Blockchain or Distributed Ledger Technology What Is in It for the Healthcare Industry?

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Keywords: Blockchain, Patient Data, Distributed Ledger Technology, Privacy, Security, Electronic Health Records.

Abstract: Distributed ledger technology has seen its debut into communities of practice in healthcare where the reliance on knowledge sharing between participants postulates the foundations of secure and distributed knowledge, especially in some sensitive context, such as patient information. This knowledge is essential for the practice of care from patient contact to research, pharmaceutical supply chain, medication adherence and management of the plethora of bedside data into a collection of knowledge about the patient, essential to quality care. We introduce different schools of thought and implementation contexts of the distributed ledger technology or Blockchain. We provide an overview of Blockchain and Distributed Ledger Technology, focused on the Healthcare industry, as an initial assessment of the validity of an application of Distributed Ledger Technology in a specific knowledge management model to solve problems related to knowledge sharing in medical knowledge management systems. The paper summarizes some instances of most likely and unlikely uses of Blockchain in the healthcare setting. The paper also introduces a few use cases where some short-term benefits from such implementation.

1 INTRODUCTION

The growth of data in healthcare has brought a disruptive foray of new technologies to find, manage, move and maintain digital information. Distributed Ledger Technology (DLT) or Blockchain will likely not revolutionize healthcare immediately, however, may transform it forever.

Communities of practice in healthcare rely on knowledge sharing between participants (Jørgensen et al, 2019) with data that must meet the foundations of secure and distributed knowledge (Li et al, 2018), especially in some sensitive context, such as patient information. Practitioners must make sense of all data presented to them and leverage technology advances for predictive modelling that has the premise to integrate all data sources into a single ecosystem and accelerate the visualization of the patient's case in order to provide accurate evidence based diagnoses (Rakic, 2018). Therefore, in practicality, Blockchains could be complementary to digital medical records. DLT with its features of handling and anonymizing data, will likely enter the healthcare IT market subtly, making certain service areas of the industry more efficient. Based on dynamic ontologies of knowledge management, which may tie into changing state of data, and status of practice processes and workflows (Jurisica et al, 2004), DLT could enable healthcare staff to get information in a shorter timeframe without searches, paperwork, signatures, etc. Similar to how electronic medical records (EMR), MPI (Master Patient Index) systems, and data analytics are slowly changing workflows by increasing the capabilities of staff in healthcare organizations (Le Nguyen, 2018).

Treatment of patient data is an essential component to building knowledge management systems for managing the quality of care and improving patient outcome (Wang et al, 2018). However, handling patient data will never be totally risk-free.

Patient data has had three major concerns:

Who owns it?

Who has access to it?

If they have access to it, how they can use it?

These concerns are complicated by the plethora of conditions of privacy, confidentiality and security.

This position paper attempts to address the data concerns through the potential implementation of

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Badr, N.
Blockchain or Distributed Ledger Technology What Is in It for the Healthcare Industry?.
DOI: 10.5220/0008348902770284
In *Proceedings of the 11th International Joint Conference on Knowledge Discovery, Knowledge Engineering and Knowledge Management (IC3K 2019)*, pages 277-284
ISBN: 978-989-758-382-7

Blockchain or Distributed Ledger Technology. Which begs the research question: Blockchain or Distributed Ledger Technology - What is in it for the Healthcare Industry?

2 DISTRIBUTED LEDGER TECHNOLOGY OR BLOCKCHAIN

Distributed ledger technology (DLT) is a digital system for recording transaction of assets in which the transactions and their details are registered in multiple places at the same time. Unlike traditional databases, distributed ledgers have no central data store or administration functionality. Basically, "*a Blockchain is a distributed, transactional database. Globally distributed nodes are linked by a peer-to-peer (P2P) communication network with its own layer of protocol messages for node communication and peer discovery*" (Glaser 2017, p. 1545).

Blockchain implementation can be *public*, open to the public, where the only protection is provided by encryption. As "*everyone can see everything*" on a Blockchain network. In contrast, Private Blockchains are Blockchains with organizational level implementations where varying levels of control of who can access data, who can modify data, and who ultimately has authority in the system (Yip, 2016).

Some claim that new technology implementations that involve a high volume of data collection, such as the case of Internet of Things (IoT), lend themselves well to novel Blockchain applications, as do networks and machine visualization, public key cryptography, web applications, certification schemes and the secure storage of Personally Identifiable Information (PII) (Taylor, et al, 2019).

