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HEALTHCARE SYSTEMS USING BLOCKCHAIN

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ABSTRACT

For a long time, blockchain has been an intriguing study field, and the benefits it brings have been employed by a variety of sectors. Similarly, the healthcare sector will gain greatly from blockchain technology because to its security, privacy, secrecy, and decentralisation. Nonetheless, concerns with data security, integrity, and management plague Electronic Health Record (EHR) systems. In this article, we explain how blockchain technology might be leveraged to alter EHR systems and potentially solve these problems. We provide a framework for the use of blockchain technology in the healthcare industry for EHR deployment.The goal of our proposed framework is to first use blockchain technology for EHR and then to enable safe storage of electronic records for users of the proposed framework by setting granular access controls. Furthermore, this framework addresses the scalability issue that blockchain technology has in general by utilising off-chain record storing. This architecture enhances the EHR system by providing a scalable, secure, and integrated blockchain-based solution

INDEX TERMS

blockchain, health records, electronic health records, decentralization, and scalability

I. INTRODUCTION

The current creation of the era affects all elements of the human lifestyle and changes the way we use and understand things. It is also finding new avenues for the development of healthcare, just as the era of coordination has taken place in different areas of the lifestyle. The main benefits brought about by the development of the times are safety, consumer enjoyment, and improved factors in various health sectors. These benefits were provided through electronic health record (EHR) and electronic medical record (EMR) systems. However, there are still some issues related to the safety of scientific facts, the possession of facts by consumers, the completeness of facts, and so on. The solution to these problems may be to use a unique era. H. Blockchain. This era provides a secure platform for storing scientific facts and other health-related information.

Before the arrival of contemporary-day technology, healthcare quarter used paper primarily based totally device to keep the scientific records, i.e., the usage of handwritten mechanism. This paper-primarily based totally scientific document device become inefficient, insecure, unorganized and become now no longer temper-proof. It additionally confronted the problem of data- duplication and redundancy as all of the establishments that affected person visited had diverse copies of affected person"s scientific records. The healthcare quarter confronted a fashion shift closer to EHR structures that had been designed to mix paper-primarily based totally and digital scientific records (EMR). These structures had been used to keep scientific notes and laboratory consequences in its more than one components [1]. They had been proposed to beautify the protection element of the sufferers with the aid of using stopping mistakes and growing data access [2]. The purpose of EHR structures turned into to remedy the troubles confronted with the aid of using the paper-primarily based totally healthcare facts and to offer an green device that could remodel the kingdom of healthcare area [3]. The EHR structures had been carried out in some of hospitals round the arena due the blessings it offers, especially the development in safety and its costeffectiveness. They are taken into consideration a critical a part of healthcare area because it offers a lot capability to the healthcare [4].

These functionalities are digital garage of scientific statistics, patients" appointment management, billing and accounts, and lab tests. They are to be had in the various EHR gadget getting used withinside the healthcare sector. The fundamental cognizance is to offer secure, temper-proof, and shareable scientific statistics throughout unique platforms. Despite the reality that perception at the back of utilization of EHR structures withinside the hospitals or healthcare changed into to enhance the best of healthcare, those structures confronted positive issues and didn"t meet the expectancies related to them [3]. A take a look at changed into performed in Finland to locate the reviews of nursing body of workers with the EHR, it changed into concluded that EHR structures confronted the issues associated with them being unreliable and having a terrible nation of userfriendliness [5].

II. RELATED WORK

Blockchain generation turned into designed through Satoshi Nakamoto [13], the simple concept turned into to have a cryptographically secured and a decentralized foreign money that could be beneficial for monetary transactions. Eventually, this concept of blockchain turned into being utilized in numerous different fields of life; healthcare area additionally being certainly considered one among them intends to apply it. A quantity of researchers have executed the studies in this area, those studies works consciousness at the truth that whether or not the concept of the use of blockchain for healthcare area is viable or not. They additionally perceive the advantages, threats, troubles or demanding situations related through using this generation. Some researchers additionally mentioned the demanding situations that could be confronted at the same time as clearly enforcing this on a bigger scale.

