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Blockchain for Secure Healthcare: Opportunities, Challenges and Solutions

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ABSTRACT

With the tremendous advancement in information and communication technologies (ICT), gradually human lives have been relying on them by means of healthcare, communication, and many other aspects. However, ICT has a major issue in terms of security which is one of the hottest areas of research at present. Among the numerous modern technologies that help improving the security and privacy, Blockchain has grabbed its place and remarkably enhanced many industries. Furthermore, Blockchain is executed within or on top of the cloud computing paradigm that allows the users to obtain the essential data with more security. With that, the inherent security and privacy related issues in the cloud computing paradigm are radically mitigated. Currently, among several industrial systems, healthcare systems are maintained through cloud-based data centers to facilitate diverse stakeholders like patients, practices, labs, pharmacies, and other healthcare entities, in terms of data processing and its ubiquity. However, that is not adequate in terms security and privacy thus vulnerable to several breaches. As a potential solution, Blockchain-based Cloud Computing offers security and availability for these records which is what Healthcare systems are mainly lacking. In this paper, we will state how Blockchain is affecting the Healthcare field, and what enhancements could happen if medical systems use Blockchain. Moreover, opportunities for Blockchain for secure healthcare systems, potential challenges and their solutions are discussed.

1. INTRODUCTION

Healthcare is among those sectors that should always be deemed and improved with the emergence of new technologies for better services to the human lives. This sector deals with the enormous records containing the patient health, doctors, diagnosis, labs, and medicines, etc. These records require the most private, secure, and instantaneous transactions among the stakeholders like practices, doctors, labs, and insurance companies etc. To cope with these demands, a technology that offers the said safety and efficiency is required, and there is no competent solution but Blockchain [1]. Moreover, the healthcare sector has been evolved tremendously over the years and now it is way different than the traditional one. For instance, the telemedicine is the near future where not only patient-doctor communication will take place for sake of online prescriptions [2, 3]. But the idea has been extended to tele-surgeries with the added robotic and augmented reality virtual reality (ARVR) systems along with other information and communication technologies (ICT) like mobile cloud computing, cloud of things (CoT) [4], blockchains, holography, artificial intelligent (AI) systems, robotics, 3D printing and much more [5]. First, the issue in current systems that uses only the cloud computing technology which stores the information in data centers, accessed by several stakeholders and that it is vulnerable to breaches and a person can access sensitive or patients' private information and damage others. According to Health Insurance Portability and Accountability Act (HIPAA) compliance checklist, the electronic health record (EHR) aka patient health record (PHR) must not be disclosed to any unauthorized entity [6]. So, Blockchain seemed to be a possible remedy for such breaches. It is a peer-to-peer (p2p) network which manages and secures the transfer between potential stakeholders/parties of information. To be more precise, decentralized cloud computing based on Blockchain takes the data and breaks it down into very small pieces of data, then takes those data and encrypts them to add more protection and then distributes them across the network. Using much Blockchain functionality, such as transaction logs, crypto-logical hash functions, public/private key encryption, and dissemination etc. [7, 8], this method is accomplished. In short, Blockchain is made up of three standalone techniques, namely peer to peer (p2p) networking, cryptography, and game theory [9]. Healthcare systems have been potentially evolving by means of ICT and several practices around the globe have been widely using them. In one way it is greatly helpful to the healthcare but on the other way it makes the healthcare sector vulnerable to the breach in privacy. As the HIPAA Act of 1996 stated, "is a federal law that required the creation of national standards to protect sensitive patient health information from being disclosed without the patient's consent or knowledge." This reveals there is a dire need of a comprehensive system to assure data security and privacy [10-13].

The goal of this paper is to briefly discuss the idea of Blockchain-based cloud computing and its potential implications in the healthcare systems, the brief history of blockchain, blockchain forms, blockchain based potential opportunities various industries especially in the healthcare systems. Implementation of Blockchain technology in the healthcare and ultimately the potential challenges of incorporating Blockchain technology in healthcare.

Rest of the paper is organized as follows: Section 2 includes the background work; section 3 highlights the opportunities for healthcare blockchain. The remainder of the paper is arranged as follows. Section 4 outlines the use of the blockchain in healthcare. In section 5, problems are discussed while the paper is concluded in section 6.

