The Impact of Blockchain on the Healthcare Environment

Gajala Praveen¹, Piyush Kumar Singh², Prabhat Ranjan³

¹,²,³Department of Computer Science, Central University of South Bihar, Gaya, India
¹gajalapraveen@cusb.ac.in, ²piyush@cusb.ac.in, ³prabhatranjan@cub.ac.in

Abstract

Bitcoin was the first electronic payment system to truly exploit the power of blockchain technology. There is currently the problem of health information inequality and health information leakage. Physicians should conduct essential routine work that wastes human and financial resources and delays treatment processes. Blockchain provides a trust-free and cost-reducing solution to manage and secure valuable health information. The aim of this study is to discuss research into blockchain healthcare applications. It addresses the management of medical data, as well as the sharing of medical information, the sharing of images, and the management of logs. We also discuss papers that overlap with other fields, such as the Internet of Things, information management, drug monitoring along their supply chain, and aspects of security and privacy. Finally, we analyze and compare the research papers in the medical area and also summarize the strategies used in healthcare with their pros and cons.

Keywords

Distributed systems, Health industry, Electronic medical records, Decentralized record management system.

1. Introduction

The field of healthcare is immense societal significance since the problems it tackles are specifically concerned with improving the quality of life that can be accomplished by overcoming real health issues [1]. Over the years, healthcare services have improved and contributed to greater competition. Valuable information on a patient’s condition may be generated by historical data contained in computerized healthcare systems. It can now be handled by the users themselves by creating decentralized architecture, and it is possible to have more stable systems. All cities and rural areas can be recorded and used to
evaluate epidemics and health services [2]. Such knowledge is great importance to researchers in different fields and can help to explain phenomena and solve complex challenges [3]. The monitoring and management of drug distribution is one of the different fields where the blockchain can be implemented. Blockchain technologies can also help in controlling drug counterfeiters [4]. Blockchain will function in various healthcare scenarios and has been inspired by the work of [5]. The points chosen in the SWOT analysis and its key features are shown in Figure 1.

2. Description of Blockchain Use in the Healthcare Sector

2.1. The Blockchain Technology

Blockchain is an emerging technology that developed around 2008/2009 from crypto currencies [6, 7]. It is currently carrying out unique activities in the areas of banking, health care, transport, public administration or other fields. More reliable and safe ways of recording properties can be created by this new technology [8]. In addition, it can also be viewed as a technology with replicated ledger focused on decentralized peer-to-peer (P2P) networks [9]. The distributed ledger methods have several components; these elements are the cornerstone of operating the blockchain network. The blockchain data structure is represented in Figure 2.

![Figure 1. SWOT analysis of blockchain in healthcare context](image)

![Figure 2. The blockchain structure](image)
2.2. Process of Verification in Blockchain

The validation method is often referred as mining in the blockchain. A consensus algorithm normally performs the process, which also sets out what rules the nodes will obey. This means that they will determine whether to insert the block into the chain [10, 11].

2.3. Smart Contracts

With the introduction of the Ethereum framework [12], smart contracts on blockchain 2.0 have arisen. It is a protocol that must be followed by all transaction in an automated manner [13, 14]. If they are using crypto currencies or sharing other properties, it executed automatically when the transaction corresponds to a certain rule set out in it. This reality will lead automatically to the detection of inconsistencies. It can allow electronic transactions which lead to greater security and efficiency and also, they can play a role in the legal system [15, 16].

2.4. Challenges in Healthcare Using the Blockchain

There are some issues when blockchain technology applied in the healthcare area [17]-[19].

- **Throughput**: High performance is concerned when dealing with healthcare systems; and if there is no easy access, this could negatively impact a diagnosis that could save the life of anyone.

- **Latency**: It takes about 10 minutes to validate a block. Healthcare networks are complicated and accessed all the time. So, it can be adversely affected by any delay.

- **Security**: When an individual is able to take control of 51 percent of the computing power of the network, this can be harmful to system security. Since a health care system that is compromised will mean that healthcare institutions lose reputation, this problem demands a great deal of attention.

- **Resource consumption**: The use of this technology, a lot of energy is expended on the mining process, threatens to entail a significant loss of resources. Energy costs are very high in a healthcare environment, since many devices are required to track patients; however, using the blockchain can also require high costs of computing and energy. Managing these expenses is an issue for organizations.