A.THEORETICAL/ANALYTICAL BLOCKCHAIN-BASED RESEARCH

Gordon and Catalini [14], carried out a examine that targeted at the strategies with the aid of using which blockchain era might facilitate the healthcare quarter. They recognized, that healthcare quarter is managed with the aid of using hospitals, pharmaceutical groups and different worried 1/3 parties. They certain statistics sharing as the important thing cause why blockchains ought to be utilized in healthcare. This examine additionally recognized 4 elements or techniques because of which healthcare quarter desires to convert for utilization of blockchain era. These encompass manner for dealing of virtual get admission to rights, statistics availability, and quicker get admission to to medical statistics and affected person identity. It additionally discusses the onchain and off-chain garage of statistics. The examine additionally blanketed the demanding situations or limitations confronted with the aid of using utilization of blockchain era those have been large quantity of medical. Eberhardt et al. [20], performed a observe to recognize feasible processes to clear up the scalability trouble of blockchain and additionally to pick out such tasks that intend to clear up this trouble. They outline blockchain as composition of numerous computational and low in cost standards primarily based totally on peer-to-peer system. The purpose of this observe become to locate which records ought to be saved on-chain and what may be saved offchain. This observe provided 5 styles for offchain garage of records and additionally consists of the fundamental thoughts and implementation framework of those styles. The authors give an explanation for on-chain records is any records this is saved at the blockchain through appearing transactions on it. While offchain records garage is to area records someplace else on every other garage medium however now no longer onchain and it additionally could now no longer consist of any transactions.

B.PROTOTYPE/IMPLEMENTATION BLOCKCHAINBASED RESEARCH

Sahoo and Baruah [24], proposed a scalable framework of blockchain the use of Hadoop database. In order to clear up the scalability hassle of blockchain, they proposed to apply the scalability supplied with the aid of using the underlying Hadoop database together with the decentralization supplied with the aid of using the blockchain technology. They used the approach to shop blocks at the Hadoop database, the blockchain on pinnacle of this framework consists of all the wished dependencies of blockchain however the blocks are saved on Hadoop database to enhance scalability of the blockchain technology. To address the scalability hassle of blockchain platform this have a look at gives to apply Hadoop database system, together with SHA3-256 for hashing used for transactions and blocks. The programming language used for this structure turned into Java. This look at, turned into beneficial in information that blockchain may be used with different structures which can be scalable to enhance or remedy the scalability of this platform. Zhang et al. [25], proposed a scalable option to the blockchain for scientific records. The simple purpose of this look at turned into to layout such an structure that complies with the Office of National Coordinator for Health Information Technology (ONC) necessities. This look at diagnosed the boundaries that this era faces in particular consist of worries associated with privacy, safety of blockchain, and scalability issues associated with big extent of datasets being transmitted in this platform, and ultimately there may be no everyday trendy enforced for statistics being exchanged on blockchain. This look at additionally consist of an illustration of a decentralized application (DAPP) primarily based totally at the layout formulated at the ONC necessities as noted before.

Kim et al. [26] proposed a machine for control of scientific questionnaires and the intention of this machine is records sharing thru blockchain era. The authors give an explanation for that choice of records garage and sharing of scientific questionnaire is to apply this records for in addition scientific and scientific studies purposes. They emphasised that it might be beneficial for growing prognosis machine, resolving terminologies being utilized in EHR structures and safety troubles related to those structures become additionally a motive because of which authors decided on blockchain era for his or her proposed framework. This observe incorporates fundamental functions, i.e., to create, keep the records amassed through questionnaires and to proportion that records. Another advantage proposed through the machine is the validation of the questionnaire being submitted withinside the machine.

III. BLOCKCHAIN TECHNOLOGY AND ITS DEPENDENCIES

This era changed into delivered with the aid of using Satoshi Nakamoto [13], for his famous paintings of virtual foreign money or crypto-foreign money, i.e., bitcoin. Nakamoto used blockchain era to clear up the double spending hassle of bitcoin however quickly this novel era changed into getting used in lots of different applications. Blockchain is a series of blocks which are related collectively and are constantly developing with the aid of using storing transactions at the blocks. This platform makes use of a decentralized technique that permits the facts to be allotted and that every piece of allotted facts or usually called information have shared ownership. Blockchains holds batches of transactions which are hashed for this reason supplying them protection and they're controlled with the aid of using peer-to-peer networks. A blockchain has positive blessings which include security, anonymity, and integrity of facts and not using a 0.33 birthday birthday celebration intervention. These blessings make it an inexpensive preference to save patient‟s clinical statistics on it, due to the fact the innovation of generation withinside the healthcare enterprise has made the safety of patient‟s clinical facts a pinnacle priority. A wide variety of researchers have additionally diagnosed that the usage of blockchain generation in healthcare might be a viable solution [14] [15][16].

