

Blockchain Technology in Healthcare: A Literature Review

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Abstract: Blockchain is the latest and emerging technology with strong impact on how data interaction and information exchange is going to happen in a global scenario. Since the introduction of Bitcoin in 2008[1], blockchain study has continued to extend its applications to instances of non-financial use. Healthcare is another sector where it is anticipated that blockchain will have important effects. Research in this region is comparatively new but is increasing quickly, so scientists and professionals in health informatics are always working hard to maintain pace with advancement in study in this technology. This article reports on a scholarly literature review of the research progress in healthcare implementation of blockchain technology. This literature review aims to highlight the progressive development of blockchain applications in healthcare industry along with its limitations for the same. Also the scope for future research is analysed.

Index Terms: Blockchain, bitcoin, literature review, applications, healthcare.

I. INTRODUCTION

The technology behind Bitcoin provides for the exchange of electronic coins among participants in a distributed network without the need for a centralized, trusted third party which provides for the main utility of blockchain. Blockchain technology can be categorised into three generations. The first generation is Blockchain 1.0 [2], which uses the concept of cryptocurrencies, like Bitcoin. Blockchain 2.0 is the generation next of blockchain technology and constitutes smart properties and smart contracts [2]. The smart properties are digital assets which are taken care by a blockchain based platform and the software programs to manage and control these smart properties are called the smart contracts. Examples of Blockchain 2.0 cryptocurrencies include Bitcoin[1], Ethereum[4] etc. Furthermore, Blockchain 3.0 is the non-financial application of blockchain [2] as blockchain technology is making its way to other industries like unique identification management, resolution of conflicts, management of contracts and supply chain, insurance sector and healthcare[5,6]. The remainder of this Literature review is organized as follows. Section 2 provides for a brief technical introductory overview to blockchain and its lineage with cryptographic primitives. Section 3 provides for the discussion of various use cases of health care domain and how blockchain is proving to be a promising technology to cater to their specific needs. Sections 4–5 presents the discussion and the conclusion, respectively.

2. BLOCKCHAIN: AN INTRODUCTION

In distributed applications, the concept of decentralization in blockchain has overcome many problems that have otherwise been encountered in centralized systems which need a trusted third party. There are many disadvantages owing to the presence of a third party in the distributed application. First is the introduction of a single point of failure, second is unnecessary delay time introduced and finally increase in cost due to transaction fees charged by central authority. All these problems are overcome in blockchain by the introduction of consensus mechanism which is used to manage communication between nodes in a distributed environment. Figure 1 illustrates this scenario.

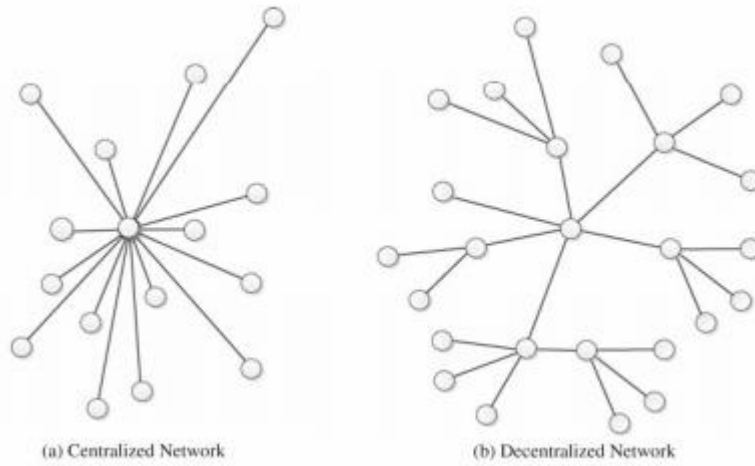


FIG. 1. ILLUSTRATION OF A CENTRALIZED AND DISTRIBUTED NETWORK ARCHITECTURE [3]

Cryptography is used in Blockchain which gives it its uniqueness. Each user in a blockchain network is a node and every node in the application uses public key infrastructure (PKI) [12] to create and propose transactions.