- **Usability**: In these types of systems, usability is also a concern because they are very difficult to manage. The systems should be clear and intuitive because health practitioners do not have the same degree of technological sophistication as IT practitioners.

- **Centralization**: Some methods tend to centralize the miners, reducing the degree of network efficiency. It may be possible to access the information through malicious attacks.

- **Privacy**: The Bitcoin network is widely believed to guarantee the privacy of its nodes. However, the observations of [20] have not agreed to this assumption. In addition, to give this capability to block chain-based systems, strategies are needed.

3. The Management of Health Details

After addressing the fundamental principles of blockchain technology, this section includes the investigation of health information management. It is of great social significance in the healthcare sector. For this purpose, the calculation may help to minimize the impact of certain issues in this field. Computer science helps in the automation of healthcare records as for example: more reliable data exchange, log management, and uses in other fields. The collection of information will speed up the time required for treatment, as well as help the doctor’s decision-making after the patient’s symptoms have been diagnosed [21]. The aim of this section is to address issues related to medical information to be exchanged and handled.
3.1. Healthcare Record Sharing

It is difficult to exchange health information because it deals with patient's personal details. Dubovitskaya et al. [22], Azaria et al. [23], and Xia et al. [24] are the primary works in the literature that address this application of blockchain technology. In the work of Azaria et al., one of the most traditional structures in literature is discussed. Several current literature articles have cited this and uses it as a base for develop the new architectures. Some of these architectures, cited in [25-28], are influenced by Azaria et al. MedRec is a feasible idea for use in exchanging health information that can be used by patients, the hospital, and doctors to integrate healthcare. In this way, the reported data in various hospital systems will minimize inconsistencies. As described by Dubovitskaya et al., the approach presents a cloud computing subject, which can also help create new architectures to exchange health records via blockchain. In order to connect a communication network with nodes, the authors suggest a cloud-based architecture that has embraced the blockchain-based data structure. It uses smart contracts to describe the logic of transactions. One of the potentials aims of these forms of architecture is to exchange photos of radiology and may be conduct research with actual patients. Xia et al. (with MedShare), discussed this issue about seeking a blockchain-based record sharing solution. The solution aims to help provide a better audit environment and monitor access to records and link to the blockchain network when smart contract tasks are performed using activation triggers. The primary aim of the solution type, such as MedShare, is to allow the implementation of certain features of healthcare systems like provenance of data, auditing, and greater systems security. If cloud computing is used by the system, it could be sufficient to satisfy the high data demand.

3.2. Image Sharing in Healthcare

Both data types as well as images can define healthcare details. Some issues with the exchange of healthcare information can also exist in photos at the moment [29]. The solution suggested by [30] could be a beneficial approach because it does not involve an intermediary and an architecture that works for this type of data with some concepts underlying this term. They plan to fundamentally propose an interface for the sharing of images from this work. The patient should exchange photographs of their healthcare in a protected and regulated manner.

3.3. Management of Logs in Healthcare Systems

It is an important concept for computer systems because logs enable the generation of historical data. In the work of Anderson [31], the implementation of these ideas in the healthcare context was discussed. The logging of the security audit is very complicated because the compilation of the collected information can often be useless or lack important pieces of information. In Anderson, a log control strategy, called the Audit Chain, was discussed and is essentially an application that tackles interoperability concerns while providing facilities for the exchange of electronic health records. In implementing this approach, the following components were used: the IBM platform and the Hyperledger Fabric, enabling the process of developing blockchain-based applications. An application is specified that helps to manage audit logs and provides users, i.e. physicians, nurses, and patients, with multilevel access control. Nonetheless, the use of AuditChain has drawbacks, such as the difficulty of locating logs specific to a single user. Also, it is important to construct the query script while carrying out the operation.

3.4. Used Strategies in the Industry

Nowadays, the concept of blockchain is growing in popularity, certain applications that are directly aimed at the industry need to be investigated. Industry plans include steps to resolve unique market-oriented concerns and to raise profits. In the healthcare world focused on blockchain, two techniques involving industry are [32, 33]. Medicalchain varies from other tech-
niques introduced in the literature. In addition to this, there is a blockchain network integration that allows data to be stored from the wearable devices of a patient. They can be used to track blood pressure, alcohol intake, physical activity that is performed and other areas that can offer valuable information to physicians when diagnosing a patient.

