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Adapting hybrid approaches for electronic medical record management and sharing using blockchain sharding

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ABSTRACT

In the past few years, it is noticed that management and sharing medical records is a key step towards increasing healthcare provider connectivity and making the healthcare system more efficient. The scalability and sustainability issues confer to mismanagement of patient is record and also raised several issues in privacy and security. The study aims to suggest more efficient alternatives for Electronic Healthcare System. Scalability and privacy are the major limitations that existing systems contain so the goal of this study is to define alternatives about how parameters like scalability, usability and data protection could be achieved in an efficient manner for healthcare system. In the healthcare industry, providing accurate, thorough, and up-to-date information on patients is critical. Another feature that allows researchers to consider efficient EHR systems is rapid access to patient records for boosting efficiency and coordination. Blockchain sharding technique is utilized along with hyper-ledger protocols and Proof-of-Authority to carry out our model implementation.

Keywords: Blockchain Systems, Blockchain Sharding, Scalability in Blockchain, Survey of Blockchain Sharding

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1. Introduction

The technological revolution has altered lifestyle of peoples. Every attempt is being made to attain a world without hu- mans. Technology is one of the most essential and prominent perspectives that has been concentrated during the last decade, during which we have witnessed tremendous growth. A slew of new technological trends has emerged, and the number of them is growing by the day. The primary goal of all this hard work on technology is to decrease human effort while producing high-quality and efficient results. Among the other technologies, blockchain is a vital center where efforts are being made to make it more helpful in this era of technology. The use of technology in every field of life changes the way of processes. The medical field is one of the most concentrated ones. New advancements are being made rapidly to increase usability and maintainability. We would have seen technology used in various fields, including retail, medical or healthcare [1], education, labour force, management, industrial, and various other areas [2]. It also supports current technologies such as the Internet of Things [3], intelligent cities and finance, cloud computing, supply chain management, and much more. When defining blockchain using a layman approach, it is more likely an interconnected and associated chain of blocks that act as distributed and open ledgers [4].

In depth details regarding the problem statement alongside objective are briefly described in Section I. The technology of blockchain is demonstrated through Consensus Mechanism alongside Transparency constraints in section II. Different Existing approaches and gaps are illustrated in Section III which enlightened the purposed model of MedRec, MedBlock, HDG. The Phases of Selective Pruning Algorithm is also illustrated in this

section. In Section IV of the paper, the existing system in the respective domains are illustrated which includes the model of ERS, AdvantaChart and NextGen. Section V of the paper illustrates the Methodology which revolves around the data collection, data categorization, blockchain net- work configuration and phase of model implementation. The evaluation and validation approaches meant for the purpose are also described in this section V of the paper. Section VI provides detail overview over the results acquired from PoA algorithm implementation which are observed through different constraints. Section VII and VIII discuss the major conclusion or achieve goals during this research while the major limitation faced down the road are discussed in limitation.

1.1. Background

W. Scott Stornetta and Stuart Harber first proposed a time-stamping approach using signatures, pseudorandom algorithms, and discussed practical implementation of cryptographical technology hash functions in 1991. They thoroughly proposed a time-stamping approach using signatures concept, pseudorandom algorithms, and discussed the practical application of crypto-graphical technology hash functions [5]. In 2014, Ethereum Blockchain System, also known as smart contracts, was launched to utilize blockchain technology outside of the financial domain [6]. Several hypergeometric distributions have been proposed for a variety of blockchain sharding concerns [7]. Sharing the information by keeping it secure from every perspective is one of the vital concepts behind blockchain technology.

Blockchain technology, which serves many other purposes, also helps in managing authentication, accountability, data exchange and confidentiality. It also helps in handling privacy related, medical resource-saving related and patient facilitation related concerns, making the smart healthcare network/system [8]. The focus of this paper is to highlight the blockchain technology. We will discuss the related work done in the past to improve the electronic medical record system that contributed towards the advancements of medical field.

