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ABSTRACT

Blockchain is a technology with potential for making ground breaking steps in addressing social, economic and healthcare challenges. The global information technology scene is being overcrowded with blockchain applications with special focus on the vast healthcare market [12]. The value of information related to healthcare creates a clear path for applying blockchain as a solution for some of the challenges in the healthcare sector, in particular with the goal of creating a fair and transparent way for sharing information and patient data. It is however a fact that while *blockchain technology* introduces additional complexity to the implementation healthcare software, the *benefit the technology actually brings still remains unclear and difficult to evaluate*. This vision paper demonstrates our research focus on providing a body of knowledge and tools to help evaluate this impact of blockchain on eHealth applications. In particular, we identify that such a research effort has to explicitly consider cost of addressing challenges inherent to the eHealth domain like integration of disparate software systems (hospitals, research institutions, government agencies, health insurance and pharmaceutical companies, etc.), the potential introduction of cryptocurrencies in healthcare systems, degree of patient service improvement, transparency and compliance to laws and regulations, and others. The more traditional influencing factors, like cost of development and running, licenses for using third-party software services, and the ones inherent to blockchain like cost of computation and energy will also have to be taken into consideration in the metrics model.

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CCS CONCEPTS

• General and reference~Evaluation • Software and its engineering~Organizing principles for web applications • Mathematics of computing~Coding theory • Hardware~Power networks

KEYWORDS

Blockchain, Healthcare, Security, Application specification

1. Introduction

The initial need for measuring the impact of applying the blockchain technology [3] comes for the rise of energy consumption from the digital cryptocurrency mining. The global additional consumption became a high-risk problem and many companies acknowledge this fact in connection to their proposed blockchain-based solutions. To better appreciate that fact many alternatives are currently being developed, taking into account the problems previous technologies had. *Distributed Ledger Technology* (DLT) is a new term that explain the overall application of blockchain. It is an umbrella term used to describe technologies that distribute records or information among all those using it, privately or publicly. DLT finds various applications related with finance, bank security, transaction tracking, food-safety supply chains and others. The realization of this transformation in data sharing and transparency, if adopted by multiple sources, will reshape economy, health industry and even more sectors

Smart contracts, currently the most popular solution for DLT, offer a digital representation of traditional contracts and contain calculations, rules and record transactions. Their prolific introduction and application in Ethereum networks substantiate their wide acceptance [18]. In conventional applications, an intermediary ensures that all parties follow through on terms, often with unsuccessful results [2]. Addressing this problem is the core application and unique characterization of blockchain, since each member is obligated to fulfill a predefined set of actions and follow a set of specific rules. This can be monitored continuously from a specific number of different consortium members on the chain. Blockchain has the unique benefit of removing the need for third party validation using this decentralized benefit. Additionally, only the set of ledger participants (members of blockchain network) knows the contract details. This enables contractual terms to be implemented automatically after the system has validated the information.

With our research, we aim at exploring the capabilities of smart contracts for different scenarios, such as financial derivatives, insurance premiums, property law, and crowd funding agreements, among others, by evaluating the costs of implementing a blockchain solution against the current situation. For example, Microsoft demonstrates a blockchain solution based on Ethereum for helping consumers that are increasingly concerned about where their products are coming from and how these products are produced [4]. Other companies, such as IBM, have also introduced the technology to their infrastructure where they implement blockchain services available via an API [13].

Handling the blockchain-based application design is essential for resources management for three main reasons: a) As dedicated service that will run constantly, the design of each Blockchain application must be scalable to the necessary level of adding new users and subscribers to the service without diminishing the performance of the network. b) Next to scalability, these networks must have a performance indication of proper resources management, since they often charge with a Pay-as-you-go license [16]. c) Another specification a well-designed network must have is the security management that comes with the application properties and can vary based on the requests of the members of blockchain network. Combining these specifications and information to describe a particular application is extremely important towards enabling the measurement of the impact of the blockchain technology for different application scenarios. creates the chain for the series of transactions.