2. BACKGROUND

Blockchain [14] is the technology behind Bitcoin, an open peer-to-peer (p2p) value transfer network that solved the double-spending issue for the first time. Cryptocurrencies became the first case of blockchain use, with the introduction of Bitcoin. Cryptocurrencies are like fiat money like USD or EUR, allowing value exchange, but instead of relying on a central authority such as banks as the basis for governance, using cryptographic protocols. In recent years, the knowledge that blockchain has far more to offer than cryptocurrencies have been enhanced; blockchain can be an ideal tool for building trust-based solutions. A blockchain conducts an append-only linear block chain or ledger distributed in Bitcoin-like cryptocurrencies across a network of computers; a block is a group of authenticated network exchange nodes and two blocks that are cryptographically connected. The blockchain has been distinct in recent years, however. The distributed ledger technology used in any P2P network that aims to solve problems such as double spending is often used as a general term [15].

The distributed ledger consists of an organized list of financial transactions and is a data structure. It is grouped into a chain of blocks that use cryptographic hashes to bind. In a stable and immutable way, these blocks are locked. A block can be referred to as a unified digital data (a tuple, a document, an object) and a chain can be more properly viewed as a public database stored in the cloud [16]. The chain is continuously rising at the end of the chain, where a new block is inserted. Below are the basic tasks of a blockchain node list, but not necessarily limited to:

- connect the blockchain network.
- store a current ledger.
- list transactions.
- pass on valid transactions into the network.
- list and validate for newly sealed blocks – confirming transactions.
- create and pass on new blocks.

2.1 Types of blockchain

There are three types of Blockchain: public, consortium and private, and they can be differentiated based on the degree of permission [17].

2.1.1 Public blockchain (permission-less)

This blockchain form is entirely available. It may be open to, and accessible to, the public. Without any consent, anyone can join and participate in the network and can act as a simple node or miner in the public permission-less blockchain (node). In a generic perspective the famous cryptocurrencies around the globe such as Bitcoin, Ethereum or Litecoin are few of the many examples of a decentralized blockchain. [17]

2.1.2 Consortium blockchain (public permissioned)

The type of consortium only allows a chosen group of nodes to participate in the distributed consensus process. It can either be used in an industry or more than one industry [17].

2.1.3 Private blockchain (permissioned)

A private blockchain only allows randomly chosen nodes to join the network. Control-approved networks are private blockchains where nodes can perform transactions, execute smart contracts, or function as miners. Hyperledger Fabric and Ripple are examples of blockchain networks which support private blockchain networks only [17].

3. OPPORTUNITIES FOR BLOCKCHAIN IN SECURE HEALTHCARE

This section presents the potential opportunities in healthcare sector where the blockchain can be implemented.

3.1 Cyber security

Blockchain can help bridge the gap in device interoperability and maintain security and reliability when using the Internet of Medical Things (IoMT), and this is often needed by the drug suppliers, pharmacies, and manufacturers to manage supply chains and patient records in their IT ecosystem. Similarly, in the telemedicine or tele-health, scenario where several healthcare providers/stakeholders are involved, a big necessity for the blockchain appears [18, 19].

3.2 Authentic telemedicine

Telemedicine is among the hottest areas in the healthcare sector that is being significantly investigated over last decade or so. In this technology, patients receive the healthcare services at home (remotely) without visiting physically to the doctors. Smart telemedicine systems connect doctors and patients via information and communication technologies [20]. Figure 1 shows an example telemedicine system [21] where patients and doctors are being connected to each other remotely. The telemedicine systems are mainly equipped with intelligent clinical decision support systems (CDSS) to equip remote doctors in terms of medication. This concept is not limited to the simple medication but much more. Like tele-surgery, where a procedure on patient is performed by a remote surgeon. The technology is equipped with robotics, artificial intelligence, augmented reality-virtual reality (ARVR) and mixed reality etc. Since many stakeholders are involved in telemedicine and sensitive operations are carried out that directly deals with human life. The situation demands a secure and private environment for the successful operations among the healthcare stakeholders like doctors, practices, patients, labs etc. Blockchain is a potential candidate to play that crucial role for the secure, private, and seamless telemedicine processes.