A. ARCHITECTURE

To understand the blockchain architecture let us use the following figure 1 that explains the whole process of a transaction being send from a user on the blockchain network.

1. A new transaction being despatched with the aid of using a person at the blockchain community indicates that a brand new block is created. A block withinside the blockchain is used for retaining transactions in them and those blocks are dispensed to all the linked nodes withinside the community. That transaction located internal a block is broadcasted to all the nodes withinside the community. All the nodes withinside the community have a replica of the whole blockchain that allows them in verification process. When a block containing the person.If Transaction is broadcasted to all of the related nodes, they affirm that the block isn`t tampered with the resource of the usage of any approach this verification consequences in achievement then the nodes upload that block of their very own replica of blockchain.
2. This complete technique of the block being brought at the blockchain is carried out with the aid of using the nodes attaining upon a consensus in which they determine which blocks are legitimate to be brought at the blockchain and which can be not. This validation is carried out with the aid of using the linked nodes the use of a few recognized algorithms to affirm the transaction and to make certain that sender is an authenticated a part of the network. When a node succeeds in acting the validation that node is rewarded with crypto-currency. This technique of validating the transaction is referred to as mining and the node acting this validation is referred to as miner.
3. After validation is performed that block is brought to the blockchain. After the entire method of validation is executed the transaction is completed.

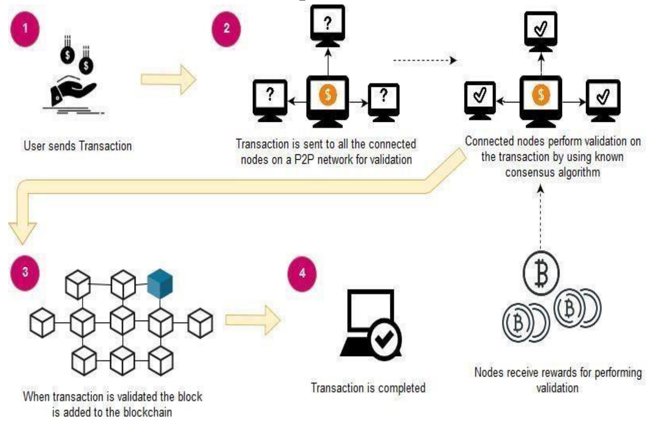

FIGURE 1.An Overview of Blockchain Architecture

Some basic concepts of blockchain technology can be understood in the following descriptions.

B. BLOCK

As defined in advance blockchain are fashioned collectively through some of blocks related collectively in a peerto-peer community for this reason creating a decentralized application. The header of those blocks incorporates hashes of preceding blocks in them. A block incorporates 3 matters in it that are statistics, hash of modern block and hash of preceding block. The statistics may be some thing because it relies upon at the sort of blockchain. As in case of bitcoin, the statistics includes cash which are really digital cash [13]. The hash this is saved in those blocks incorporates a SHA-256 cryptographic set of rules that is used for specific identity of a block at the chain.

C. CONSENSUS ALGORITHM

Each block added to the chain must fulfil specific consensus rules in order to be included to the blockchain. Blockchain technology employs consensus algorithms for this purpose. The Proof of Work (PoW) method is the most often used consensus algorithm, and it was utilised by Nakamoto [13] in the bitcoin network. Because there are a number of nodes or participants on a blockchain network, when a transaction is requested to be added to the network by any participating node, it must be computed. This process is known as mining, and the nodes that do these computations are known as miners [17].

D. KEY FEATURES OF BLOCKCHAIN

Decentralization: Instead of being centralised, information is disseminated across the network via blockchain. This also allows for information control to be spread and handled by consensus established through shared input from network nodes. Data that was formerly centralised is now managed by a number of trusted organisations.

Data transparency: To achieve data transparency in any system, organisations must have a trust-based relationship. The data or record at stake should be safeguarded, and checksums for digital data that cannot be exploited for data extraction should be generated. As a result, blockchain is a decentralised platform made safe by cryptographic technologies, making it a suitable alternative for privacy protection in specific applications..