While Blockchain may have significant potential to improve data interoperability (Brodersen, et al, 2016), and address issue in security and privacy (Esposito et al, 2018), it is important to note the boundaries of the technology: Blockchain is not a substitute for an enterprise database and are not optimized for high volume data exchange necessary for applications in an organization. *Blockchain solutions are designed to record specific transactional data events that are meant to be shared across a network of parties where transparency and collaboration are mission critical* (RJ Krawiec, et al, 2016). Each party on the Blockchain has access to the whole database; no single party controls the information. Communication is directly between peers, each node stores and forwards information to other nodes; transactions occur between Blockchain addresses (pseudonyms); once the record is entered, it cannot be altered (Iansiti and Lakhani, 2017).

Furthermore, though debatable, the literature has touted the "transparency and trust" element of Blockchain technology (Agbo et al, 2019). The inherent data verifiability of Blockchain could add an atmosphere of trust, however, trust is still a difficult factor to establish as it relates to data quality, access, security and other human factors.

2.1 Two Schools of Thought

There are two schools of thought on the use of DLT for healthcare. One professes that a Blockchain could unlock the true value of interoperability (Krawiec, et al, 2016). Another, more centred on protecting data privacy, recognizes the fundamental role of the Blockchain as an access-control manager for health records and data (Linn and Koo, 2016).

In broad terms, both directions support principles of integration of healthcare information across a range of uses and stakeholders. There are varying levels of control of who can access the data, who can modify the data, and who ultimately has authority in the system.

With a distributed ledger technology, all participants would have access to the distributed ledger to maintain a secure exchange without complex brokered trust. Thus, establishing a "Trust Network" that would reduce the complexity of sharing clinical information among different healthcare information systems, as an intermediary to establish point-to-point sharing and "book-keeping" of what data is to be exchanged (RJ Krawiec, et al, 2016).

2.2 The Healthcare Context

In the healthcare context, research has concentrated on applications using distributed ledger technology to focus on integration, integrity and access control of health records and related patient data (Dagher et al, 2018). However, other diverse and interesting applications are emerging, addressing clinical trials (Nugent et al, 2016), biomedical databases (Kleinaki et al, 2018) and medical insurance (Zhou et al, 2018). Some works have advanced architectures that aim at protecting data and sense-making of data collected by embedded devices, wearables (Brogan et al, 2018), and sensors (Angeletti, 2017), designs to build building tamper resistant M-health devices (Ichikawa, 2017), in addition to proposals for

extending the technology to manage medicines supply chain (Tseng, et al, 2018),

Recently, this subject has occupied the forefront of the biomedical research. Scholars have reported on the potential of using DLT to maintain the integrity and access control of data collected in clinical trial records (Benchoufi, 2018) and presented use cases where medical transaction records (Tseng, et al, 2018), consent forms (Benchoufi, 2018), and financial records, have been managed by a form of DLT implementation for features of traceability, provenance, and non-repudiation. Drosatos and Kaldoudi, 2019, for instance, summarize current coverage of the literature on DLT in the biomedical domain (Figure 1).

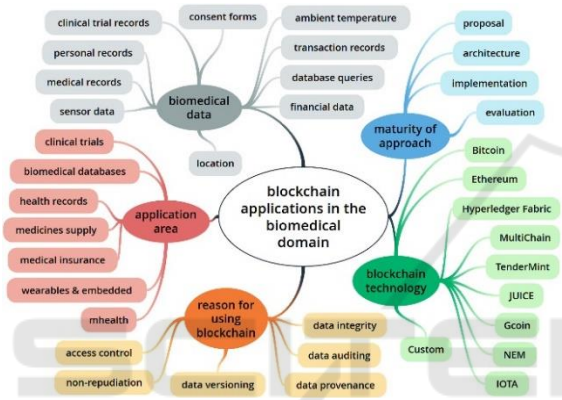

Figure 1: Blockchain application in the biomedical domain (from Drosatos and Kaldoudi, 2019; Fig 7).

