EXAMINING THE USE OF BLOCKCHAIN IN HEALTH AND CARE

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Abstract

Blockchain technology has the potential to revolutionize the healthcare industry by providing a secure, interoperable, and transparent platform for the storage and sharing of patient data in a decentralized manner. By its ability to create a peer to peer, decentralized, highly encrypted, tamper-proof digital ledger and smart contracts, blockchain technology can provide a secure and efficient way of managing healthcare data and electronic health records as an interoperable data lake. This technology can help healthcare providers to improve the accuracy, speed of diagnosis, treatment, and research by providing doctors and researchers with instant access to a patient's complete medical history even scattered and available as fragmented, silos and unreferenced. It can also help to ensure the privacy and security of a patient's data, by giving patients more control over their own data and allowing them to share it only with trusted parties. Besides these pros of blockchain technology, there are still some challenges to be addressed and unlocked, such as regulatory issues, interoperability with existing systems, and the need for standardized data formats. Nonetheless, by seeing these vast potential benefits of blockchain technology in healthcare, it is an area of enormous interest to examine healthcare systems in different countries with respect to unlocking relevant use cases of blockchain and to examine blockchain-based platforms as validated, recommended proof of concepts for healthcare providers in both developed and developing economies

Introduction

Blockchain technology's primary use case is the creation of decentralized, peer to peer, and secure digital ledger records that can be used for various purposes. One of the most well-known applications of blockchain technology is in the creation of cryptocurrencies like Bitcoin BTC & Etherium ETH, which are digital assets that can be used as a medium of exchange of Decentralized Finance (DEFi). As blockchains provide trustless and decentralized systems, they enable secure and more effective transactions, particularly in banking, healthcare, and supply chain management [1].

In economic terms, according to the states and facts from [2] around $126 billion is the projected value of blockchain technology in the healthcare market by 2030. Nearly $100 billion is the saved amount per annum by healthcare companies by adopting blockchain for improving their IT operations and about $242 million is the amount pharmaceutical and medical device companies invested in blockchain to replace their traditional systems in 2021.

From the digitization perspective, Denmark is one of the most digitized countries in the world. The Danish healthcare sectors and service providers store enormous amounts of data about Danish citizens' pathways in health and care. Often these data are stored in a "passive" manner, and not actively used to improve personal health and care. With the advances in artificial intelligence, machine learning, metaverse and data sciences, there is a huge potential waiting to be explored related using the already available data, datasets to enable better health and care for Danish healthcare system.

Additionally in this digitized era, an increasing number of citizens collect data about their own health monitoring activities via wristbands, smart watches, telemedicine, virtual clinics and other telecare mobile applications and portals etc. Thus, from that data stored in a scattered, unstructured manner, even more data insights can potentially be made available to improve healthcare and electronic medical records (EHRs). Also, it is crucial that data is stored and shared in a secure manner and with the necessary permissions from the citizens – both with respect to the purpose and the duration of the use as well as the actors using them.

For this, Blockchain technology has recently received much attention and has been mentioned as a potential framework for secure data sharing across the various health and care actors as depicted in Figure 1.

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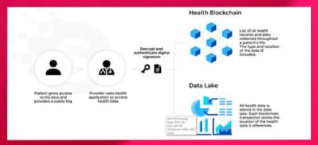

To demonstrate the potential of blockchain frameworks, it is necessary to examine and define use cases of blockchain technology in healthcare. Likewise, it is important to explore issues and challenges related to areas such as Patient Data Management, High security standards in Data Encryption, Healthcare Transaction Control, Drug supply chain management, Clinical Trial and Healthcare Research Improvement, Medical Paperwork Management, Integration with Wearable IoT Devices, Tracking medical credentials, Blockchain as a Healthcare Service (BAHS) related to secure data sharing and exchange across the various healthcare providers and actors. As outlined above, these use cases can potentially be explored by storing EHRs and related data as nodes and then these nodes could be securely used for data sharing even built of within the blockchain or in different blockchain architectures to improve data exchange with trusted security but even when a blockchain node desires to perform a transaction from one blockchain network to another of the different blockchain network.

Overall, this work aims to address the mentioned issues and provide Proof of Concept (POC) implementations to validate possible solutions and to recommend solutions to technical challenges such as data exchange, interoperability, lack of decentralization and transaction exchange problem within block communication & cross link communication.

Literature review

As a literature, some of the previous work in blockchain technology in healthcare will be reviewed. The reviews are done for blockchain technology with respect to trust management, EHRs, health care and its use cases and available protocols.

In a technical report from the National Institute of Standards and Technology (NIST) blockchain technology and its trust, interoperability is defined as "a composition of distinguishable blockchain systems, each representing a unique distributed data ledger, where automated transaction execution may span multiple heterogeneous blockchain systems, and where data recorded in one blockchain are reachable, useable, verifiable, and referable by another possibly foreign transaction in a semantically compatible" [6].