E. CHALLENGES FACED BY BLOCKCHAIN TECHNOLOGY

Scalability and storage capacity: The storage of data on the blockchain creates two major issues: secrecy and scalability. The data on the blockchain is available to everyone on the chain, making the data exposed, which is not what a decentralised platform wants. The data saved on the blockchain would include patient medical history, records, lab results, X-ray reports, MRI findings, and many more reports; all of this enormous data is to be kept on the blockchain, which would have a significant impact on the blockchain's storage capacity [18].

Lack of social skills: Only a small number of individuals understand how blockchain technology works. This technology is still in its early stages and is rapidly evolving. Furthermore, the transition from trusted EHR systems to blockchain technology would take time since hospitals and other healthcare institutions would need to totally convert their systems to blockchain.

Lack of universally defined standards: Because this technology is still in its early stages and is continually growing, there is no set standard for it. As a result, using this technology in the healthcare industry would entail additional time and effort. Because it would necessitate recognised standards from international bodies who disregard the standardisation process of any technology [19]. These universal standards would be useful in determining the data size, data format, and data type that might be kept on the blockchain. Furthermore, the stated standards would make adaption of this technology easier because they could be readily enforced in businesses.

TABLE I
Benefits and Barriers of Blockchain Technology

Benefits	Decentralized	The data or information stored on the blockchain is distributed across the network
	Data Transparency	Data stored on the blockchain is temper-proof
	Security and Privacy	Blockchain uses cryptographic algorithms to secure any information being stored on it
Barriers	Scalability, Storage Capacity	Storing huge volumes of data on the blockchain would cause storage and scalability problems
	Lack of social skills	As blockchain is an evolving technology and it is not a well understood technology so, it is quite challenging to shift the previously used systems on this technology
	Lack of universally defined standards	There are no defined standards and principles for blockchain technology that are universally applied which makes it difficult to enforce it throughout a specific domain

IV.SYSTEM DESIGN AND ARCHITECTURE

The section on related work contains work done in the subject of health care that is being implemented utilising blockchain technology. As previously said, they gave specific answers to the widespread challenges in blockchain technology. The experiments under consideration mostly addressed scalability and data sharing issues using blockchain. They suggest employing an underlying database to solve issues, in accordance with some ONC regulations and any other stated standards. In contrast to existing alternatives, our proposed framework solves the scalability challenge by utilising IPFS's off-chain scaling mechanism. Furthermore, Ethereum is employed in the framework's overall implementation. The previous portions of this article also cover Ethereum and its dependencies.

A. SYSTEM DESIGN

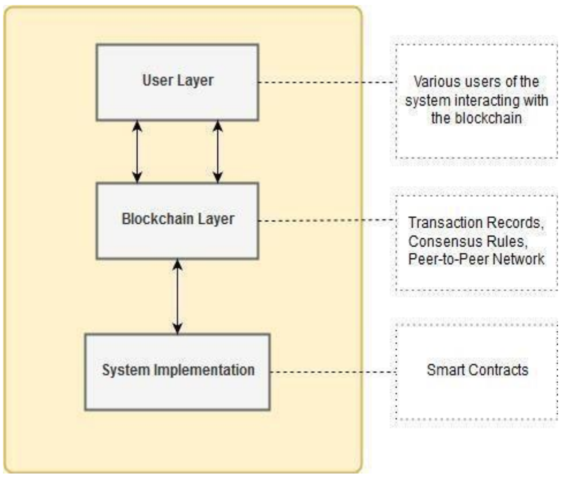

FIGURE 2.System Design of Proposed Framework The suggested structure includes users such as patients, physicians, administrators, and nursing personnel. Granular access was granted to them since they should have various levels of power on the system..

1) USER LAYER

A system user is described as a person who makes efficient use of the system and its resources. A user has many responsibilities and characteristics on the system that make him identifiable. This system's users might include patients, physicians, and administrative personnel, among others. These users' primary responsibility would be to communicate with the system and accomplish simple activities like as

Medical records can be created, accessed, updated, and deleted. Users of this system would access the system's capabilities through a browser, which we refer to as a DApp browser because it contains the GUI. The DApp's (Graphical User Interface), i.e., our suggested system framework. The GUI contains all of the functionality that a certain user may access. According to the designated role, the user might utilise this GUI to interface with the system's other layer, namely the blockchain layer.