Our analysis also included a survey of industry-focused strategies using the healthcare environment-focused Sandgaard and Wishstar framework. In this way, when designing healthcare apps, it aims to have more protection and transparency. Medchain, as several layers are plugged into it, adopts a modular approach in its architectural applications. The data layer is one of the key layers that the instrument has, and it acts as the foundation for all the others. This layer also allows for the relation of other applications. The basic data layer also offers for Distributed Features (DApps) applications that help patients access their health care less. These are obtained from an application on the user interface that interacts with DApp. The GovTech programme from Estonia (starting in 2011), a use case associated with blockchain in healthcare. Similarly, blockchain technology aims to ensure the safety and protection of government healthcare systems. According to the paper by Heston [34], blockchain offers some advantages when used in this sense, such as the storage and management of health records. Blockchain provides protection, tamper-proof, scalability, and a third trusted portion is not required. This technology can also increase audibility through the development of immutable logs, provide healthcare records with privacy, and even reduce healthcare costs.

3.5. Consensus Protocols Used on Healthcare

Consensus protocols are essential frameworks in blockchain networks. These protocols help to organize the validation of transactions. It also supports tools that use the PBFT consensus protocol. The outcome of this research is shown in Figure 3.

| Consensus Protocol | Overview |
|--------------------|----------|
| **Proof of Work**  | Sharing healthcare records |
|                    | Sharing healthcare records privately and user-friendly |
| **POS**            | Sharing healthcare imaging |
| **PBFT**           | Sharing safe and reliable healthcare records |
|                    | Management and audit of access logs from healthcare records |
|                    | Exchange healthcare |

The table presents data relating to the most commonly accepted protocols in healthcare methods, based on the research performed in this study, which are proof-of-work and PBFT. There are two protocols explored known as proof of accessibility and proof of time and space. For proof of accessibility, the algorithm is intended to ensure that access to the data is given even if it is removed from the network by the node that stores it. To carry out this process, the protocol uses data backup, replication, and fragmentation techniques. The data fragmentation technique uses data fragments that are distributed throughout the network to various storage nodes, where more than 50 percent of the fragments of a given database cannot...
be retained by each node. The protocol proof of time and space checks whether the data has been stored and demands space at periodic time intervals. The integrity of the stored health records is verified by these criteria, while the nodes involved in these procedures obtain a reward in MedCoins.

3.6. Patient Monitoring

Patient monitoring is a necessary practice within the healthcare system, and it supports the healthcare provider during the treatment of patients. Sensors produce confidential personal data while tracking patients. There is a need to comply with legislation for the security of personal data, such as the Lei Geral de Proteção de Dados (LGPD) in Brazil [35]. To strengthen and empower conventional structures, many innovations have arisen. The IoT, sensor networks, and wearable devices are some examples of these technologies. It refers to a personal network consisting of many embedded or wearable sensors where there is a central data transmission unit [36]. Figure 3 demonstrates the simplified layout of a WBAN network for block chain patient monitoring [37].

![Figure 3. Structure of Wireless Body Area Networks (WBANs) for patient monitoring.](image)

There are some limitations on the reliability, performance, and accuracy of the ability to exchange patient information [38], although blockchain technology can help to resolve these problems. Since it provides a secure means of sharing information between network nodes and uses principles such as immutability and privacy of data. Based on the factors described above, by forming frameworks that can make the process more efficient, blockchain can aid in tracking patients. In the paper, Linn and Koo [39] propose a block chain-based system for exchanging health information. Another example of blockchain technology patient tracking has been discussed by. They investigate the use of personal sensor networks to remotely track patients. This framework also uses blockchain technology to transmit sensor generated data. It should also be noted that a blockchain network structure must be traversed when exchanging data before it reaches the end-users, in order to ensure better protection and reliability [40].
4. Supply Chain Management

It is one of the managerial mechanisms for the creation of an enterprise, since it links a network of participants, ranging from the raw material supplier to the distribution organization. It covers a range of sectors, such as the healthcare sector, and other applications, including blockchain technology, are introduced into this field as a result of technological advances. The management of the supply chain includes the handling of assets from the manufacturing line to their delivery in order to meet the final customer on time and in a good quality state [41]. For certain industries, such as healthcare and the pharmaceutical industry, business planning is a vital factor.

