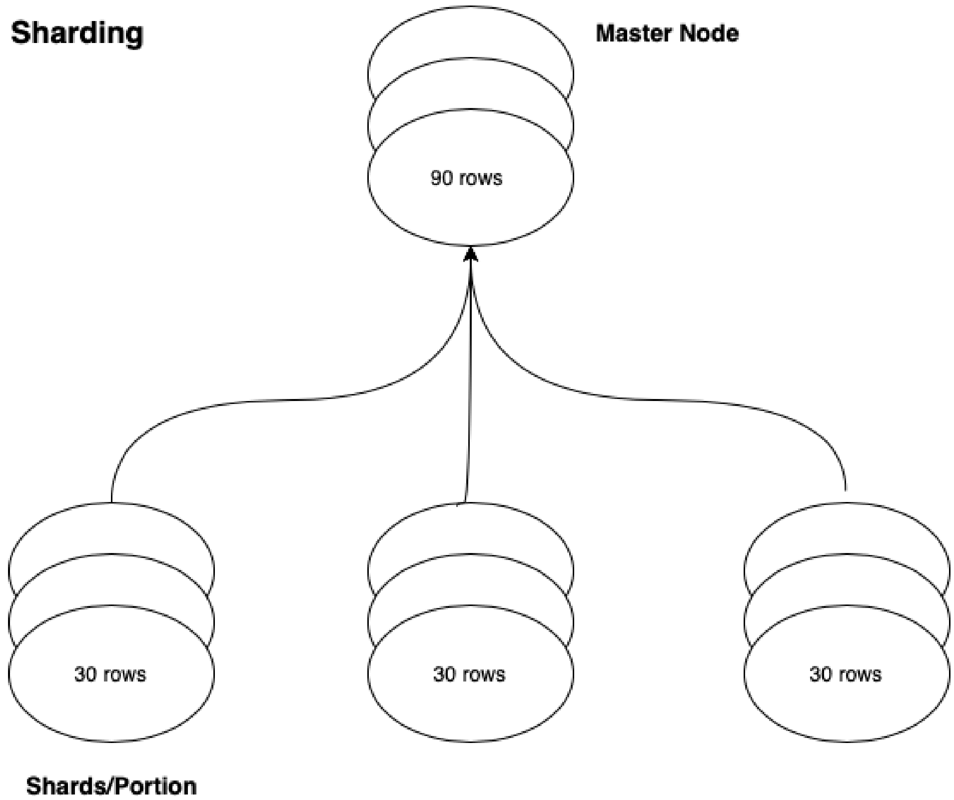

Figure 2, An example of how Sharding can help to increase the Scalability in the system.

In addressing the concerns surrounding identification and access to permissioned data within blockchain systems, Bai et al (2022) advocate for the incorporation of Zero-Knowledge Proof (ZKP) as a robust solution. The researchers emphasise that ZKP introduces a privacy-preserving mechanism, allowing users to validate their information securely without the necessity of disclosing sensitive details like private keys. This not only bolsters user privacy but also ensures a secure identification process within the system. Furthermore, Bai et al (2022) underscore a pivotal advantage of ZKP implementation—the reduction in the size of the dataset on the main blockchain. This reduction, as indicated by performance tests, enhances the scalability of the system, a critical aspect for blockchain platforms grappling with scalability challenges. Notably, the authors report that in the proposed system they were able to demonstrate that the throughput exceeded 400 transaction per second (TPS). This signifies the practical viability and efficiency of the proposed solution, highlighting its potential to significantly improve both privacy and scalability aspects in blockchain systems handling identification and permissioned data access. Figure 2 demonstrates one of the many examples of how ZKP can resolve the matter.

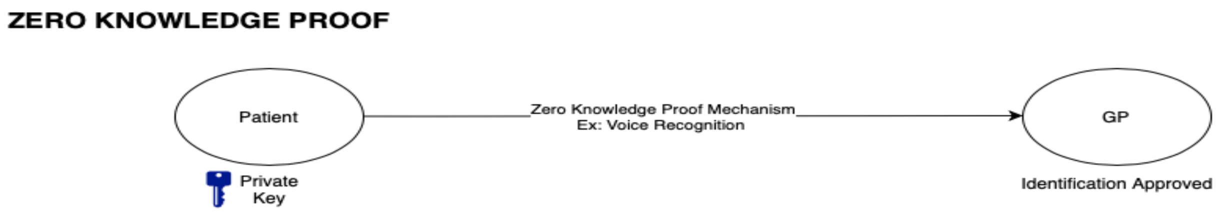

Figure 3, An example of how patients can benefit from ZKP to prove their identity to their GP.

Decentralised Autonomous Organisations (DAOs) operate based on predefined rules, devoid of central governance, presenting an opportunity to enhance organisational transparency (Mateus et al, 2023). DAOs utilise smart contracts to facilitate decision-making processes through voting on various aspects such as rules, regulations, and membership within the organisation. The introduction of DAOs has the potential to augment the decentralisation of systems. In healthcare, a sector facing challenges in achieving decentralisation, an obstacle lies in the substantial ratio of private to public hospitals. In the UK, approximately 1 in 5 hospital is private (Soffe et al, 2023). This significant imbalance can impact decision-making, with more than 51% of the network influenced by the public sector. DAOs offer a solution by allowing authorised personnel to vote and enact rules across the entire network without the need for central government approval. While concerns may arise about undue influence on critical decisions, it is crucial to note that any decision within the network necessitates the approval of at least 51% of the entire network, ensuring that influential decisions involve the consensus of a majority, including professionals in the field. Additionally, the professionals or authorities within the DAO can be selected democratically. DAOs provide the option to vote on the inclusion or removal of members, ensuring a transparent process that can be observed by all participants. This democratic approach ensures that decisions are made collectively and 8with visibility, fostering a system of governance that reflects the input and consensus of the participating professionals and authorities in the healthcare network.

6. Conclusion

To conclude, there are many challenges that the healthcare sector faces today. Solutions proposed in the MedRec case study such as blockchain technologies could help this field grow greatly. However, these emerging technologies do face challenges such as scalability or transparency issues. Off-chain transactions and sharding techniques are good solutions to increase scalability levels. DAO’s, avoiding central governance can also help enhance transparency as well as provide voting rights for participants. The challenge remains to allow these changes to take place on a global scale. The establishment of universally accepted frameworks and regulations can allow the healthcare industry to be international, allowing accessible collaboration, standardization, and improved patient care outcomes.

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