Consider the following example of a fair-trade, non-GMO, and organic certifications, which may often carry the risk of being faked, are essential to keep in a secure phase. Counterfeit products, especially in food and pharmaceuticals, could be dangerous for consumers and disastrous for brands that are discovered selling them. Tracing product inputs and attesting production techniques on the blockchain creates an immutable record of asset provenance. Organizations can author smart contracts instructing what participants must follow before they take action on or custody of a product and the entire record can be shown to concerned end customers to prove the veracity of product claims. In these smart contracts, information such as manufacture ID and delivery route can by encrypted in the blockchain, but date and time of production may not be part of the encrypted information of the contract. Applications based on the blockchain technology vary from one sector to another, e.g. from the financial sector, through cryptocurrencies and to food supply chain. Since not all information is sensitive there is also the possibility of having to deal with data that are not encrypted on the chain. This approach must be evaluated with proper testing algorithm for each case under consideration of the above mentioned application specifications.

The rest of the paper is organized as follows: We present the challenges related to the eHealth domain in section 2 and give more details in the context of the eHealth record and data sharing in section 3. In section 4 we present our roadmap towards enabling the measuring of the impact of blockchain technologies on eHealth applications. Our conclusions and future work are presented in section 5.

2. Application in the eHealth field

Based on recent developments there are various applications building around blockchain in eHealth [3,19,20] to establish safe and secure patient data use. The various applications that are currently used in patient data management are now being redesigned to implement *data sharing and storage* using blockchain technology (for example MediLedger [5]). Medical practice, daily routines and integrated health systems are major part of patient-doctor relationship. As the term eHealth is defined as a new era with improved health providing skills and knowledge, patient advantages are also enhanced [20]. In order to enable these advantages, we claim that both the application design and the data use and sharing have a significant role and can bring multiple added benefits to a universal Healthcare system. Consider, for example, a use case of a Greek patient that goes to a national hospital. He wants to show his latest X-ray to doctors. Thanks to a blockchain-based health system, he can give authorization to the doctor to access his data and obtain all the traceability information on the screen. Therefore, the doctor decides to either do or not an additional X-Ray. By eliminating unnecessary X-Rays, expenses are lower and the patient is not exposed to unusual radiation. This scenario required that several healthcare providers from different organizations have a blockchain application with a copy of the patient's data [5]. The consequence is that medical data is not siloed onto one location, data sharing follows security requirements and patient care improves.

Another important application of blockchain technology is the *payment of medical practices with cryptocurrency* from patients in the near term future. This evolution would come from the healthcare insurance company industry. The massive change would be on payments. Healthcare would have to back some implementation of cryptocurrency [24]. Hospitals are showing a constant interest to accept payment on cryptocurrencies, thus opening a new way of how patients and insurance companies operate together. The consequence will be no delay in payments and more channels to access better Health care.

3. Electronic Health Record and Securing Data in a New Age of eHealth - Challenges

Medical practitioners have a complex relationship with electronic health record [8, 10, 20] since they need the information without having themselves to integrate the health record into their daily routines. As national and international health records are necessary for patient-oriented solutions, to enable robust and secure applications that allow sharing of information easier and safer; blockchain-based applications must be a distributed application, which can communicate with multiple backend information systems in such a way that data ownership and secure access are combined so as to benefit the patients. For example, due to lack of connection between government agencies, the life-saving information that can be included on your records may not be available for data security reasons. Towards solving this problem, blockchain literature, mainly whitepapers, claim to find a solution to this problem and various applications related to healthcare appeared in recent months. Blockchain solutions can facilitate the reduction of medical errors and ensure secure information ownership; however, they require a vital “good” architecture in order to avoid problems. Data would always be protected and secured, however, access is the vital part [7]. Finally, the system should implement a reading log on all patient's medical records [8].

Addressing the example above a health record can be stored on the service database (DB) that must add the encrypted information. The service DB stores also the unencrypted information as shown in Figure 1. If doctors’ and patients’ data belong to the same blockchain based application, the patient can predefine who can access their information. This way without any real user interfacing with blockchain hashes and complex architecture, the users can trust the security layers and share their data through this application. Each application accesses a blockchain network via an API, such as the one provided by Microsoft Azure and others.