4.1. Blockchain and IoT for Supply Chain

It is possible to apply IoT technology to many applications, including the transmission of real-time information and the tracking of properties in the chain [42]. Furthermore, other IoT-integrated technologies, Hospitals may become smart hospitals with the IoT, enabling such processes for healthcare professionals [43]. The company’s goal is to combine IoT principles in order to track improvements in drug conditions (Kshetri [44] and Campbell [45]). The technology tests whether clear transport requirements are fulfilled in order to ensure that quality is preserved before the goods reach their destination. Via a smart contract, the Modum operates a blockchain Ethereum-based framework and checks state of the drug. The prescription will be rejected if there are any issues in the trans-action when reviewed.

4.2. Management of Health Assets in the Supply Chain

The management of the supply chain is monitoring this problem by blockchain-based supply chains [46]. The paper by Erhun et al. [47] explores the value of drug distribution management in Nigeria, where there is a shortage of medicines, and relies on imported medicines to address the problem. The poorly drug control occurred in Nigeria in 1990, after taking a dose of medicine several children under the age of four died, the medications had toxic effects. This case highlights the urgent need, by poorly controlled supply chains, to monitor the compounds that are added to the medications. Thus, the traceability of these assets is important and it must be addressed appropriately in the distribution of drugs. This is because, depending on the type of medicine, or even stolen for illegal sale. It ensures that the blockchain ledger (i.e., the drug log records) records all the assets that are distributed; therefore, it can no longer change significantly once the data is stored.

5. Privacy and Security in the Healthcare Blockchain

Some considerations that relate to the blockchain with regard to safety in healthcare systems are discussed in this section. First of all, blockchain health care systems will boost cryptography-related systems. This paper [48] sets out a method for looking for the best smart contract cryptography models. Nevertheless, blockchain privacy concerns are not completely discussed. Some areas of privacy need to be investigated when submitting information and when the transaction is related to patient data [49]. The use of patient health records gives rise to a question about patient privacy, because personal information is included in the information aggregated in these records. Such records which consist of a personal identification number, the credit card number used by the patient to make a private network payment, and other things. Several approaches in the literature that can help solve these issues are discussed by [50]. The HIPAA law helps to (a) enhance the exchange of information in healthcare settings, (b) establish national standards, and (c) protect personal health data. These rules offer greater reliability and personal data protection for users of healthcare systems. Blockchain technology will enhance the protection and reliability of personal patient information with the help of privacy rules [51]. The use of blockchain is another tool that can be used to improve privacy when exchanging healthcare data. With the support of this system, since they are extracted from the blockchain network, healthcare organizations will not have to worry about the reliability of the
results, and therefore the consumers themselves will be able to handle them [54-62]. The multimedia data (e.g., images, sounds, and videos) is one form of healthcare data. Patel's paper explores digital imaging that relates to the blockchain. It should be stressed that in a healthcare environment, data protection is important, and blockchain technology can help ensure security for this environment. In addition, there is an emerging development in the use of cryptography techniques to boost the degree of privacy in healthcare systems, which includes a differential privacy-based blockchain [52, 53].

6. Conclusion and Future Work

Blockchain technology is a new phenomenon, and its implementation in the field of healthcare started in 2016. The approach discussed is to guarantee privacy when sharing health information and the most relevant publications in this area between 2016 and 2020. Blockchain may make a major contribution to maintaining privacy. In order to retain this service on the network, hospitals will have to spend a lot of money on infrastructure. The purpose of this research was to present a series of works for researchers interested in implementing healthcare systems based on blockchain. We also addressed some of the frameworks for developing healthcare applications based on blockchain, presenting their drawbacks and benefits. As a result, we can observe from the development of this research that blockchain technology can be applied to various perspectives in the field of healthcare. One of them worth exploring more thoroughly is the IoT-integrated monitoring of healthcare equipment. Along with these innovations, it is important to note the possibilities of providing fitness and mental health monitoring environments with more protection of patient data may be mitigated with the help of blockchain technology. Finally, we summarized several techniques and applications used for healthcare by blockchain, which are relevant to each area of knowledge. In order to form a point of reference between these methods, Figure 5 shows the pros and cons of these strategies. For future studies, a baseline can be used.