2) BLOCKCHAIN LAYER

The blockchain layer is the next tier on the system; this layer contains the code or method for user interaction with the DApp that is running on the blockchain. This layer is made up of three parts. They are as follows:

- **Blockchain Assets:** A transaction on the Ethereum blockchain is the method by which an external user can edit the state of a record or information kept on the Ethereum blockchain network. The Ethereum blockchain treats these transactions as assets since they are pieces of information that a user may give to another user or just store for later use.
- **Governance Rules**: Blockchain technology, in general, adheres to some consensus criteria in order for transactions to be completed and calculated. To do this, various consensus techniques are required to make the blockchain temper-proof and safe. The Ethereum blockchain employs the Proof of Work (PoW) consensus mechanism, which ensures that blockchain governance is maintained in a trustworthy way by obtaining approval from all trusted nodes connected to the blockchain network.
- **Network:** The Ethereum blockchain employs a peer-to-peer network. All nodes in this network are connected as peers. With no node operating as the central node, regulating all network processes. The objective for creating this network was to establish a distributed platform rather than a centralised one. As a result, using a network in which all linked nodes have equal status and rights was the finest decision this technology could have made.

TRANSACTION

The system includes following transactions:

Add records would create patient‟s medical records in the DApp. It contains the fields of ID, name, co-morbid, blood group, and IPFS hash.

- containing the lab results or other medical records of patient.
- **Update records:** would update the patient's medical records This can only affect the patient's fundamental information, not the IPFS hash. To assure record security, the IPFS hash is not updateable.
- **View records:**This would allow the user to examine a patient's medical records stored in DApp. Both physicians and patients utilise the view records tool. The technology authenticates the patient and allows him to examine just his own medical records. For this reason, the system leverages the patient's public account address to guarantee that only relevant medical records are displayed to the patient.
- **Delete records:** would allow the user to erase any patient's record The physicians are the users in this case, as they have been granted the authority to erase any patient record recorded on the blockchain.
- **Grant access:** Each of the aforementioned transactions would need a certain user to have access to them, i.e., only the doctor or nursing staff may update or add to the patient's data. As a result, only these entities would be able to add and alter records. Furthermore, the patient will be able to read his medical records but will not be able to add or change them.

3) SYSTEM IMPLEMENTATION

As already explained in the previous sections, the system was implemented by using the Ethereum and its dependencies. This section explores system implementation in more detail to get an insight on the system various functions.

SMART CONTRACTS

As explained earlier, smart contracts are an important part of DApps as they are used for performing basic operations. Following contracts are included in this framework:

- Patient Records
- Roles

The Asset library, which is a sub-component of the OpenZeppelin library, contains the Roles smart contract. The asset library has alternative contracts for establishing access rules, but the roles library provides a detailed role specification method, which is why this smart contract was chosen.

The following algorithm is used to define the Patient Records smart contract. It describes all of the processes that take place in it, as well as the numerous circumstances that are linked with them. It also describes how roles are maintained for allowing access to certain functions.

Algorithm 1 Smart Contract for Patient Records

Assign Roles: **function** Define Roles (New Role, New Account)
add new role and account in roles mapping **end function** Add Data: **function** Add Patient Record (*contains variables to add data*)
if (msg.sender = = doctor) **then**
add data to particular patient"s record
else Abort session **end if** **end function** Retrieve Data:
function View Patient Record (patient id)
if (msg.sender = = doctor || patient) **then**
if (patient id) = = true **then**
retrieve data from specified patient (id)
return (patient record) to the account that requested the retrieve operation **else** Abort session **end if**
end if **end function** Update Data:
function Update Patient Record (*contains variables to update data*) **if** (msg.sender = = doctor) **then** **if** (id = = patient id && name = = patient name)
then update data to particular patient"s record
return success
else return fail **end if**
else Abort session **end if** **end function** Delete Data: **function** Delete Patient Record (patient id)
if(msg.sender = = doctor) **then** **if** (id = = patient id) **then**
delete particular patient"s record
return success **else**
return fail **end if**
else
Abort session
end if
end function