1.2. Statement of problem

Blockchain technology has recently been widely utilized for securely exchanging medical records among healthcare providers. Patients who have many caregivers must success- fully exchange their medical history in order to get better treatment. As a result, it is critical that health records be shared across many stakeholders in the healthcare system, including doctors and their patients and persons, as well as other concerns like insurance organizations. Management and sharing medical records are a key step towards increasing healthcare provider connectivity and making the healthcare system more efficient. The major problem in focus is the scalability of Electronic Health Records (EHR). In addition to that, the privacy of users and throughput or efficiency are also under consideration to be resolved through the proposed system, as most of the existing system lacks these quality attributes.

1.3. Motivation and objective

Moreover, the tempering of medical records is another issue that is still encountered. According to research, the number of breaches is growing by 10% on an annual basis, which appears to highlight the healthcare system weaknesses. In the 15 years, i.e. from 2005-2019, there are about 249 million people who got affected by data breaches in the healthcare sector [9]. EHRs aid in the delivery of improved patient care and the automation of a range of duties in the practice.

Scalability is one of the existing issues that most of the EHRs facing these days. Scalability refers to a system is capacity to grow gracefully when new resources are added [10]. The scalability and sustainability issues confer to mismanagement of patient is record and also raised several issues in privacy and security. The incorporation of blockchain in EHR system enables to security develop such system that fully protect the sensitive or private data as well as providing accessibility to authorized users only so the information could be kept secure. The improvement in scalability to ensure sustainability in EHR systems is major concern in medical sector. This motivates us to initiate this study for that overcomes the scalability issues and challenges in Electronic Health Record (HER) system.

Keeping this in view, main objective major goal of this thesis is to deal with the scalability issue in healthcare Blockchain networks and to offer a feasible solution for administration and sharing across several organizations. In order to achieve the project is aim, the following four goals are set that defines the successful completion of the project.

This study aims to provide better alternatives for the problems or constraints like scalability and privacy in the existing systems, by using Hyper-ledger oriented Blockchain technology for health care systems and to deliver smart con- tracts for E-HealthCare system to improve throughput. The main objectives include designing a novel, scalable model of healthcare that is based on Blockchain technology for management of Electronic Health Record or EHR, using Proof- of-Authority (PoA) for all the Blockchain network nodes, evaluation measures of suggested model are performance and network lifespan in a simulated scenario and testability of blockchain sharding in EHR management.

2. Blockchain technology

In this section, we will the important constructs of blockchain technology. In the previous discussion, a number of research work was discussed related blockchain sharding and we see what models are already present in the current era of technology and more advancements are carried out to achieve better performance and desired outcomes. In the upcoming sub-headings of this section, we will see the characteristics of blockchain technology in a brief manner to demonstrate more about this technology.

2.1. Consensus mechanism

Blockchain technology has specified consensus mechanisms [9] which allows the users or nodes to keep their accounts. These consensuses include the Proof-of-Work (PoW) or Proof-of-Stake (PoS) mechanisms. Moreover, from much other participation, only a single node or participant is selected whereas other time costs and resources are wasted. In the other mechanism i.e., PoS, the account keeping depends upon the assets nodes have or digital currency which the blockchain technology analyze and record. Another similar to PoS mechanism is called Delegated Proof-of-Stake (DPoS), in which verification of proxy and accounts is done for accounts. There are number of off-the-shelf cryptographic technique that can be used for manipulating data by different organizations [10].

2.2. Transparency

The nodes could be ledger for any information on the network. This means that the transparent behavior is provided by the blockchain technology, and it opens for all the participating nodes to gain access to information defined as public. This makes the addition of openness and transparent attribute in the blockchain technology.

3. Related work

Decentralization, security, transparency, and anonymity are all characteristics of blockchain technology, and it is intended to enhance the healthcare system. Blockchain technology has the potential to change how medical records are managed and shared across numerous healthcare providers, therefore boosting treatment quality and efficiency. Through- out the years, many Blockchain systems have been proposed in the literature. The following is a collection of some of the literature about Blockchain.