| Area                             | Methods                  | Pros                                      | Cons                                      |
|---------------------------------|--------------------------|-------------------------------------------|-------------------------------------------|
| Sharing health information      | MedRec                   | Improve data quality for medical research  | Not have contract encryption              |
|                                 |                          | System interoperability                    | It’s just a prototype                     |
|                                 | MediChain                | Could use mobile interface and a web application | Loss of patient access key               |
|                                 |                          | Reduces risk to identify the patient from data leaked | Problems with privacy                   |
|                                 | Medicalchain             | Health data marketplace                    | Tokens could be used just within Medicalchain |
|                                 |                          | Patient control access with MedTokens     | There are risks for acquiring the MedTokens |
| Remote care with IoT            | Patient centric agent (PCA) | Provide access control role-based         | Requires devices with high power processing for encryption |
|                                 |                          | Uses a protocol to improve security and authentication of patient’s smartphone | Vulnerable to man in the middle attack     |
| Supply chain for healthcare     | Modum                    | Uses good practice of the GDPR            | Business oriented                         |
|                                 |                          | Monitors the pharma chain with NFC        | Poor documentation and complexity         |
| Security and privacy            | Decentralized Sharing of Health Records (DSHR) | Uses attribute-based encryption to ensure privacy | Complexity to use                         |
|                                 |                          | Stores sensitive data in off-chain        | Increases cost as the number of attributes increases |

Table 2. Methods Used on Blockchain to Healthcare with Pros and Cons
Applications. In 2017 4th International Conference on Advances in Biomedical Engineering and Web and Grid Services 14, 4 (2018), 352-367. DOI:https://doi.org/10.1016/j.wsns.2018.06.006

[8] Melanie Swan. 2015. Blockchain: Blueprint for a New Economy (1st ed.). O’Reilly Media, Inc., Sebastopol, CA.

[9] Nabil Rifi, Elie Rachkidi, Nazim Agoulmine, and Nada Chendeb Taher. 2017. Towards using blockchain technology for eHealth data access management. In 2017 4th International Conference on Advances in Biomedical Engineering (ICABME17). IEEE, 1-4. DOI:https://doi.org/10.1109/ICABME.2017.8167555

[10] L. S. Sankar, M. Sindhu, and M. Sethumadhavan. 2017. Survey of consensus protocols on blockchain applications. In 2017 4th International Conference on Advanced Computing and Communication Systems (ICACCS17). IEEE, 1-5. DOI:https://doi.org/10.1109/ICACCS.2017.8014672

[11] George Pirlea and Ilya Sergeev. 2018. Mechanising blockchain consensus. In Proceedings of the 7th ACM SIGPLAN International Conference on Certified Programs and Proofs. ACM, 78-90. DOI:https://doi.org/10.1145/3167086

[12] Vitalik Buterin. 2014. A Next-Generation Smart Contract and Decentralized Application Platform. Retrieved August 20, 2018 from https://github.com/ethereum/wiki/White-Paper.

[13] Krishnendu Chatterjee, Amir Kafshdar Goharshady, and Yaron Velner. 2018. Quantitative analysis of smart contracts. In Programming Languages and Systems, Amaal Ahmed (Ed.). Springer International Publishing, Cham, 739-767.

[14] Nick Szabo. 1997. Formalizing and securing relationships on public networks. First Monday 2, 9 (1997), 22. DOI:https://doi.org/10.5210/fm.v2i9.548

[15] Joshua A. T. Fairfield. 2014. Smart contracts, bitcoin bots, and consumer protection.Washington and Lee Law Review Online 71, 2 (2014), 36. https://scholarlycommons.law.wlu.edu/wlulr-online/vol71/iss2/3/.