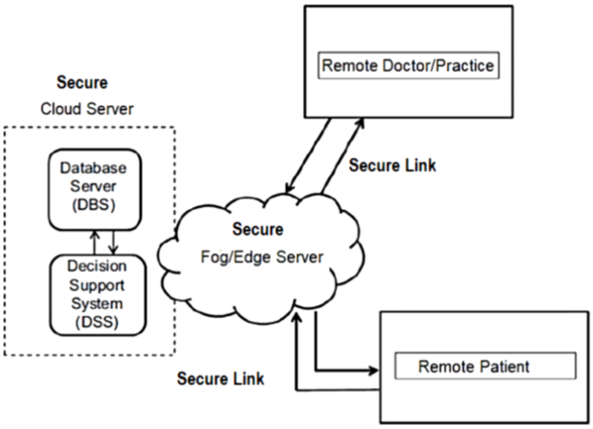

Figure 1. An example of secure telemedicine system

3.3 Secure medical transcription and billing

Medical Transcription and Billing (MTB) is among the advanced techniques being used in the modern healthcare systems. The process involves several stakeholders including doctors/practitioners, practices, pharmacies, insurance companies and MTB companies. Processes of medical transcription and medical billing are shown in the Figure 2 and Figure 3, respectively. Per Figure 2 [22], the medical transcription process is initiated from the physician. The information is encoded into Health level seven (HL7) format. It is a language for easy electronic data interchange among the devices without human intervention. It is further processed for reviewing and missing entries are completed. Consequently, the information is sent to the doctor for approval and then distributed among other stakeholders. The entire process contains patient's sensitive information that is his/her personal information (name, SSN, gender, address, contacts etc.) as well as complete medical history. Hence, the process must be secure, and authentication must be enforced. Blockchain can be a must-have in this situation to control all the processes.

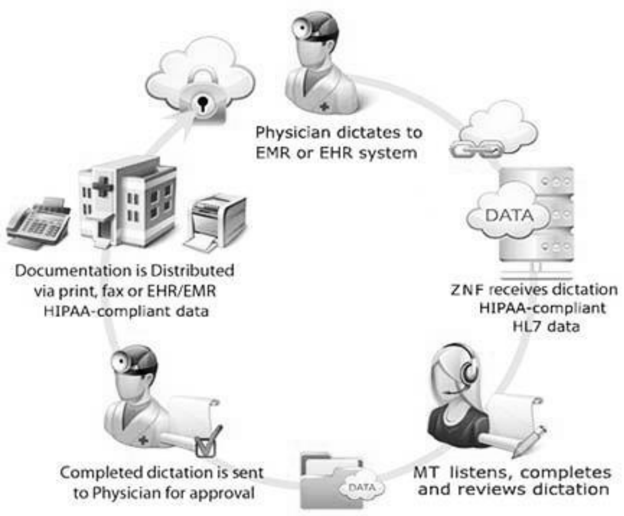

Figure 2. Medical transcription process

Figure 3 shows the medical billing process [23]. As a first step, the process starts when a patient visits a doctor, and the doctor sends the insurance claim. At second step, the claim is verified in terms of scope and coverage etc. and at third step it is sent for patient demographic entry and disease/procedure coding. At step four, after changing the entry, the claim is submitted to the insurance company for payment posting. In step six the follow ups are made through the automated systems. Finally, in the seventh step, the denials are managed and reported if there is any. As the process involves several stakeholders and billing related transactions, it must secure by the blockchain technology. So, every link must be secured.

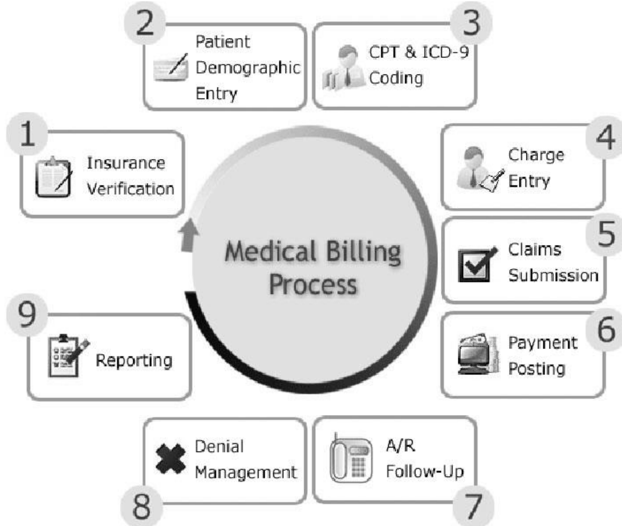

Figure 3. Medical billing process

3.4 Universal access

Blockchain can help manage access to patient data and ensure accessibility by the authorized entities through their access rights and this reduces the competition of organizations because they have access to the same information. Moreover, providing and managing users' accounts, ledgers, keys, and certificates, it is easier to provide adequate separation among the users in terms of data access without any chances of unauthorized access.