3.1. Real-time maintenance of patient health information / record

The faculty of Science and Technology, University of Macau, China has proposed MedRec, a decentralized distributed ledger solution based on Blockchain technology that enables the exchange and maintenance of patient health in- formation [11]. It was created in 2016 by MIT researchers to facilitate EHR management and sharing. The objective of this proposed system was the live record management of patient records or exchange of relative information among other members of the system. The MedRec platform ensures patients privacy and exchanges health records in real-time. A data block of MedRec represents both viewing and shared ownership by through network users via a private P2P proto- col. To protect medical records against manipulation, Proof-of- Work (PoW), a consensus technique, was developed. However, as the number of network users grows in Blockchain, the computational cost of PoW rises, leading to poor performance on a network with a large number of transactions with regard to this element, MedRec did not suggest a means for scaling up the system.

3.2. Secure and efficient medical data sharing

Data sharing among the other members of the network is an important task that is somehow continuously happening all the time. Sharing of information or records with other members serves no purpose if the security of the information is comprised in any manner. Hence, MedBlock [12] provides facilitating effective data interchange and collaboration, presents a Blockchain- based approach for resolving the issue of large-scale

medical record sharing in healthcare systems, allowing healthcare providers to obtain patients treatment history prior to consulting with them. These processes, on the other hand, are conducted in a sequential manner rather than simultaneously. Therefore, some nodes remain dormant until a single operation has been performed on them because of the presence of medical records hash values, the method considers the encrypted summary diagnostic records to be additional storage on the distributed ledger, which is considered additional storage on the distributed ledger. This consumes ledger storage and makes it difficult to handle a large number of transactions at the same time.

3.3. Privacy control risk

The fact that multiple organizations maintain separate and fragmented patient health data is one of the key concerns in today healthcare [13]. Third-party inclusion in the system may offer various privacy risk that may not be acceptable to the users. When talking about the security of records, information of the patients are their private rights where and controlling the risks to damage the safety of information is another concern for intelligent healthcare systems. Healthcare Data Gateway (HDG) [14] is an intelligent solution that allows a patient to manage and share the flow of their medical data. It is a Blockchain software that depends on a portal and a traditional database. Patient medical records are stored in the main ledger and a storage pool by an intelligent application.

3.4. Nodes segmentation: A sharding approach

Preservation of patient's medication history is another important construct that enables the medical operators to identify future actions to ensure better and safe health. The authors of [15] proposed a system for securely and efficiently exchanging medication histories across several healthcare institutions. Re- searchers describe healthcare Blockchain on sharding-based architecture and compare this model performance to with healthcare Blockchain unsharded model in this study [16]. It is the first of its type, with shards produced for patient visits and processed simultaneously. With the successful deployment of hashing in the healthcare Blockchain, the model performance in terms of consensus latency has improved; nonetheless, the model requires improvements in terms of security prototypes, health records management, and rapid patient record updates.

3.5. Transparency in personal health records (PHRs)

As the earlier sub-headings of this section highlighted the record management of patients. However, transparency is another key aspect that should be a targeted concern of the researchers. The authors of [17] conducted a study on Blockchain applications and found out that the technology has the potential to enable an equitable, secure, and transparent data management in medical records. The study further concluded that Blockchain technology is advantageous in distribution of ownership, access, and control of data for end users. The study found that one of the most critical factors in the application of Blockchain technologies in health records management is the aspect of scalability. Basic scalability ideas that arose from the study include, new BFT consensus framework, Proof-of-Authority, tiered sidechains, and tiered chains, among motley of other modified Blockchain architecture.