B. USAGE SCENARIO FOR ALGORITHM 1

The first algorithm describes how the smart contract for patient records works. This algorithm contains five functions: role definition, record addition, view, update, and deletion. The administrator and other system users use these functions. The administrator will conduct the first function of Algorithm 1 define roles, which comprises two variables new role and new account, which will be used to add new roles and accounts to the role mapping list. This list would be used subsequently to access the roles of the system's users. The second function is add patient record, which is executed by the doctor once the administrator has assigned them this job in the definition. This function also ensures that this task is being carried out by the doctor's verified public address and not by any other third party. They utilise the phrase "msg.sender" in programming language, i.e., the Solidity language used by Ethereum, to identify the user's address. After this validity check, the doctor can add the patient's records and then conclude the function by saving that record.
The final function is see patient records, which requires the patient id as a variable. The system would use this id to hunt for the patient's data, and after doing so, it would return those records to the account that requested them. This function also validates the assigned roles of patient and doctor. Because only the patient and doctor would have access to the records. The fourth function is update patient records, which is used to make changes to the patient's stored records. The validation procedure is repeated to guarantee that only authorised users may access this function. The final function of Algorithm 1 is remove patient records, which, as the name implies, is used to erase the records of a certain patient. This method takes the unique id of the patient as input and deletes those entries after checking that the doctor is the one executing this action. This role-based access would ensure that no third party has access to these functionalities and that only the system's authenticated users have access to them.

C. WORKING EXAMPLE FOR PROPOSED FRAMEWORK

As noted in the previous section, Ethereum was utilised for implementation, and the predicted block time is between 10 and 19 seconds. By block time, we mean the length of time it takes for a new block to be created. The time it takes for a smart contract transaction to be verified is 38 seconds, and this relies on the gas price given for the transaction. Unlike Bitcoin, Ethereum has a gas limit rather than a block size constraint; the words gas price and gas limit are described in the preceding sections. Depending on the quantity of the data, the time required for an append function of Algorithm 1, i.e., Add Patient Record, would be about 12 minutes. View Patient Record's retrieval function, such as Algorithm 1, would take 50 seconds.
Consider the following example to show the functioning of Algorithm 1 in terms of transaction size.

Let, Average number of transactions per hour = 31474 Average number of blocks per hour = 269 Average transactions per block = average transactions per hour / average blocks per hour = 31474/269 =117 Average transaction size = Block Size / Average transaction size per block = 21.7KB / 117 = 0.19 KB According to the preceding figures, the average transaction size is around 0.2 KB. It should also be noted that the data presented above are real-time values for the Ethereum blockchain network.

D.USAGE SCENARIO FOR PROPOSED FRAMEWORK

Figure 3 displays the proposed framework's basic usage scenario. The system is primarily composed of two entities: Administrator and User. For our suggested structure, users are further separated into two categories: doctor and patient. The system administrator, who is a member of the hospital's administrative staff, assigns these users duties. The administrator is tasked with setting granular access to our system's two primary users, the doctor and the patient. So, the first action is that the administrator allocates roles, which includes the Position Name and Account Address of the person who is allocated that role. Every user of this suggested system would be assigned a role name and an account address. So, once the administrator assigns this user a role, the role name and account address are saved in a roles list for subsequent confirmation. And roles are assigned, when a user wants to execute some activities on the proposed system, he must first request that they be performed. After validation returns success, the system will check the user role name and account address from the Roles List and enable them to do those functions. After the functions are completed, the system will store the data on the Ethereum Blockchain and make transactions on that data. Once the transaction is verified, the system receives a success message from the blockchain layer, which users can view on the DApp browser, which displays the entire proposed framework.