Similarly, practitioners have positioned DLT in Healthcare IT implementations, to address Master Patient Index (MPI) challenges that arise from the need to synchronize multiple patient identifiers between systems while securing patient privacy. Distributed Ledger Technology could use private and public identifiers secured through cryptography, to create a singular, more secure method of protecting patient identity. Varying data standards reduce interoperability because records are not compatible between systems. Distributed Ledger Technology could enable near real-time updates across the network to all parties. Other institutions, in Population Health management, have identified a benefit in Distributed Ledger Technology that could enable secure access to patient longitudinal health data across the distributed ledger. Blockchain technology can provide the means to aggregate and identify where data are – so that organizations can access patient data on a large scale in an interoperable, secure and traceable form. Distributed Ledger Technology could therefore establish low cost, near-real time, rule-based methods for accessing patient data that can be permissioned to selected health organizations.

Before initiating Blockchain projects, hospital IT leaders and decision makers, should consider whether the technology is suitable to the hospital's needs. Not all problems require a DLT solution. That said, DLT promises to be truly effective when multiple parties generate transactions that change information in a shared repository where intermediaries are inefficient or not trusted as arbiters of truth - If this condition is not met, a shared database may be a more appropriate solution.

3 PROMISING USES OF BLOCKCHAIN FOR THE HEALTHCARE INDUSTRY

Figure 2 below, published by Chartier-Rueg and Zweifel (2017) shows an illustration for promising uses of Blockchain for the healthcare industry.

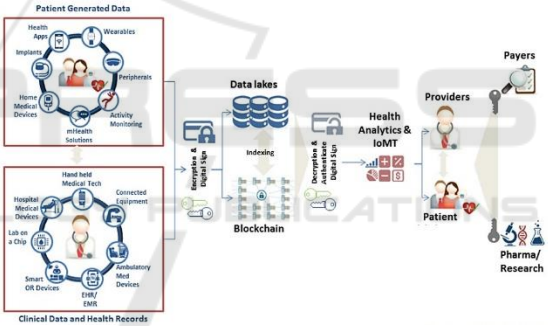

Figure 2: Promising uses of Blockchain in healthcare (simplified from Chartier-Rueg and Zweifel, 2017).

Patient generated data, clinical data and health record data are maintained in what is referred to as a data lake, a repository that holds a vast amount of raw data [BigData] in its native format until it is needed. A data lake architecture usually incorporates search and analytics techniques for decision-making, reporting, legislation and census. Blockchain implementations in this context can provide a complete index history of the patient's unique identifier and an encrypted link to health records. Each record is time stamped. Providers use health applications to access data, patients may use mobile devices to assign access permission to data. The patient has control over the permissions on whom to share data with and what portions of the data. Blockchain network consensus enables the automation of claim processing through predefined

inherent Blockchain features referred to as Smart Contracts [ensuring tokenization of the data and anonymization].

3.1 Likely and Unlikely Uses of Blockchain in the Healthcare Setting

The dynamic nature of health data and its expansiveness prohibits replicating all health records to every member in the chain, as is in the case of traditional Blockchains, this would prove bandwidth intensive, wasteful on resources and cause serious data throughput concerns (Linn and Koo, 2016).

In the immediate, for healthcare to realize benefits from distributed ledger technology, the distributed ledger technology would need to function, primarily, as an access-control manager for health records and data (Linn and Koo, 2016). That said, likely uses for distributed ledger technology in Healthcare aim at improving medical record management, enhancing insurance claim process and accelerating clinical/biomedical research (Kuo et al, 2017).

Distributed ledger technology may also prove effective as provider and patient directories, and care plans, as historical ledgers of patient care data, in support of pharmaceutical research and supply (Agbo et al, 2019) chain and medical research and in hospitals as back office component for admission, discharge, and transfer systems (ADT/ATD) (Yip, 2016).

Likely Uses:

- ✓ Improved medical record management
- ✓ Historical ledgers of patient care data
- ✓ Provider directory
- ✓ Patient directory and care plans
- ✓ Enhance insurance claim Processing
- ✓ Accelerate pharma/ medical research
- ✓ ADT back office component

Unlikely Uses:

- Full featured Electronic health record systems
- Global patient ID software
- Public Health Data Access

3.2 Improve Medical Record Management

Implementation of Blockchain technology may clear obstacles to patients acquiring copies of their healthcare records or transferring them to another healthcare provider (Patel, 2018). Records signed by the source and added to the Blockchain allow legitimacy of records to be verified. Data are stored in the private Blockchain cloud. Blockchain may guarantee unalterable patient records, as encrypted data in the Blockchain can only be read with the patient's private key (Kuo et al, 2017), which would empower patients to control access to their sensitive data (Esposito et al, 2018), which is Consistent with the European General Data Protection Regulation (GDPR) and other healthcare security regulation (HIPAA).