[16] Steve Omohundro. 2014. Cryptocurrencies, smart contracts, and artificial intelligence. AI Matters 1, 2 (Dec. 2014), 19-21. DOI:https://doi.org/10.1145/2685328.2685334

[17] Matthew B. Hoy. 2017. An introduction to the blockchain and its implications for libraries and medicine. Medical Reference Services Quarterly 36, 3 (2017), 273-279. DOI:https://doi.org/10.1080/02763869.2017.1332261

[18] Thomas McGhin, Kim-Kwang Raymond Choo, Charles Zhechao Liu, and Debiao He. 2019. Blockchain in healthcare applications: Research challenges and opportunities. Journal of Network and Computer Applications 135 (2019), 62-75. DOI:https://doi.org/10.1016/j.jnca.2019.02.027

[19] Jesse Yli-Huumo, Deokyoon Ko, Sujin Choi, Sooyong Park, and Kari Smolander. 2016. Where is current research on blockchain technology?A systematic review. PLoS One 11 (2016), 1-27. DOI:https://doi.org/10.1371/journal.pone.0163477

[20] Zibin Zheng, Shaoan Xie, Hong-Ning Dai, Xiaping Chen, and Huaimin Wang. 2018. Blockchain challenges and opportunities: A survey. International Journal of Web and Grid Services 14, 4 (2018), 352-375.

[21] Robert H. Miller and Ida Sim. 2004. Physicians use of electronic medical records: Barriers and solutions. Health A_airs 23, 2 (2004), 116-126. DOI:https://doi.org/10.1377/hlth._23.2.116 arXiv:https://doi.org/10.1377/hlth._23.2.116 PMID: 15046136.

[22] Alevtina Dubovitskaya, Zhigang Xu, Samuel Ryu, Michael Schumacher, and Fusheng Wang. 2017. Secure and trustable electronic
medical records sharing using blockchain. CoRR abs/1709.06528 (2017), 1-10. arxiv:1709.06528http://arxiv.org/abs/1709.06528

[23] Asaph Azaria, Ariel Eklaw, Thiago Vieira, and Andrew Lippman. 2016. MedRec: Using blockchain for medical data access and permission management. In 2016 2nd International Conference on Open and Big Data (OBD). IEEE, 25-30. DOI:https://doi.org/10.1109/OBD.2016.11

[24] Q. Xia, E. B. Sifah, K. O. Asamoah, J. Gao, X. Du, and M. Guizani. 2017. MedShare: Trust-less medical data sharing among cloud service providers via blockchain. IEEE Access 5 (2017), 14757-14767. DOI:https://doi.org/10.1109/ACCESS.2017.2730843

[25] Joel Alwen, Jeremiah Blocki, and Ben Harsha. 2017. Practical Graphs for Optimal Side-Channel Resistant Memory-Hard Functions. Cryptology ePrint Archive, Report 2017/443. Retrieved September 20, 2018 from https://eprint.iacr.org/2017/443.

[26] Tsung-Ting Kuo, Hyeon-Eui Kim, and Lucila Ohno-Machado. 2017. Blockchain distributed ledger technologies for biomedical and health care applications. Journal of the American Medical Informatics Association 24, 6 (Nov. 2017), 1211-1220. DOI:https://doi.org/10.1093/jamia/occ068

[27] A. Lei, H. Cruickshank, Y. Cao, P. Asuquo, C. P. A. Ogah, and Z. Sun. 2017. Blockchain-based dynamic key management for heterogeneous intelligent trans-oration systems. IEEE Internet of Things Journal 4, 6 (Dec. 2017), 1832-1843. DOI:https://doi.org/10.1109/JIOT.2017.2740569

[28] Ricardo Neisse, Gary Steri, and Igor Nai-Fovino. 2017. A blockchain-based approach for data accountability and provenance tracking. In Proceedings of the 12th International Conference on Availability, Reliability and Security(ARES17). ACM, New York, NY, Article 14, 10 pages. DOI:https://doi.org/10.1145/3098954.3098958

[29] Ana Sofia de Oliveira Guedes Bastos. 2011. Quality of Health Information on Acute Myocardial Infarction and Stroke in the World Wide Web. Masters Thesis. Universidade do Porto.