3.6. Efficient data management and increasing throughput

As we know, there can be urgencies when talking particularly about health of the community, where availability of information could be required on urgent basis like in case of heart stroke or other issues like that. In such conditions, the retrieval of required data swiftly and efficiently plays a vital role in saving the life. This statement can technically be described as increasing the transaction of records per seconds which is also known as throughput. Authors in [18] provided a critical analysis on how Blockchain technology would provide an effective and constructive scheme anchored on transactional categories in patient data management. The entire experiment in [18] demonstrated that shard protocols resulted into elevated throughput with the subsequent DAG Blockchain showing massive evidence of high scalability. The study concluded that the presence of low performance is a critical issue in sharded blockchain. In this regard, major network downtimes and transaction

delays have been observed to arise from disordered sharded blockchains due to data verification and cross-shard communication architecture.

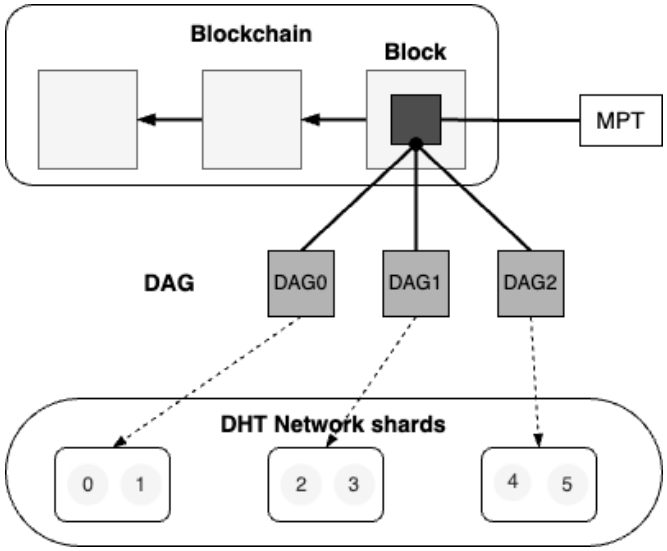

Figure 1. Architecture of SSC blockchain model

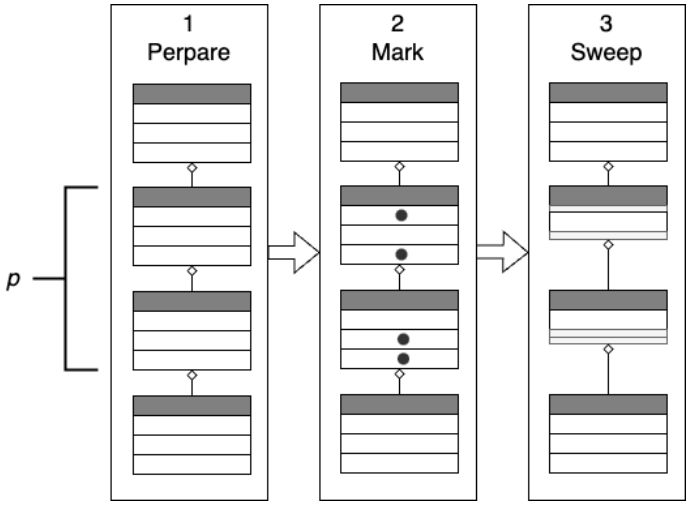

Figure 2. Phases of selective pruning algorithm

We can see in Figure 3. the intra-shard transaction where different categories of users are represented in a different color filled circles and the corresponding transaction frequency graph.