A valid transaction proposal received within a timeframe, say 8 min[1] is called a Block. The validation process ensures that only a legitimate and authorized user node originates a transaction. The order of new appended blocks in the ledger is decided by the consensus algorithm that are run by special nodes called miners and the process is called mining. Thus a new block of validated transactions is linked to the previously added blocks, creating a chain of blocks, known as blockchain.

Based on the access and sharing rules, two types of blockchain are classified which are : permissioned and public[13].

Another cryptographic structure called hash function is used to structure the chain of blocks. The collision-resistant property of hash function is the basis of block chaining as it guarantees that same hash output is never produced for two different messages. The last appended block contains the digital fingerprint of its previous block and this scenario creates a link of blocks called the blockchain. Figure 2 gives a generic idea of the process.

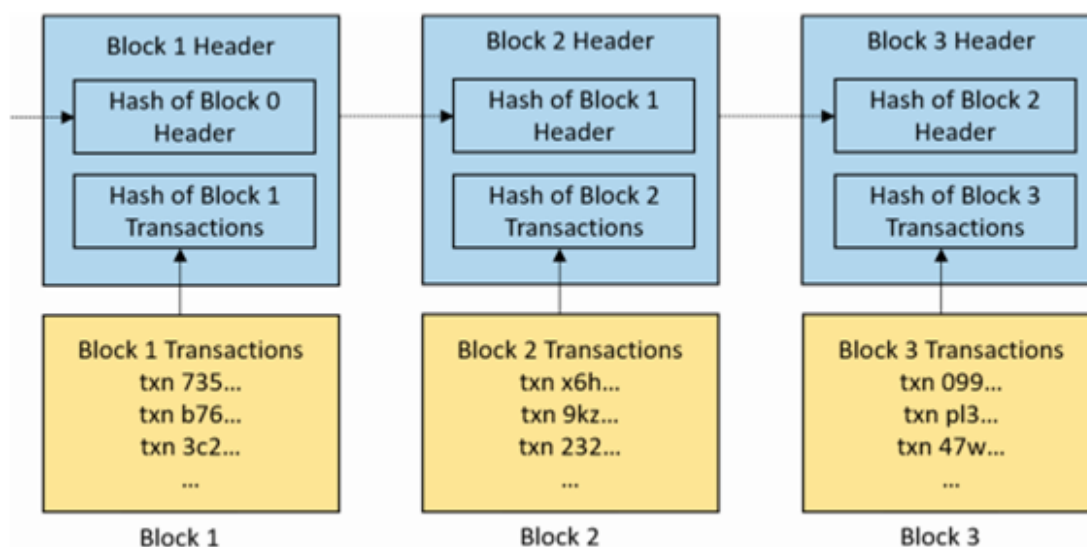


Fig.2.An overview of how blockchain is formed by linking every block to previously appended block

Miners in the distributed network must all agree on the order of the blocks to be added. This is done by the consensus protocol. Cryptocurrency Bitcoin uses the consensus protocol called as Proof of Work (PoW) [1]. Thus the concept of consensus protocol ensures a consistent and validated true state of the ledgers in the distributed application. There is no need for a central authority or a third party. Hitherto, blockchain can be used as a distributed application ledger, shared by peers in a distributed database where records need to be added with a timestamp. With all the above discussions in foregoing, we can now state important features of blockchain with respect to healthcare applications. Decentralization feature of blockchain can help to implement healthcare application that do not require central authority. Also, the replication of information in blockchain amongst every node, provides for the transparency called for by all the stakeholders. This can ensure to the patients that they have information about who is accessing their data when and how. Besides this, replication also prevents loss of data thus providing further protection to critical healthcare data. Also, owing to the property of immutability of the blockchain, integrity and validity of patient health records is ensured. Security of patients' data and their privacy is also there as use of cryptographic primitives in the blockchain calls for only legitimate and valid access to the healthcare data records.