[30] Vishal Patel. 2018. A framework for secure and decentralized sharing of medical imaging data via blockchain consensus. Health Informatics Journal 25, 4 (2018), 1398-1411. DOI:https://doi.org/10.1177/1460458218769699 arXiv:https://arxiv.org/10.1177/1460458218769699 PMID: 29692204.

[31] Jessie Anderson. 2018. Securing, Standardizing, and Simplifying Electronic Health Record Audit Logs through Permissioned Blockchain Technology. Ph.D. Dissertation. Dartmouth College.https://www.cs.dartmouth.edu/trdata/reports/abstracts/TR2018

[32] Abdullah Albeyatti. 2018. Medicalchain. Retrieved September 30, 2018 from https://medicalchain.com/Medicalchain-Whitepaper-EN.pdf [White paper].

[33] Joachim Sandgaard and Steve Wishstar. 2018. MedChain. Retrieved September 30, 2018 from http://medchain.us/doc/Medchain20Whitepaper%20v1.0.pdf [WhitePaper].

[34] Thomas F. Heston. 2017. A case study in blockchain health care innovation. International Journal of Current Research 9 (2017), 1-2. https://www.journalcr.com/article/case-study-blockchain-health-care-innovation.

[35] Caitlin Sampaio Mulholland. 2018. Dados pessoais sensíveis e a tutela de direitos fundamentais: Uma análise a luz da lei geral de protecao de dados (Lei 13.709/18). Revista de Direitos e Garantias Fundamentais 19, 3 (2018), 159-180.

[36] Aftab Ali and Farrukh Aslam Khan. 2015. Key agreement schemes in wireless body area networks: Taxonomy and state-of-the-art. Journal of Medical Systems 39, 10 (Aug. 2015), 115. DOI:https://doi.org/10.1007/s10916-015-0272-9

[37] O. Salem, Y. Liu, A. Mehaoua, and R. Boutabia. 2014. Online anomaly detection in wireless body area networks for reliable healthcare monitoring. IEEE Journal of Biomedical and Health Informatics 18, 5 (Sept. 2014), 1541-1551. DOI:https://doi.org/10.1109/JBHI.2014.2312214

[38] Y. Ren, R.Werner, N. Pazzi, and A. Boukerche. 2010. Monitoring patients via a secure and mobile healthcare system. IEEE Wireless Communications 17, 1 (2010), 59-65. DOI:https://doi.org/10.1109/MWC.2010.5416351

[39] L. A. Linn and M. B. Koo. 2016. Blockchain for Health Data and Its Potential Use in Health IT and Health Care Related Research. Retrieved August 25, 2018 from https://www.healthit.gov/sites/default/les/11-74-ablochainforhealthcare.pdf

[40] Md. Ashraf Uddin, Andrew Stranieri, Iqbal Gondal, and Venki Balasubramanian. 2018. Continuous patient monitoring with a patient centric agent: A block architecture. IEEE Access 6 (2018), 32700-32726. DOI:https://doi.org/10.1109/ACCESS.2018.2846779

[41] DouglasM. Lambert,Martha C. Cooper, and Janus D. Pagh. 1998. Supply chain management: Implementation issues and research opportunities. The International Journal of Logistics Management 9, 2 (1998), 1-20. DOI:https://doi.org/10.1108/09574099810805807 arXiv:https://doi.org/10.1108/09574099810805807

[42] B. Yan and G. Huang. 2009. Supply chain information transmission based on RFID and internet of things. In 2009 ISECS International Colloquium on Computing, Communication, Control, and Management, Vol. 4. IEEE, 166-169. DOI:https://doi.org/10.1109/CMMM.2009.5267755

[43] Amir M. Rahmani, Tuan Nguyen Gia, Behailu Negash, Arman Anzanpour, Iman Azimi, Mingzhe Jiang, and Pasi Liljeberg. 2018. Exploit-
ing smart e-Health gateways at the edge of healthcare Internet-of-Things: A fog computing approach. Future Generation Computer Systems 78 (2018), 641-658.DOI:https://doi.org/10.1016/j.future.2017.02.014

[44] Nir Kshetri. 2018. Blockchains roles in meeting key supply chain management objectives. International Journal of Information Management 39 (2018), 80-89. DOI:https://doi.org/10.1016/j.ijinfomgt.2017.12.005

[45] Rebecca Campbell. 2016. Modum.ios Temperatue-Tracking Blockchain Solution Wins Accolades at Kickstarter Accelerator 2016. https://bitcoinmagazine.com/articles/modum-ios-temperature-tracking-blockchainsolution-winsaccolades-at-kickstarter-accelerator-1479162773/.