3.5 Pharmaceutical research

Blockchain helps improve and accelerate the research and development of new drugs. It can also reduce the cost of clinical trials, as well as the possibility of simplifying drug development through the availability and ease of information exchange [24]. In addition, blockchain helps improve regulatory compliance, patient experience, and reduces health care costs [25]. A significant example of such an opportunity is currently evident during the COVID-19 pandemic [26, 27]. Several agencies have been struggling for the potential vaccine. In this regard, there is a dire need for secure communication among such groups around the world that are working on the vaccine and trials.

4. APPLICATIONS OF BLOCHCHAIN IN SECURE HEALTHCARE

Healthcare is known to have enormous potential for blockchain technology. The recent evolution of this type of healthcare is coined as healthcare 5.0 [28]. Concentration must be provided to data processing to take advantage of the opportunity to connect different systems and increase the accuracy of electronic medical records. Blockchain technology can be used to enable drug prescribing and supply chain tracking and other risk data management, as well as to assist with access control and exchange of data. Since patients oversee their records, it is decided that Blockchain-based healthcare systems enhance the security and reliability of their data. We will cover two types of management and supply chain applications for blockchain-based secure and authentic healthcare applications in this article.

4.1 Blockchain-based healthcare management applications

With the growth of electronic health-related data, cloud health data storage and patient data privacy regulations, new opportunities are starting for health data management, as well as for patients allowing access and sharing of their health data. We live in a global village where information and communication technology have progressively changed our lives rigorously. In this period, for any data-driven organization to secure data, storage, etc., the transaction is highly beneficial. It covers many types of organizations, such as corporations, industries, agriculture and particularly healthcare, where blockchain technology can solve these critical problems efficiently and effectively. The healthcare sector is more important than commercial companies since it directly impacts human lives. Some of the management applications in the healthcare field have been addressed subsequently.

4.1.1 Data storage (Cloud-based application)

In blockchain technology, each transaction in healthcare is stored on a shared storage network in blocks. In Electronic Health Records (EHRs) in a healthcare application, which are considered the building blocks of a broad distributed medical storage, the medical data of a patient is structured. The cloud storage system consists of multiple storage devices, all connected to build a large size of storage that adapts to a lot of IT infrastructure. An example of IT infrastructure is known to be a blockchain-based healthcare system. The strengths of cloud storage technology include fast transmission, good sharing, storage space, low cost, and simple access [29, 30].

However, a new BlockCloud model, a combination of blockchain and cloud computing, was suggested by Kaur et al. [31]. The idea behind it, without involving any third parties, is to keep the data distributed and protected under the same roof. Telemedicine technology, where the patient can use information and communication technologies (ICT) to consult practices and medical service providers, may be another aspect of blockchain data storage [32, 33]. Data storage is mainly implemented in the cloud and fog-based systems due to the easy accessibility [34, 35].

4.1.2 Data sharing

The sharing of medical data in healthcare [36] is an important move towards improving the quality of healthcare facilities and making their systems even more intelligent. Blockchain technology plays a key role in facilitating and securing a convenient distribution system of electronic health data. Shen et al. [37] launched MedChain, which is an efficient session-based healthcare data blockchain exchange. MedChain uses a digest chain structure approach to check the integrity of a shared medical IoT data stream [38]. The results of the evaluation show that MedChain can achieve high efficiency and fulfil the healthcare data sharing protection requirements. MedChain's system design network [38] is illustrated in Figure 4. The information is stored in a distributed chain of healthcare databases (HDB). For privacy and security, a Certificate Authority (CA) is employed for key exchange and management among stakeholders. Super peers refer to potential healthcare stakeholders, such as hospitals or healthcare centers, which connect several small practices, etc. The data for healthcare consists of mutable (variable) and immutable (constant) objects exchanged via blockchain and directory services.