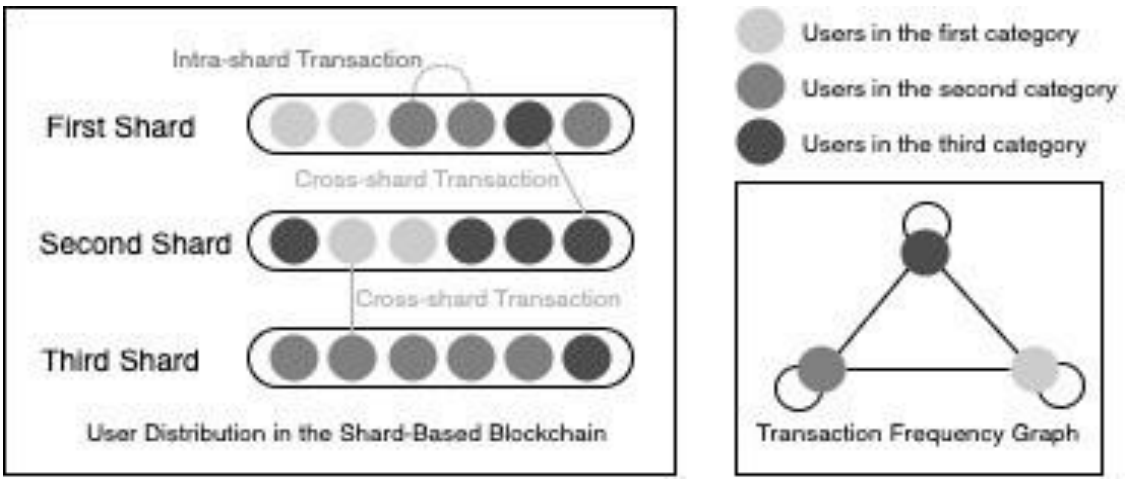

Figure 3. Shard-based dynamic model for blockchain

4. Existing systems

4.1. Electronic registry system (ERS)

During 1995-96, Singapore National Computer Board began work on the ERS (Electronic Registry System), which served as a unified platform for all government departments at the time. Several government entities, including NCB, spearheaded the automation effort. The ERs Project goal was to implement ERS throughout all public service organizations and institutions, reducing duplication in development and maintenance and achieving scale and scope synergies.

4.2. AdvantaChart

This is a Windows-based EMR programme that was developed in collaboration with gynecologists and obstetricians. The technology is simple to use and comes at a reasonable price. Aside from that, this technology might be utilized to optimize workflow and deliver high-quality medical care. Doctors and healthcare workers may record all phone conversations, patient records and several tests' results using the user- friendly interface. The system is dependable in that it allows patients information and records to be accessed from faraway places via an Internet connection. To develop, manage, and retrieve patient information, this system combines recognition and image classification and other technological procedures. It aids in the tracing of patient data; the movement of a specific patient may be tracked at all times [19].

4.3. NextGen

It may accommodate small to large medical practices. This system is ideal for healthcare practitioners that need to keep track of administrative and clinical data. It a complete system with built-in user-friendly features that allow convenient and simple adaptation of work processes and options for over 20 different specialties, including dermatology, orthopedics, urology, neurology etc. The system has the potential to enhance quality, lower risk, lower costs, and boost income for the user [20].

5. Methodology

In the case of healthcare networks based on blockchain technology, scalability has been a barrier in the adoption of any fast-growing technology. Not every entity in such a network needs a comprehensive blockchain ledger. As a result, our suggested strategies concentrate on interactions between just the network concerned participants, i.e., on a need-to- know basis. To do this, the suggested approach employs the sharding technique, successfully resolving the scalability issue. As previously stated, sharding is a strategy that involves partitioning and parallel transaction processing. Shards are several groups/committees that make up a traditional blockchain implementation. Each shard analyzes its own events and keeps track of the distributed or shared ledger in a single view. The whole network is scaled out by adding all shard operations in parallel.

The major goal of this research is to develop a sharding Blockchain-based approach for keeping and exchanging medical information. The nodes are separated into shards that perform the defined purpose in sharding Blockchain technology. This improves scalability while also allowing for decentralization. The privacy feature will be implemented utilizing blockchain. When setting sharding, the Proof of Authority (PoA) protects data confidentiality. As a result, the hyper-ledger and sharding blockchain technology addresses the concerns raised in the problem description and achieves the goals of this proposal.

5.1. Data collection

As we know that data plays a vital role in every field these days where business intelligence and other data-driven terminologies are being implemented. The need of data is getting higher, and several mechanisms are adopted to gather the intended data. For our blockchain system, heterogeneous medical data will be gathered from a variety of potential sources, including text records, medications, x-rays, and CT scans, all of which contain medical records data for several people.