[46] Ogbonna Brian Onyebuchi. 2016. National drug distribution in Nigeria; implications for the goals of national drug policy. European Journal of Pharmaceutical and Medical Research (EJPpMR) 3, 1 (2016), 1-4.

[47] W. O. Erhun, O. O. Babalola, and M. O. Erhun. 2001. Drug regulation and control in Nigeria: The challenge of counterfeit drugs. Journal of Health & Population in Developing Countries 4, 2 (2001), 23-34. http://www.nigeriapharm.com/Library/Drug regulation.pdf.

[48] Lanxiang Chen, Wai-Kong Lee, Chin-Chen Chang, and Raymond Kim-Kwong Choo. 2019. Blockchain based searchable encryption for electronic health record sharing. Future Generation Computer Systems 95 (2019), 420429.DOI:https://doi.org/10.1016/j.future.2019.01.018

[49] Qi Feng, Debiao He, Sherali Zeadally, Muhammad Khurram Khan, and Neeraj Kumar. 2019. A survey on privacy protection in blockchain system. Journal of Network and Computer Applications 126 (2019), 45-58.DOI:https://doi.org/10.1016/j.jnca.2018.10.020

[50] Latanya Sweeney. 2002. K-anonymity: Amodel for protecting privacy. International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems 10, 5 (Oct. 2002), 557-570. DOI:https://doi.org/10.1142/S0218488502001648

[51] U.S. Department of Health & Human Services (HHS). 2013. Summary of the HIPAA Privacy Rule. Retrieved February 4, 2016 from https://www.hhs.gov/hipaa/for professionals/privacy/laws-regulations/index.html.

[52] Cynthia Dwork and Aaron Roth. 2014. The algorithmic foundations of differential privacy. Foundations and Trends in Theoretical Computer Science 9, 3-4 (Aug. 2014), 211-407. DOI:https://doi.org/10.1561/0400000042

[53] G. Zyskind, O. Nathan, and A. Pentland. 2015. Decentralizing privacy: Using blockchain to protect personal data. In 2015 IEEE Security and Privacy Workshops. IEEE, 180-184.DOI:https://doi.org/10.1109/SPW.2015.27

[54] Singhal, P., Sharma, P., & Hazela, B. (2019). End-to-end message authentication using CoAP over IoT. In International Conference on Innovative Computing and Communications (pp. 279-288). Springer, Singapore.

[55] Singhal, P., Sharma, P., & Rizvi, S. (2019). Thwarting Sybil Attack by CAM Method in WSN using Cooja Simulator Framework. International Journal of Engineering & Technology, 8(1.5), 116-125.

[56] Singhal, P., Sharma, P., & Arora, D. (2018). An approach towards preventing iot based sybil attack based on contiki framework through cooja simulator. International Journal of Engineering & Technology, 7(2.8), 261-267.

[57] Molla, T., Khan, B., & Singh, P. (2018). A comprehensive analysis of smart home energy management system optimization techniques. Journal of Autonomous Intelligence, 1(1), 15-21.

[58] M. Vinny, P. Singh (2020) Review on the Artificial Brain Technology: BlueBrain. Journal of Informatics Electrical and Electronics Engineering,1(1), 3, 1-11

[59] A. Sahani, P. Singh and A. Kumar (2020) Introduction to Blockchain. Journal of Informatics Electrical and Electroncs Engineering,1(1), 4, 1-9.

[60] F. Abbasi and P. Singh (2021) Cryptography: Security and Integrity of Data. Journal of Management and Service Science,1(2), 4, pp. 1-9.

[61] F. Abbasi and P. Singh (2021) Quantum Cryptography: The Future of Internet and Security Analysis. Journal of Management and Service Science,1(1), 4, pp. 1-12.

[62] S.K. Tomar and P. Singh (2021) Cyber Security Methodologies and Attacks. Journal of Management and Service Science,1(1), 2, pp. 1-8.