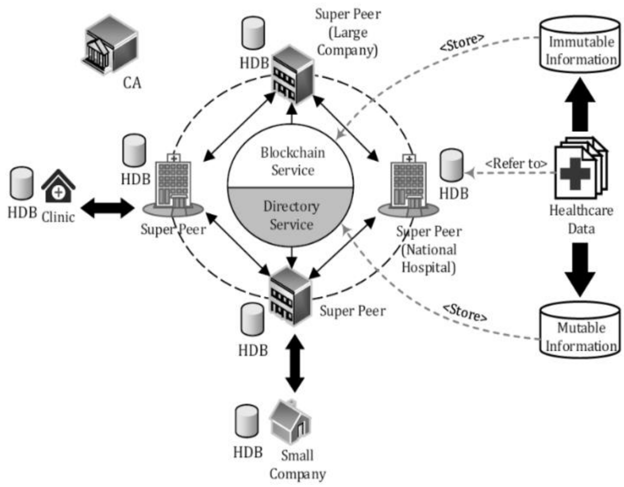

Figure 4. MedChain architecture [38]

4.1.3 Electronic Health Record (EHR)

Initial medical records are paperwork, and it is exhausting to keep track of the chronological assessment of patient status. Furthermore, they are prone to faulty knowledge that is frequently misdiagnosed by patients. Computer technology has provided the opportunity to minimize these efforts by developing EHRs, also known as patient health records (PHR) or electronic medical records (EMR). The quality of diagnosis in physicians' practices has advanced through electronic access to health records.

A secure blockchain network for the sharing of medical data was introduced by Chen et al. [39] by implementing secure cloud storage for private patient medical records. In their system, medical records management is carried out using a digital archive that has access control rights to its owner's information. This is processed by setting up cloud encryption under the chain.

Figure 2 describes the evolution of the EHR in blockchain technology [40]. It explains that the data collected from the patient is stored in the EHR on his/her proper visit to his/her doctor/practitioner and further customized by user access. As a result, it can be stored in a database, stored in the cloud, and distributed to health facilities such as hospitals, pharmacies, labs, and doctors, etc. It is noteworthy that the data distribution function is assigned to the blockchain for the sake of data integrity, privacy, and security. This process starts with a patient's visit to his/her doctor and ends with data distribution to the healthcare providers.

4.2 Blockchain-based healthcare supply chain management applications

Supply Chain Management (SCM) is prepared to include best practices in the sector to streamline the whole supply process from ordering to delivery. SCM is a challenging scope of healthcare; there is an inherent risk of undermining the process of the supply chain with scattered ordering settings of medical products, drugs, and critical services that could directly impact patient safety [41, 42]. In the healthcare sector, we have listed some SCM applications below.

4.2.1 Clinical trials

Clinical trials in healthcare face many challenges, including personal data security, data sharing, and patient enrollment [43, 44]. These problems can be solved by Blockchain technology, which provides clinical trial models with data sharing that facilitates transparency and secure reproducibility [45]. Nugent et al. [46] have deployed smart contracts on the private Ethereum network to address trust degradation and to boost data transparency in clinical trials. The aim of the analysis was to strengthen the scientific reliability of findings from clinical trials that could be undermined by missing data and selective reporting problems.

In another study, Choudhury et al. [47] proposed a novel data management framework based on permission blockchain technology using smart contracts. The aim of this study was to reduce the administrative burden, time, and effort to ensure data integrity and privacy in multi-site clinical trials. Similarly, Zhuang et al. [48] suggested a Blockchain-based clinical trial platform to automate and resolve the inherent recruitment issues of clinical trials.

4.2.2 Pharmaceutical

Pharmaceutical firms are constantly trying to improve the consistency of medicine, in addition to inventing new medications for various diseases. Such medicines are required to go through long operations to ensure patient protection, safety, efficacy, statistical validity, and approval by regulatory authorities. It normally takes several years for this technique to be completed, beginning from discovery to marketing, where clinical trials take up a significant part of the duration [49]. Blockchain technology can be used in the entire pharmaceutical process to eliminate the barrier described earlier.