5.2. Data categorization

Categorization is another important aspect in scalability. As we know, in blockchain network when specifically talking about scalability issue, there is a need to share the information amongst the authorized users only. Also, making it possible for user to find the filter data when required is also a major part. This makes the categorization another important step in our EHR system. The collected medical record data will be classified, named, by type and description, while maintaining patient privacy.

5.3. Blockchain network configuration

A consensus algorithm is a technique that ensures that all network participants in a decentralized distributed system agree on the present state of the distributed ledger. In the blockchain ecosystem, many consensus algorithms are utilized, including Byzantine Fault Tolerance (BFT), Proof-of- Authority (PoA), Proof-of-Work (PoW), Proof-of-Stake (PoS), Practical Byzantine Fault and Fault Tolerance (PBFT). PoA has quickly acquired traction in a variety of blockchain applications, spanning from software applications to the healthcare domain. For its comparatively simple and rapid transaction processing, our proposed approach employs a PoA consensus algorithm. At this stage, the settings and parameters of the blockchain network will be adjusted, and the environment will be prepared to implement the proposed design to suit the management and sharing of medical records.

5.4. Model implementation

Implementation of the proposed model components for management and participation, in addition to the attention of powers and insurance. Smart contracts are executing scripts that handle requests on the blockchain network. Because the blockchain does not launch any code itself, smart contracts initiate all processing on the blockchain network. Smart contracts in the proposed network trigger numerous events that serve as a bridge between various layers in layered models, such as node enrollments, shard formation, request transactions, data search, reacting to the request node, triggering the consensus protocol, and appending blocks to the blockchain network. Node allocation to a shard is dependent on the nodes in a network matching the patient public key, i.e. the BN validates the DS they got and checks their patient registry for a reference of the propagated patient public key. The request is discarded by nodes which do not discover a record for patient public key. Nodes that detect a reference for patient public key in their database create a digital instance of the node for the forming shard. If a patient has previously explored a hospital and needs to discuss his or her medical history with his or her present provider, a full shard based on the patient public key is created, which includes all of the patient previously visited entities.

5.5. Validation and evaluation

Validation of the proposed model will be tested through a simulation and evaluation of the results of sharing and management, and monitoring of records and outputs. There are many Block technology based EHR systems as there are extant BT protocols, depending on the requirements of the Health Care System to be met. Some writers, for example, have used the Hyperledger Composer Fabric platform to construct EHR systems, while others have chosen Ethereum, and yet others have chosen Bitcoin. A simulation model is created in this study based on the design of three of the most potential blockchain frameworks for creating health care systems: Ethereum, Dogecoin, and Bitcoin. Each of these three procedures was chosen for the current study based on distinct but supportive criteria for conducting a comparative analysis.

6. Result and discussion

Using blockchain for processing patient's records in the system, the results showed that average processed records for appointment increased greatly as compared to the system without blockchain technology. Figure 4. shows the results for EHR processed against each node on similar simulation configuration. This is because the PoA algorithm when used parallel inclined the processed results.