Cryptographic keys can help share health data of patients without revealing their identities. Furthermore, smart contracts [2] can be used to make rules to allow patients to control access to their data for usage. Thus Blockchain paradigm can play a major role in the development of an EHR (Electronic Health Record) Management System.

3. USE CASES IN HEALTHCARE : A LITERATURE REVIEW

3.1 *Electronic Health or Medical Record (EHR or EMR)*

Blockchain's main features of immutability, decentralization, reliability etc have made it very suitable for storage and management of patients' electronic medical records (EMR) [10]. The processing of patients that may be both personal and sensitive is not allowed until consented by the concerned party as specified in the European General Data Protection Regulation (GDPR) [14]. Guardtime, uses blockchain to implement EMR of over and above 1 million patient records in Estonia [7,9]. An MIT project MedRec [20], is aimed at deciding access permissions to its patients over their data. In United States Gem Health Network (GHN) implements multisharing by giving access of same data to numerous healthcare companies by using Ethereum blockchain platform [20]. Another venture called Healthcoin [8] proposes to construct a global Electronic Medical Record System by allowing sharing of patients' health records globally. In another instance, the modular architecture of IBM's Hyperledger Fabric [6] is used in HealthChain [16] to develop a permissioned, private blockchain network. To implement security of access, another architecture for blockchain called GAAFQ (Granular Access Authorization supporting the Flexible Queries) was proposed by Zhang and Poslad [15].

3.2 *Supply Chain Management of health related drugs*

Delivery of fake medications is one big nuisance faced by the healthcare industry. In a survey done by Engelhardt [8], it is pointed out that some pharmaceutical companies have implemented blockchain by recording every transaction of drug prescription. This makes the whole process transparent to all manufacturers, distributors, doctors, patients and pharmacists who are stakeholders and connected to their distributed network. Companies like Nuco and HealthChainRx are mentioned in the said research paper which are big names in United States in healthcare sector. This detects and thus avoids any spurious activity in the supply chain network. This clearly indicates that industrial players are considering blockchain far too seriously even when there is a lot of research gap in this area.

3.3 Remote Patient Monitoring (RPM)

Blockchain technology can also facilitate remote patient monitoring(RPM) which enables to monitor patient's health by storing, sharing and retrieving the biomedical data when he or she is away from such facility like Medical labs and health centres. Blockchain construct of Smart contracts (Ethereum) can support patient monitoring applications in real time as demonstrated by Griggs et al [18] . SMEAD [22] is a blockchain based mobile-enabled app to monitor diabetes patients. Hyperledger Fabric is used to transmit data to a blockchain application using smartphones [23].

3.4. Health Insurance Claims

Blockchain features of decentralization, immutability and transparency can benefit the Insurance Claims in healthcare [17]. A company called Pokitdok has announced to work in collaboration with Intel [8] to facilitate verification of insurance claims in healthcare by using Blockchain Technology.

3.5 Data Analytics in Health (HDA)

Another use case of healthcare using Blockchain Technology is in predictive Analytics of healthcare data and precision medicines [24]. Blockchain is used to classify arrhythmia via deep learning architecture by Juneja and Marefat [19].

3.6 Others

ONE VERY IMPORTANT APPLICATION AREA OF BLOCKCHAIN FOR HEALTHCARE INDUSTRY IS TO IDENTIFY RELEVANT METRICS FOR EVALUATING APPLICATIONS BASED ON BLOCKCHAIN IN HEALTHCARE AND IS DISCUSSED BY ZHANG ET AL.[21].

ALSO THE SOCIAL AND ECONOMIC IMPACT OF USING BLOCKCHAIN PARADIGM IN HEALTHCARE IS EXPLORED BY WONG[24,26,27].

4. DISCUSSION

We conclude our study by discussing through following research paradigms of Blockchian in healthcare industry.