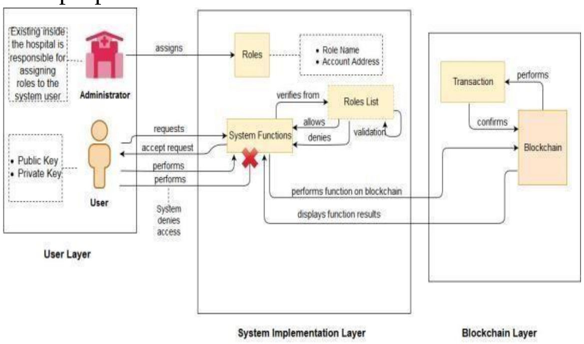

FIGURE 3.***User Interaction with DApp***

V. CONCLUSION AND FUTURE WORK

We examined how blockchain technology may be beneficial in the healthcare sector and how it can be utilised for electronic health records in this article. Despite advancements in the healthcare sector and technical progress in EHR systems, several challenges remained that were solved by this unique technology, namely, blockchain. Our proposed system combines safe record storage with granular access controls to those documents. It offers a system that is simpler for consumers to use and comprehend. In addition, because IPFS's off-chain storage technique is used, the framework provides ways to ensure that the system addresses the issue of data storage. Furthermore, rolebased access enhances the system by limiting access to trusted and connected persons. This also overcomes the EHR system's information asymmetry problem. In the future, we want to include the payment module into the current structure. Certain considerations must be made in order to determine how much a patient would pay for a doctor's consultation on this decentralised system based on the blockchain. We would also need to develop specific regulations and norms that adhere to healthcare industry values.

VI.REFERENCES

[1] G. Jetley and H. Zhang, "Electronic health records in IS research: Quality issues, essential thresholds and remedial actions," *Decis. Support Syst.*, pp. 113–137, 2019.

[2] K. Wisner, A. Lyndon, and C. A. Chesla, "The electronic health record's impact on nurses' cognitive work: An integrative review," *Int. J. Nurs. Stud.*, vol. 94, pp. 74– 84, 2019.

[3] M. Hochman, "Electronic Health Records: a ``Quadruple Win,'' a ``Quadruple Failure,'' or Simply Time for a Reboot?," *J. Gen. Intern. Med.*, vol. 33, no. 4, pp. 397–399, Apr. 2018.

[4] Q. Gan, "Adoption of Electronic Health Record System : Multiple Theoretical Perspectives," *2014 47th Hawaii Int. Conf. Syst. Sci.*, pp. 2716–2724, 2014.

[5] M. Reisman, "EHRs: The Challenge of Making Electronic Data Usable and Interoperable.," *P T*, vol. 42, no. 9, pp. 572– 575, 2017.

[6] W. W. Koczkodaj, M. Mazurek, D. Strzałka, A. Wolny-Dominiak, and M. WoodburySmith, "Electronic Health Record Breaches as Social Indicators," *Soc. Indic. Res.*, vol. 141, no. 2, pp. 861–871, 2019.

[7] S. T. Argaw, N. E. Bempong, B. EshayaChauvin, and A. Flahault, "The state of research on cyberattacks against hospitals and available best practice recommendations: A scoping review," *BMC Med. Inform. Decis. Mak.*, vol. 19, no. 1, pp. 1–11, 2019.

[8] A. McLeod and D. Dolezel, "Cyber-analytics: Modeling factors associated with healthcare

data breaches," *Decis. Support Syst.*, vol. 108, pp. 57– 68, 2018.

[9] L. Coventry and D. Branley, "Cybersecurity in healthcare: A narrative review of trends, threats and ways forward," *Maturitas*, vol. 113, pp. 48– 52, 2018.

[10] "The Future of Health Care Cybersecurity," *J. Nurs. Regul.*, vol. 8, no. 4, Supplement, pp. S29– S31, 2018.

[11] D. Spatar, O. Kok, N. Basoglu, and T. Daim, "Adoption factors of electronic health record systems," *Technol. Soc.*, vol. 58, no. February, p. 101144, 2019.

[12] S. Nakamoto, "Bitcoin: A Peer-to-Peer Electrnic Cash System," pp. 1–9, 2008.

[13] W. J. Gordon and C. Catalini, "Blockchain Technology for Healthcare : Facilitating the Transition to Patient-Driven Interoperability," *Comput. Struct. Biotechnol. J.*, vol. 16, pp. 224–230, 2018.

[14] A. Boonstra, A. Versluis, and J. F. J. Vos, "Implementing electronic health records in hospitals: a systematic literature review," *BMC Health Serv. Res.*, vol. 14, no. 1, p. 370, Sep. 2014.

[15] T. D. Gunter and N. P. Terry, "The emergence of national electronic health record architectures in the United States and Australia: models, costs, and questions," *J. Med. Internet Res.*, vol. 7, no. 1, pp. e3–e3, Mar. 2005.