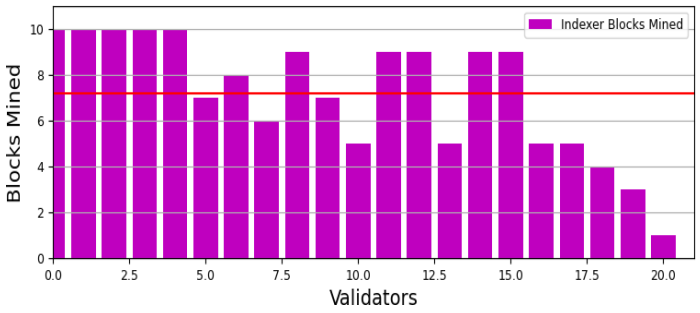

Figure 4. Validators with mined blocks

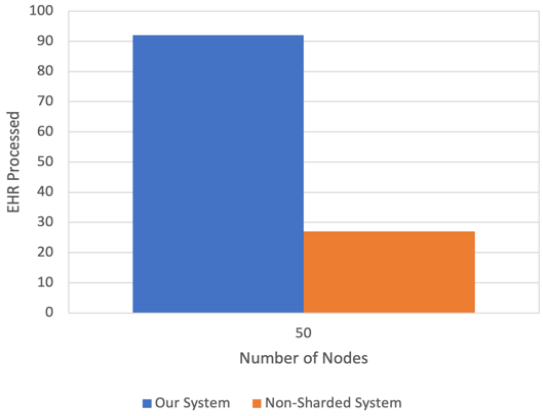

Figure 5. Number of EHR processed

The stability is also checked under the same conse- quences when increased the number of nodes. Within the shards that are created based on the patient's medical history, transactions are executed. Because not all nodes engage in the consensus process, increasing the number of blockchain nodes has little impact on performance because only shard nodes participate in the block validation for each appointment as shown in the Figure 6.

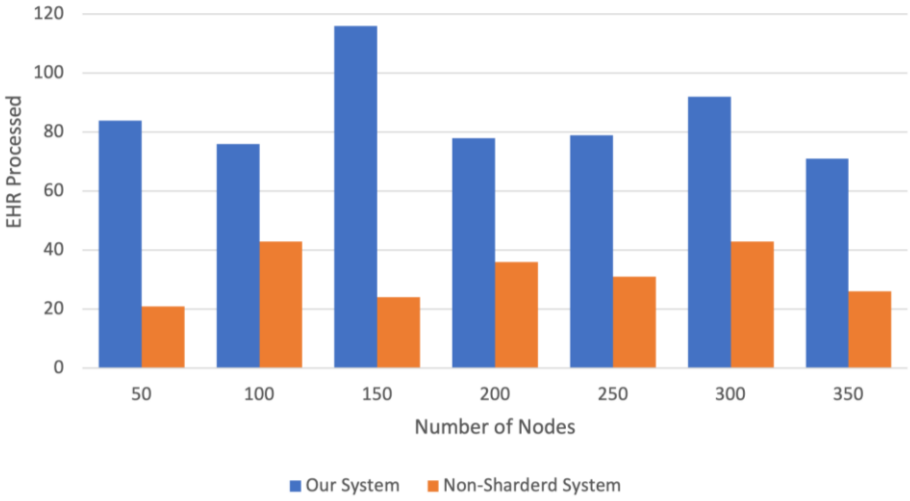

Figure 6. Average results processed

7. Conclusion

In this paper, we offer a healthcare blockchain model based on sharding and evaluate its performance against a model without sharding. According to the simulation findings, our suggested approach performs better with regard to the consensus delay, throughput, and the quantity of appointments handled. The suggested technique removes cross-shard communication, which in any sharded paradigm reduces system performance. Following the implementation of sharding in the healthcare blockchain, numerous improvements should be taken into account in upcoming studies from a practical standpoint. These improvements include modelling related security threats, handling urgent cases, managing EHRs, and facilitating patient record updates. However, there is still way forward to make Electronic Health Record system by using other technologies to make it more efficient and more secure when it comes to global implementation and distribution to wide networks.

8. Limitations

The decentralized nature of Blockchain means that any- one may check and conduct financial digital transactions. Several Blockchain applications have been developed recently by researchers. Despite this, Bitcoin has been subjected to a wide range of security and privacy issues. For example, once a person associates a public key with a person identity, he can search the Blockchain for previous transactions and analyze all transactions involving that public key. As a result, the key difficulty is to strike a balance between an individual privacy and security, as well as accountability. They first highlighted several assaults on systems based on Blockchain before delving into the connections between them. Scalability is the most prevalent flaw and exploit in Electronic Health Record Systems.

Declaration of competing interest

The authors declare that they have no known financial or non-financial competing interests in any material discussed in this paper.

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