4.1 Use of Blockchain in Health Care Industry

As illustrated and discussed above, the blockchain use cases in healthcare find its application in the electronic health or medical records (EHR or EMR), supply chain management of health related prescription drugs, patient monitoring remotely (RPM), verification of health insurance claims, health data analytics and other potential areas of healthcare applications. Patients and other stakeholders of healthcare industry can control their applications for data access and sharing properly aggregated by blockchain technology and benefit from its huge potential.

4.2 Challenges of Blockchain Technology

Major challenges of implementing Blockcain Technology are interoperability, privacy, scalability and speed [17]. In the absence of a standard for developing healthcare applications using blockchain, the information from one platform may not be able to interoperate to another platform [18]. In the view of various reported attacks on the blockchain networks of different crypto currencies [11], there is a substantial risk that the identity of a patient may be revealed by associating data together or other security breach by criminals that can compromise the privacy of patient. Also, the inherent property of immutability of blockchain, interferes with the right of people to request for complete erasure, as the data that has been saved once on Blockchain cannot be deleted or altered

completely as against the desire to get it completely removed from database of medical history. Scalability and speed of blockchain are another issue in healthcare application as the data involved is way too much to handle with limited knowledge as of now.

5. CONCLUSIONS

In the light of discussions above, we can concur through this literature review that blockchain has a huge potential in many healthcare applications including electronic medical records (EMRs), supply chain management of health related drugs, remote patient monitoring(RPM), health data analytics and others. Various prototypes and applications based on smart contracts, permissioned and permissionless blockchain, hyperledger fabric, ethereum, etc have been developed. Blockchain Technology, being comparatively new, requires a lot of research to be used in Healthcare industry. Also there is a research gap in Blockchain metrics for healthcare and other quality issues like interoperability, security, scalability, all with respect to application of Blockchain in Healthcare.

REFERENCES

- [1] NAKAMOTO, S. BITCOIN: A PEER-TO-PEER ELECTRONIC CASH SYSTEM. 2008. AVAILABLE ONLINE: WWW.BITCOIN.ORG
- [2] SWAN, M. BLOCKCHAIN: BLUEPRINT FOR A NEW ECONOMY; O'REILLY MEDIA, INC.: SEBASTOPOL, CA, USA, 2015
- [3] A. S. Tanenbaum and M. Van Steen, Distributed systems: principles and paradigms. Prentice-Hall, 2007
- [4] Ethereum Project. Available online: <https://www.ethereum.org/>
- [5] Burniske, C.; Vaughn, E.; Cahana, A.; Shelton, J. How Blockchain Technology Can Enhance Electronic Health Record Operability; Ark Invest: New York, NY, USA, 2016.
- [6] Androulaki, E.; Barger, A.; Bortnikov, V.; Cachin, C.; Christidis, K.; De Caro, A.; Enyeart, D.; Ferris, C.; Laventman, G.; Manevich, Y.; et al. Hyperledger Fabric: A Distributed Operating System for Permissioned Blockchains. In Proceedings of the Thirteenth EuroSys Conference; EuroSys '18; Association for Computing Machinery: New York, NY, USA, 2018; pp. 30:1–30:15.
- [7] Angraal, S.; Krumholz, H.M.; Schulz, W.L. Blockchain Technology Applications in Health Care. *Circ. Cardiovasc. Qual. Outcomes* 2017, 10, e003800
- [8] Engelhardt, M.A. Hitching Healthcare to the Chain: An Introduction to Blockchain Technology in the Healthcare Sector. *Technol. Innov. Manag. Rev.* 2017, 7, 22–34
- [9] Mettler, M. Blockchain Technology in Healthcare the Revolution Starts Here. In Proceedings of the 2016 IEEE 18th International Conference on E-Health Networking, Applications and Services (Healthcom), Munich, Germany, 14–17 September 2016; pp. 520–522
- [10] Kuo, T.T.; Kim, H.E.; Ohno-Machado, L. Blockchain Distributed Ledger Technologies for Biomedical and Health Care Applications. *J. Am. Med. Inform. Assoc.* 2017, 24, 1211–1220.
- [11] Yli-Huumo, J.; Ko, D.; Choi, S.; Park, S.; Smolander, K. Where Is Current Research on Blockchain Technology? A Systematic Review. *PLoS ONE* 2016, 11, 1–27.
- [12] Housley, R. Public Key Infrastructure (PKI). In *The Internet Encyclopedia*; JohnWiley & Sons, Inc.: Hoboken, NJ, USA, 2004.