Moreover, a private blockchain can also be used to ensure that all pharmaceutical products adhere to the protection of patent protection. This can be accomplished by using a smart contract providing legitimacy, traceability, and transparency [50, 51] to build a pharmaco-surveillance blockchain system in a virtual network to test the feasibility of applying the technology and its principles in a pharmaceutical surveillance system. The aim was to improve the traceability of falsified goods. The framework tolerates traditional forgery in the drug supply chain, which is considered a major problem for some Asian countries [52, 53].

5. CHALLENGES IN IMPLEMENTING BLOCKCHAIN TECHNOLOGY AND PROPOSED SOLUTIONS

In the previous sections, we have described the opportunities and potential application areas of blockchain in the healthcare. However, it may not be that straightforward and may involve certain challenges. These challenges are mainly in terms of blockchain implementation in the health sector. This section highlights these challenges and suggests some viable solutions.

5.1 Challenge 1

The first problem is the lack of interoperability due to the lack of data collection, sharing, and analysis systems. The current systems are managed using an offline architecture, in addition to centralized local databases while blockchain is decentralized and uses the cloud. Blockchain can be applied in the health field only when there is an effective electronic health record system that can adequately facilitate interoperability as well as collaboration between technical and health communities.

Solution: Electronic Data Interchange (EDI) is among the vital frameworks for appropriate information exchange in various fields especially among the healthcare stakeholders like practices, practitioners, pharmacies, and labs etc. In this regard Health Level Seven (HL7) is a developed standard that is a customized language for exchanging patient electronic health record among the concerned healthcare stakeholders. A joint venture of HL7 with Blockchain or a Blockchain enable HL7 approach can be a potential solution to the said problem/challenge [54].

5.2 Challenge 2

The second challenge is the difference in interoperability between providers and hospital systems, which leads to inconsistencies and difficulty in sharing data. In addition to how to transfer data from an electronic health record to blockchain, knowing that the techniques are different, this makes the data not ready for development and integration.

Solution: The solution to challenge-1 is also applicable for challenge-2. Since the HL7 has already been widely recognized, used, implemented by several healthcare stakeholder and possible standardization issues have been greatly resolved, it can be a potential solution to the said issue. In addition, the Portability and Transparency Act for Health Insurance (HIPAA) complies with HL7 [55] for data transformation. HIPAA widely covers the issues related to patient data during interoperability among various healthcare stakeholders.

5.3 Challenge 3

The main challenge is the fear of officials from using some modern technologies, and not enabling technicians to apply them to their systems. The biggest concern is the violation of privacy and security because they do not know the scope of security provided by the blockchain [16, 56].

Solution: As mentioned earlier, HL7 is HIPAA compliant that guarantees the privacy and security of the patient data. In case of healthcare systems, data exchange with privacy has been successfully implemented and widely used. A blockchain enabled HL7 standard can optimally solve this issue [57]. Moreover, the healthcare service providers should be educated for the potential benefits of the blockchain technology. Especially, if the guidance and encouragements come from the government bodies, the trust for the blockchain technology will be created [58].

The solution can be summarized as, there is a dire need to design a comprehensive framework that combines the ideas of electronic data interchange in compliance with the related acts suggested by various nations. Additionally, equipped with blockchain technology to ensure the automated data interchange seamless and secure in all aspects. Administratively, there is need to educate the concerned authorities over the importance of blockchain in healthcare and involving other current and state-of-the-art technologies on board [59-70].

6. CONCLUSIONS

In conclusion, blockchain is a technology that offers privacy, security, and efficiency in the transaction of the information, which is needed for healthcare systems. There are three types of Blockchain which are: Public, consortium and private and can be differentiated between them based on permission level. Many healthcare applications that use Blockchain as part of them are blockchain-based healthcare applications Management and Supply Chain applications.

Moreover, there is one administrative and two technical challenges in implementing Blockchain in the healthcare. For instance, the healthcare systems lack interoperability due to the lack of structures for information collection, exchange, and analysis, and the difference in interoperability between providers and hospital systems, which leads to inconsistencies and difficulty in sharing data. Blockchain enabled HL7 can be a potential solution to the said issues.

Apart from that, the administrative challenge is to convince the authorities in the implementation of the blockchain in healthcare sector. This study provides a significant roadmap in the implementation of the said system for a secure healthcare environment.

Moreover, one of Saudi vision 2030 goals is transforming healthcare services electronically, so, implementing Blockchain enabled HL7 for EHR will help in the transformation of the healthcare services in Saudi Arabia.

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