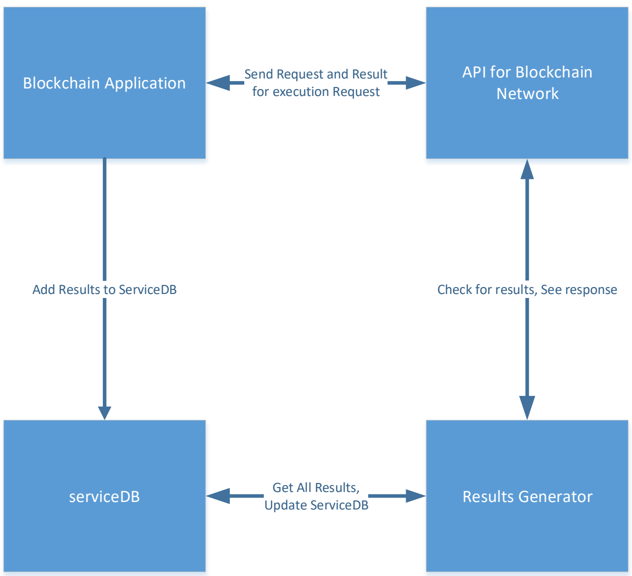

Figure 1: A blockchain-based application supports eHealth applications to deal with privacy of data and data access and sharing.

Blockchain technology addresses the global problem with an essential solution and through the transparency of the technology. Existing supply chains have opened up a world of connected commerce, however, with this comes unprecedented complexity as multiple parties must cooperate to exchange patient data and use them only were it is necessary. All these requirements have caused an essential attention on Blockchain.

Regarding the preference for cryptocurrency payment in healthcare, ICO (Initial Coin Offering) turned to be the most popular procedure to raise funds for a company related with blockchain, giving the possibility to outside investors for early support. A blockchain related company can launch an ICO (which is roughly equivalent to an Initial Public Offering) and in exchange of the outside investors receive a new cryptocurrency token specific to the ICO, which they hope to perform well in future and provide huge return on investment [15].

Getting a blockchain application set up for eHealth may require a setup of a similar form to exchange information and provide users with a coin for usage. Often these coins are labeled as tokens and their application can vary from financial to health reasons and issues. Regulating such interactions may remain a concern in future.

Transparency is essential to information related with patient data. The users need to be confident that their data are carefully taken care of, in addition to the possibility of having these data available anywhere when they need it. A system needs to ensure the integrity of outsourced health data along with its privacy preserved. For example, health companies need specific patient data to improve future predictions [10] drug development, personalized medicine and eHealth mobile applications. Additionally, eHealth creates in an essential change in the ethical standing of health information professionals (HIPs), by taking a more protective standing towards patients that they did not have before [11]. The new regulations regarding data sharing like GDPR [9] increase the complexity of the situation and need to be addressed.

4. Measuring the Impact of the Blockchain Technology on eHealth Applications

Blockchain technologies are bringing various opportunities for new applications related with healthcare. Several domains such as patient data sharing and data security have a priority on preventing illegal use of information by various parties. Labelling each party with “secure” or “unsecure” can be replaced by having partners in or out of the blockchain protocols. As doctors and scientists require a continuous evaluation of their collaboration capabilities and data sharing, blockchain trust networks will raise the confidence in healthcare and healthcare related scientific research too. A combination between current collaboration platforms and blockchain technologies, e.g. [17], can be a foundation of future data exchange and a necessary assessment for all data usage and exchange.

Blockchain, as a peer to peer network, uses internet resources and hardware infrastructure to complete the process of encryption and transformation. As a fully functional application we need to identify the actual impact that the blockchain infrastructure will have on specific applications. This will include cost for a maintenance process for the whole system. Cost of transaction will inevitably be a part of the impact measurement. For a practical example, an implementation of an Ethereum Consortium of Microsoft’s Azure platform [5] requires three types of specifications, which set the overall size and resources requirement of the whole network. These sets are divided into General, Etherium Consortium and Supply Chain. Key resources that demonstrate deployment type and resource group have a key impact on the overall throughput of the network.

Load testing application: Breaking down the essential qualities that testing software must have, our proposed software will measure key parameters starting from load testing of a blockchain application shown in Figure 2 and the execution time of connecting with the database for real-time results. As blockchain technologies evolve, platforms perform a different set of calibrations based on execution technologies like Turing code [24]. These different technologies such as Ethereum, create automated digital contracts with a specific load for each execution. These properties must add up to demonstrate the actual expansion cost. Thus, each distributed ledger technology may also have a different applicability on each case. Our vision software must drive the developer to choose the most appropriate ledger to proceed with the development. For example, applications such as banking, are reported [24] to perform much better in Ethereum than in Bitcoin. This happens because smart-contract use cases have much lower load than Bitcoin operation.