Based in a study [7], we described two pressing issues in healthcare, focusing on the need to (1) create an interoperable system to facilitate clinical communications and data exchange and (2) enable patient-centric care to provide patients with access and control of their complete medical history. We then identified seven concrete healthcare scenarios that share similar technical pain points, which can be alleviated with blockchain technology. However, the complexities associated with healthcare involvement and regulations create additional challenges inevitably facing blockchain-based systems, such as system resolvability, information privacy and communication scalability. Targeting a subset of these healthcare-specific challenges, we presented four design recommendations demonstrated with a case study prototype that we have previously developed. From our experience, we have seen the great potential of blockchain technology in creating secure and effective healthcare ecosystems with its inherent unique properties. In addition, we have also observed the importance of integrating domain-specific concerns and needs into blockchain-based designs. Overall, blockchain has a wide range of possibilities in healthcare, which invites many research opportunities in this space.
According to [8], blockchain technology has evolved from the time it was introduced to the world through Bitcoin into a general-purpose technology with use cases in many industries including healthcare. To understand the state-of-the-art of the application of blockchain technology in healthcare, we conducted a systematic review in which we created the map of all relevant research using the systematic mapping study process. Specifically, the objectives of the study were to identify the blockchain technology use cases in healthcare, the example applications that have been developed for these use cases, the challenges and limitations of the blockchain-based healthcare applications, the current approaches employed in developing these applications and areas for future research.

Their research and paper selection protocol produced 65 papers which we analyzed to address the research questions. This study also shows that blockchain has many healthcare use cases including the management of electronic medical records, drugs and pharmaceutical supply chain management, biomedical research and education, remote patient monitoring, health data analytics, among others. Several blockchain-based healthcare applications have been developed as prototypes based on emerging blockchain paradigms, such as smart contracts, permissioned blockchain, off-chain storage, etc.

However, more research still needs to be conducted to better understand, characterize, and evaluate the utility of blockchain technology in healthcare. Further research will be done to supplement the current overview of relevant literature.

Research Approach

In this section we will investigate some of the key factors of the research which includes definition of problem statement, the primary aims and objectives that must be reached to tackle the problems, and research questions to address alongwith hypothesis that will be tested during the project.

Problem statement

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In this section, we will first review some of the most important limitations in blockchain technology and blockchain in healthcare perspective (e.g. technical and institutional) and hypothesis will be tested and addressed .

Blockchain technology is a complex system that involves several components, and there are various technical issues that can arise when using it. Some of the most common technical issues in blockchain include:

- Scalability: As the number of transactions on a blockchain network increases, the system may experience performance issues due to the limitations of its underlying technology.
- Interoperability: Blockchain are often isolated from one another, making it difficult for users to interact across different networks.
- Security: Although blockchain technology is inherently secure due to its decentralized nature, it is still vulnerable to hacking and other security threats.
- Privacy: Although transactions on a blockchain network are secure and transparent, there are still concerns around privacy, particularly in cases where sensitive personal or financial information is involved.
- Consensus: Consensus is the process by which blockchain participants agree on the state of the ledger. Achieving consensus can be challenging, particularly in large networks with many participants.
- Governance: Blockchain networks require governance to ensure that the system is maintained and updated over time. Governance can be difficult, particularly in decentralized systems where there is no central authority.
- Energy consumption: Proof-of-work blockchains, such as Bitcoin, require a significant amount of energy to maintain the network, which can be environmentally and economically unsustainable.
- User experience: Blockchain technology can be difficult to use for non-technical users, particularly when it comes to managing keys and wallets.

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Addressing these technical issues requires ongoing research and development efforts from the blockchain community.

From the blockchain in healthcare perspective, it is quite problematic to address the issues of privacy, security, and interoperability of healthcare data, as such data is sensitive and must be protected from unauthorized access, tampering, and breaches. However, the current healthcare system is fragmented, and patient data is passive, scattered across multiple systems, making it challenging to access, share, and manage to extract the diagnosis. Blockchain technology has the potential to solve these problems by creating a secure and decentralized network for healthcare data storage and management. With blockchain, healthcare providers can securely share patient data across different systems without compromising patient privacy. Moreover, blockchain can ensure the accuracy and integrity of medical records by creating an immutable and tamper-proof record of all healthcare transactions.

However, implementing blockchain in healthcare requires overcoming several challenges, such as ensuring interoperability between different blockchain networks and healthcare systems, addressing regulatory compliance issues, and developing a robust governance framework to ensure data privacy and security. Furthermore, the high cost of implementing blockchain technology and the need for skilled professionals to maintain it are significant barriers to adoption.