3.3 Enhance Insurance Claim Processing

Implementation of Blockchain technology may provide the ability to maintain verifiable claim transactions to support healthcare financing tasks and facilitate real-time claim adjudication by replacing the health plan intermediation with transparent Blockchain technologies. Blockchain' s transparency, immutability and auditability of records stored can be of great value to payers and insurance providers (Boulos et al, 2018). In addition to increased security of patient medical insurance information, payers, private and government insurers, and individual payers have the benefits of audits facilitation and better fraud detection based on Blockchain immutability (Crawford, 2017).

3.4 Accelerate Clinical/Biomedical Research

Several firms contemplate accelerating secondary use of clinical data (ie, clinical and biomedical studies and research) using Blockchain technology (Roman-Belmonte et al, 2018). The decentralized but traceable functionality of Blockchain may imply that, each institution can keep full control of their own computational resources, while collaborating with other institutions for data sharing and analysis without ceding control (Benchoufi and Ravaud, 2017). Clinical trial would have a solid dataset, reducing the risk of underreporting and exclusion (Shae and Tsai, 2017). Furthermore, the immutability property of Blockchain would be useful to certify the integrity of data collected through Blockchain for clinical study.

Personal patient-generated health data may now become available to researchers. If anonymized and then tracked in the research process with a timestamp, this secondary source of data would engage millions of individuals, healthcare providers, healthcare

entities and medical researchers to share vast amounts of genetic, diet, lifestyle, environmental and health data with guaranteed security and privacy protection (Boulos et al, 2018).

3.5 Illustrative Use Case: Back Office Component for Admission, Discharge, and Transfer Systems (ADT).

Below is a description of how a hospital (or healthcare organization) may likely adopt Blockchain into its infrastructure (Yip, 2016).
Yip, 2016 proposed, as an illustration (Figure 3), a use case of a network of public hospitals using different and disconnected electronic medical record systems (EMR).

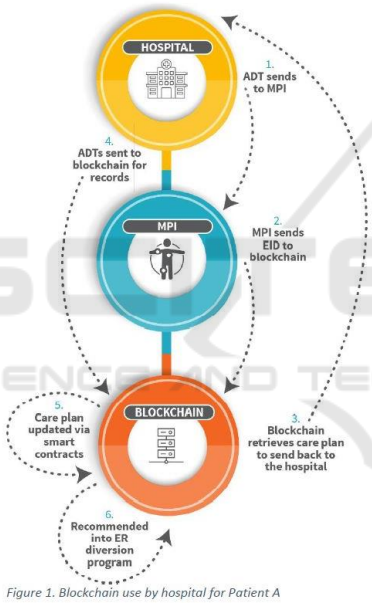

Figure 3: Illustrative Use Case: Back Office Component for Admission, Discharge, and Transfer Systems from (Yip, 2016, Fig 1).

The public hospitals, in lieu of normalizing their systems, which can be a costly endeavour, with often unsurmountable challenges, have implemented Blockchain technology to identify patients going to the hospital and clinics and determine whether were part of the network. The hospital IT team has setup a Blockchain with nodes at each of the hospitals and clinics, plug-ins and interface engines were used to connect the Blockchain with the different EMR systems at each point of care setting. For our case, we consider a patient who has moved from one city to another and now seeks admission in the local clinic in the public/national hospital network.

1. The patient's ADT information is transmitted to the MPI.
2. The MPI queries the Blockchain for patient information. [If the MPI finds no record of the patient, suggesting that the patient is a new patient in this hospital. Noticing this, staff asks if the patient wants to self-register and quickly enrolls the patient through a web interface on the intranet that connect to the Blockchain].
3. The patient directory information, with care plan data, in the Blockchain, are returned to the ADT system as a response.
4. ADT messages are sent during the admission time and discharge time respectively to the Blockchain.
5. After completion of the intervention, the patient is now waiting to be discharged.