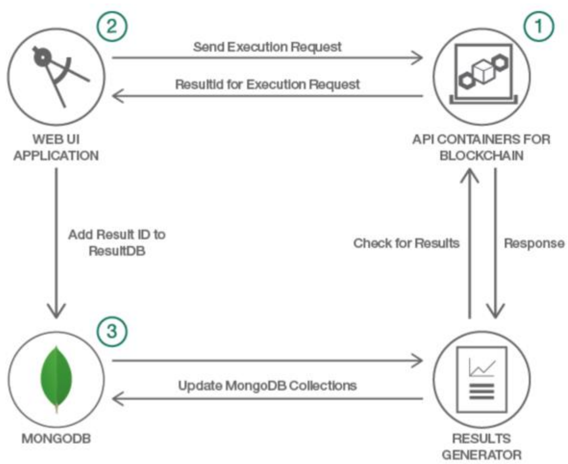

Figure 2: Load testing as performed by IBM [23]

Impact can be measure in several different metrics that combine the security, information rate, accessibility and network latency, and scalability of a network [13]. However, these are only a fraction of the necessary information any user must obtain to be able to run a stress test on an application. These measurements do not take into account the vast power consumption of blockchain, which creates a series of very important mining costs issue [3]. The most popular blockchain system nowadays, Bitcoin, contains a vast series of transactions and the hash of the preceding block. As Proof-of-Work (PoW) is introduced [21] every block must be generated from the unique hash that encrypts the entire block. Based on the resources requirement for each network an adjustment must be made to respect the computational power to maintain a standard rate per block and minute [13, 21]. In starting Bitcoin networks this latency was just short of 10 minutes per block and part of the necessary information along with block size [22]. This specific parameter grows to create the vast mining complexity we are now familiar with [3].

Roadmap: There are two potential approaches we could use to create a set of concepts and tools for measuring the impact of the blockchain technology on eHealth applications. The first one would focus on identifying deriving the parameters that define the impact of the blockchain technology on one particular application in the context of the organization and then assess the impact for that application only. Eventually, based on a significant number of assessed applications and the parameters identified, the model for assessing impact of the technology can be derived. The second approach we envision would start with investigating different blockchain-based eHealth applications and will identify a reference architecture for such applications. An impact assessment model will be derived for the reference architecture which then will be applied for the assessment of other applications. The sensitivity to the context of application of the research results, i.e. the reference architecture and the impact assessment model, will be evaluated in the context of other eHealth applications. The feasibility of these two approaches needs to be evaluated as part of our research work.

Based on the above mentioned research results, we envision the development of a software tool that combines stress analysis and an energy consumption monitoring when assessing the blockchain technology impact. Our goal is to provide a body of knowledge and tools that will information to the implementation stakeholders in order to clearly decide if the blockchain technology is appropriate for their application, what blockchain consensus technologies can be combined for the best performance of their applications, an estimate of the cost of development, computational and energy costs and others.

5. Conclusion

In this paper, we briefly overviewed current state of the art of blockchain applications in various sectors along with the emerging directions of how scalable blockchain technology is. This gives also our contribution on what the most important factors are a blockchain application design must take into account. Also having the additional information from medical applications, along with the financial problems current systems have, we aim at providing a metric system as a basis for the developing the application most appropriate for the requirements of the eHealth domain.

Blockchain provides a solution for sharing information while addressing security issues and enabling transparency of all transactions and records [24]. These benefits allow for building applications that enable trust and data sharing while gaining value. This provides a unique opportunity to develop a secure and trusted data management and sharing system based on modern laws. Blockchain technology can lead to systems modular design integrated with medical providers' existing systems, local data storage solutions, facilitating interoperability and developing convenient and adaptable systems [4, 7, 8]. We can conclude that the interaction between blockchain technology and the healthcare domain is inevitable, since the technology provides real solutions to data sharing while considering required security properties. Nevertheless, the resources required for the implementation have to be projected in order to have sustainable development and a long-term solution.

Our future work will follow our envisioned methodology and will first focus on the identification of measurable properties of blockchain-based application and their use as parameters when designing applications so as to evaluate the impact of the technology use on the application implementation. The project cost for the application development will include a cross platform design for the validation tool to be able to act on different scenarios for use of each application.

REFERENCES

[1] Walport, M. G. C. S. A. (2016). Distributed ledger technology: Beyond blockchain. UK Government Office for Science.