Research Questions

Generally, Blockchain technology has recently received much attention and has been mentioned as a potential framework for secure data exchange across the various nodes, networks, and platforms in digital means; this increased blockchain trust and interoperability multiply hazards addressed above. It is also crucial that health data is stored and shared in a massive amount in a secure manner with the necessary permissions of patients and from the distributed apps (DApps) and networks – both with respect to the purpose and the duration of the use as well as the actors using them; this needs to be examined. These aspects justify the attention of researchers and their questions regarding research direction of usage blockchain and its interoperability along with standard, framework for the decentralized applications and other digital assets such as EHR and DApps. The research questions (RQ) are given as below:

RQ1: What is the current landscape concerning blockchain in health and care with trust, interoperability in all industry, government, and academia?
RQ2: Are technological requirements for blockchain technology and interoperability currently satisfied in terms of framework and standards?
RQ3: Are there real use cases, proof of concepts requiring blockchain in health and care?
RQ4: How can a blockchain model be developed, evaluated, validated, and recommended for further use together with relevant stakeholders from the health and care sectors?

Objectives

In the previous sections, we investigated some of the most important limitations in the domain. In this section, we will propose a set of new possible solutions which can be seen as the aims of this research project.

The PhD project has the following objectives:

1. Study of existing concepts & potential of blockchain for EHRs and healthcare.
2. A review of the usage, international practices, implications, and compliance of blockchain DApps for EHRs and other blockchain networks i.e., Bitcoin, Etherrum and HIPAA, GDPR compliance-based systems including available data sources and interoperability standards.
3. Proposing a POC model focused on secure data exchange of EHRs, DApps and blockchain, interoperability & security standards for health systems in Denmark and developing countries such as Pakistan.
4. Designing an interoperable model for various use cases as different segments/ DApps for healthcare on blockchain networks; this might be coined as Blockchain Healthcare As A Service (BHAAS).
5. Developing a framework that simulates the use of the developed model.
6. Evaluation of the potential applicability and implications of the model for making recommendation, review, compliance, and validation of the proposed study.

Research Methodology

Research methods are categorized as quantitative or qualitative types that have some differences in the methods and the techniques that are used. According to [13], in quantitative research, usually numerical data, statistical testing, and experiments are used. While in qualitative research verbal data, historical research and case studies are seen as good sources of research. In fact, in quantitative research the main concept is the variables, while in qualitative one, the main concept is meaning and essay. Usually, quantitative research is used in literature, arts, and history studies while quantitative research is considered as a method for engineering, statistics, and accountancy.

Qualitative research aims to explain the fact and completes a theory and some other explanations about the natural phenomena, and on the other hand the quantitative research focuses on testing of a theory, explaining the facts statistically, and predicting the behavior.

Since these two types of research are applicable in two different areas of science, the research designation process is different. The method that is used in quantitative method is more experimental, quasi-experimental, or non-experimental. While in qualitative research design the research more relies on case studies, narrative, content analysis, and ethnography.

The sample which is used in quantitative research usually is large and is created based on probability and random selection. The samples of data used in qualitative research are small size and the data is selected based on a certain aim and purpose. These two methods not only have differences in samples and population but also the differences are in collection and gathering the required data. In quantitative research the method used for gathering is structural, and formal while in qualitative research the method of data gathering is subjective and non-structured and uses informal methods of collection.

The following iterative methods will also be used in the project (the numbers relate to the parts listed above):

- Desk research (1, 3, 4, 6)
- Structured literature review (2)
- Interviews and workshops with central actors in the health and care sectors (1, 3)
- Iterative (agile) development and testing through simulation (4, 5)
- Qualitative data collection and analysis (6)

Requirements and Deliverables

In this section, we will discuss the requirements to accomplish this research project and also describe the planned deliverables.

SDU Health Informatics and Technology (HIT) will provide the necessary computing (and other) facilities and human resources for supervision and discussion in relation to this study. SDU HIT will make use of its large network of health and care providers to help involve relevant Danish and international actors in the study.
In the view of the present studies and recognized above as the open issues and challenges, this work will propose research directions based on some systematic study & survey which includes research on architecture for use cases enabling blockchain interoperability and its allied connectors with specific focus on trusted, secure and interoperable technology for EHRs for their exchange with prior permission and linkages of patients and actors of use on different blockchain segments/networks (if implemented) with complete compliance and proofs. Finally, this work will result on supporting technologies, standards, use cases, and other necessary compliance to solve the mentioned issues of blockchain technology and blockchain in healthcare to improve the architecture for blockchain interoperability as mentioned below:

- Systemic study on blockchain technology and its properties such as trust, interoperability, semantics by exploring, for example, the research area of integration, cross linkages, security, and compliance for EHRs and their DApps for healthcare systems.
- Defining a maturity model to examine use of blockchain technology in healthcare with interoperability/security, modeling interoperability at its various layers, connectors based on exploration.
- To model the different views of EHRs based on the types of interoperability as per accordance to the needs of different stakeholders (for instance: the provider's technical view on a cross-blockchain DApp vs. the semantic view of the end-user on the same cross-blockchain DApp).