- [13] Alhadhrami, Z.; Alghfeli, S.; Alghfeli, M.; Abedlla, J.A.; Shuaib, K. Introducing Blockchains for Healthcare. In Proceedings of the 2017 International Conference on Electrical and Computing Technologies and Applications (ICECTA), Ras Al Khaimah, UAE, 19–21 November 2017; pp. 1–4
- [14] Patients and Privacy: GDPR Compliance for Healthcare Organizations—Security News - Trend MicroDK. Available online:
- [15] <https://www.trendmicro.com/vinfo/dk/security/news/online-privacy/patients-and-privacy-gdpr-compliance-for-healthcare-organizations> (accessed on 12 March 2019).
- [16] Zhang, X.; Poslad, S. Blockchain Support for Flexible Queries with Granular Access Control to Electronic Medical Records (EMR). In Proceedings of the 2018 IEEE International Conference on Communications (ICC), Kansas City, MO, USA, 20–24 May 2018.
- [17] Ahram, T.; Sargolzaei, A.; Sargolzaei, S.; Daniels, J.; Amaba, B. Blockchain Technology Innovations. In Proceedings of the 2017 IEEE Technology & Engineering Management Conference (TEMSCON), Santa Clara, CA, USA, 8–10 June 2017; pp. 137–141.
- [18] Boulos, M.N.K.; Wilson, J.T.; Clauson, K.A. Geospatial blockchain: Promises, challenges, and scenarios in health and healthcare. *Int. J. Health Geogr.* 2018, 17, 25.
- [19] Griggs, K.N.; Ossipova, O.; Kohlios, C.P.; Baccarini, A.N.; Howson, E.A.; Hayajneh, T. Healthcare Blockchain System Using Smart Contracts for Secure Automated Remote Patient Monitoring. *J. Med. Syst.* 2018, 42, 130
- [20] Marefat, M.; Juneja, A. Leveraging Blockchain for Retraining Deep Learnign Architecture in Patient-Specific Arrhythmia Classification. In Proceedings of the 2018 IEEE EMBS International Conference on Biomedical & Health Informatics (BHI), Las Vegas, NV, USA, 4–7 March 2018
- [21] Azaria, A.; Ekblaw, A.; Vieira, T.; Lippman, A. MedRec: Using Blockchain for Medical Data Access and Permission Management. In Proceedings of the 2016 2nd International Conference on Open and Big Data (OBD), Vienna, Austria, 22–24 August 2016; pp. 25–30
- [22] Zhang, P.; Walker, M.A.; White, J.; Schmidt, D.C.; Lenz, G. Metrics for assessing blockchain-based healthcare decentralized apps. In Proceedings of the 2017 IEEE 19th International Conference on e-Health Networking, Applications and Services (Healthcom), Dalian, China, 12–15 October 2017; pp. 1–4
- [23] Saravanan, M.; Shubha, R.; Marks, A.M.; Iyer, V. SMEAD: A secured mobile enabled assisting device for diabetics monitoring. In Proceedings of the 2017 IEEE International Conference on Advanced Networks and Telecommunications Systems (ANTS), Odisha, India, 17–20 December 2017; pp. 1–6
- [24] Ichikawa, D.; Kashiya, M.; Ueno, T. Tamper-Resistant Mobile Health Using Blockchain Technology. *JMIR mHealth uHealth* 2017, 5, e111

Shae, Z.; Tsai, J. Transform Blockchain into Distributed Parallel Computing Architecture for Precision Medicine. In Proceedings of the 2018 IEEE 38th International Conference on Distributed Computing Systems (ICDCS), Vienna, Austria, 2–5 July 2018.