The clinical staff admit the patient for the procedure or check-up. The Blockchain automatically updates the patient records and care plan. [In this hypothetical case, the Blockchain adds a recommendation to put the patient into an ER diversion program after noticing that the discharge message was for a minor diagnoses and this has marked three ER visits for minor diagnoses in the last month].

Similarly, as reported by Yip, 2016, on the payer's side of the data interchange, each of the hospitals and clinics used the interface engine to connect their claims system and providers to the Blockchain.

Payers were able to connect directly to the national record for the patient and process insurance claims and payments, while avoiding costly processing workflows and delays in duplicate records management.

Hospital management was able to make a dashboard of cost vs. quality measures.

Patients received access to portals connected to this Blockchain; they are able to view their medical and financial records. The Blockchain was able to provide information with a single source of truth.

4 CONCLUSION

Blockchain or distributed ledger technology (DLT) has the potential to become the backbone for digital health, incorporating data from patient-based technologies and the electronic medical records to provide a pool from which authorized users, such as providers and patients, have access.

The paper has touched upon the initial research question by demonstrating the potential of DLT technology to address major concerns in data ownership, access and use. All data are stored in a decentralized manner, with no single entity storing or having singular authority to access. This technology has already made its impact in improved medical record management, enhanced insurance claim processes and accelerated clinical/biomedical research. We conclude that DLT has a promising proposition to define data ownership and access to sensitive data; however, the jury can still be out on controlling use.

Implementation of Blockchain for healthcare are at their burgeoning stage: HealthChain, for instance, is an EMR application that uses smart contracts, or chain codes that are developed on IBM Blockchain's Hyperledger Fabric and deployed on Bluemix (Ahram et al, 2017), to control authorizations and access privileges.

4.1 A Winning Proposition

The growth of the distributed ledger technology and its premise to fuel incremental innovations will eventually become indispensable for proper data stewardship for the proper use of patients, providers, payers, pharma, medical researchers and public health analysts while respecting the privacy, confidentiality and integrity of the data asset.

For healthcare organizations that have decided to initiate Blockchain projects, the next step is to design the use cases. In this paper, we presented one illustrative use case on the effectiveness of Blockchain implementations in enhancing the security, ensuring integrity of the system and maintaining the originality of the data.

For MedTech, the use of embedded blockchain-like technology can provide a real-time mechanism to track data ownership, collection, usage and when it is used and for what purposes. A value added proposition for medical technology companies who are looking to participate in the Internet of Medical things ecosystem [1]. These companies can now leverage the added privacy, security and data protection, by design, which would improve enhance practitioners' and patients' access to trusted information, improve diagnosis, care and treatment, thus advancing the vision of medicine that is predictive, preventive, personalized and participatory ('P4') (Hood et al, 2012).

However, essentially, it seems like, until more rigor is placed on managing public keys and protecting against data loss due to hacks or otherwise, issues related to transparency and confidentiality may prohibit the use of DLT for public healthcare data. Whereas, private Blockchain implementations, with some level of control over access, would likely be the norm in healthcare settings (Dagher et al, 2018).

4.2 A Position Paper

Blockchain is among the top health technologies touted to streamline healthcare operations, lower costs and enhance quality of care. Artificial intelligence (AI), voice search, chat-bots and virtual reality (VR) are also among the list most promising health technologies in 2019[2].

Our position paper is an attempt to socialize the enigmatic distributed ledger technology and highlight its potential value in the healthcare setting. We invite researchers and practitioners to use to start the practical discussion of the technology. At this stage, a set of questions that remain without answer:

How far could public Blockchains be useful at a larger scale for public healthcare?

What will the advantages be in public health and epidemic management?

Can DLT be useful at the service of the consumer through integration with Consumer Heath Informatics?

How resilient can this technology be in correcting user errors introduced by practitioners?

How scalable could DLT become in order to integrated data and analytics from the ever-increasing integration of medical devices; scaling to accept internet of things (IoT) big data storage levels?

Can clinical researchers and practitioners obtain authorized access to clinical trials before a major drug announcement? or, to report certain reactions by their patients, then have that information be joined with other decision support criteria for drug interaction management? This would inevitably be a step in the right direction as medical trials expand into real time field data capture. Etc.

[1] https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Life-Sciences-Health-Care/gx-lshc-medtech-iomt-brochure.pdf

[2] https://healthcareweekly.com/health-technologies/

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