[2] Chatterjee, A. (2018). Artificial Intelligence based IoT Automation: Controlling devices with Google and Facebook. Artificial Intelligence, 5(04).

[3] O'Dwyer, K. J., & Malone, D. (2014). Bitcoin mining and its energy footprint.

[4] Discover how blockchain can create smarter, supply chains. https://azure.microsoft.com/en-us/solutions/blockchain/

[5] https://www.mediledger.com/

[6] https://www.forbes.com/sites/robertpearl/2018/04/10/blockchain-bitcoin-ehr/

[7] Azaria, A. e. (2016). Medrec: Using blockchain for medical data access and permission management. Open and Big Data (OBD), International Conference on. IEEE.

[8] Liu, P. T. S. (2016, November). Medical record system using blockchain, big data and tokenization. In International Conference on Information and Communications Security (pp. 254-261). Springer, Cham.

[9] Shu, I. N. (2017). The Impact of the new European General Data Protection Regulation (GDPR) on the Information Governance Toolkit in Health and Social care with special reference to Primary care in England. Cybersecurity and Cyberforensics Conference (CCC), 31-37.

[10] Desarkar, A. &. (2018). Exploration of Healthcare Using Data Mining Techniques. In Big Data Management and the Internet of Things for Improved Health Systems, 243-259.

[11] Fanning, K., & Centers, D. P. (2016). Blockchain and its coming impact on financial services. Journal of Corporate Accounting & Finance, 27(5), 53-57.

[12] Iansiti, M., & Lakhani, K. R. (2017). The truth about blockchain. Harvard Business Review, 95(1), 118-127.

[13] Vukolić, M. (2015, October). The quest for scalable blockchain fabric: Proof-of-work vs. BFT replication. In International Workshop on Open Problems in Network Security (pp. 112-125). Springer, Cham.

[14] Xu, X., Weber, I., Staples, M., Zhu, L., Bosch, J., Bass, L., ... & Rimba, P. (2017, April). A taxonomy of blockchain-based systems for architecture design. In Proceedings of 2017 IEEE International Conference on Software Architecture (ICSA), (pp. 243-252). IEEE.

[15] https://www.investopedia.com/terms/i/initial-coin-offering-ico.asp

[16] Curry, E., Derguech, W., Hasan, S., Kouroupetroglou, C., & ul Hassan, U. (2019). A Real-time Linked Dataspace for the Internet of Things: Enabling "Pay-As-You-Go" Data Management in Smart Environments. *Future Generation Computer Systems*, *90*, 405-422.

[17] Karastoyanova, D., & Stage, L. (2018, June). Towards Collaborative and Reproducible Scientific Experiments on Blockchain. In *International Conference on Advanced Information Systems Engineering* (pp. 144-149). Springer, Cham.

[18] Christidis, K., & Devetsikiotis, M. (2016). Blockchains and smart contracts for the internet of things. *Ieee Access*, *4*, 2292-2303.

[19] https://www.forbes.com/sites/civicnation/2018/12/14/a-community-promise-regardless-of-borders/#172d32f22039

[20] Schiza, E. C., Neokleous, K. C., Petkov, N., & Schizas, C. N. (2015). A patient centered electronic health: eHealth system development. *Technology and Health Care*, *23*(4), 509-522.

[21] Karame, G. O., Androulaki, E., Roeschlin, M., Gervais, A., & Čapkun, S. (2015). Misbehavior in bitcoin: A study of double-spending and accountability. ACM Transactions on Information and System Security (TISSEC), 18(1), 2.

[22] Eyal, I., Gencer, A. E., Sirer, E. G., & Van Renesse, R. (2016, March). Bitcoin-NG: A Scalable Blockchain Protocol. In NSDI (pp. 45-59).

[23] https://github.com/IBM/loadtesting-the-Blockchain-Network

[24] Karafiloski, E., & Mishev, A. (2017, July). Blockchain solutions for big data challenges: A literature review. In Smart Technologies, IEEE EUROCON 2017-17th International Conference on (pp. 763-768). IEEE.

[25] Sahama, T., Simpson, L., & Lane, B. (2013, October). Security and Privacy in eHealth: Is it possible?. In e-Health Networking, Applications & Services (Healthcom), 2013 IEEE 15th International Conference on (pp. 249-253). IEEE.