



# BlockcareX : Safe and Secure Healthcare platform

\*Prof. Sanjivani Adsul<sup>1</sup>, Shivam More<sup>2</sup>, Bhushan Sonsale<sup>3</sup>,  
Komal Thakare<sup>4</sup>, Rohan Waware<sup>5</sup>

Department of Artificial Intelligence and Data Science, Vishwakarma Institute of Technology, Pune

**Abstract**— In contrast to traditional paper-based medical records, electronic health records (EHRs) have gained widespread adoption due to their efficiency, enhanced security, and the reduction of data redundancy. Despite these advantages, EHRs continue to grapple with issues related to poor interoperability and unresolved privacy concerns. Blockchain, as a distributed ledger protocol utilizing encrypted blocks of data organized in chains, emerges as a promising solution to address the shortcomings of EHRs, particularly in terms of interoperability and privacy. This paper delineates the definitions of EHRs and blockchain technology and introduces several established schemes based on blockchain to bolster EHR interoperability and enhance privacy protection. The discussion also encompasses a review of current challenges in areas such as data management efficiency, fair access, and trust in existing systems. As part of this commentary, we propose ongoing research needs in health informatics, data sciences, and ethics to establish EHRs based on blockchain technology. It is imperative for blockchain-based EHR schemes to navigate potential challenges, including addressing healthcare resource inequalities, mitigating the substantial carbon footprint associated with computational needs, and managing potential distrust among health providers and patients stemming from the widespread use of blockchain technology. text.

**Keywords**— *electronic health records, blockchain, interoperability, privacy*

## I. INTRODUCTION

The concept of blockchain is completely opposite to traditional methods; while the conventional approach stores data in a centralized database, blockchain stores data in a decentralized way. Blockchain records a timestamp to avoid tempering the stored data. This novel approach was first devised to run Bitcoin cryptocurrency, but it is now being advocated by different industries including healthcare due to its enhanced authentication, confidentiality, transparency, and unique data sharing characteristics verified by consensus. Bitcoin is an example of this kind since it is wide-open, permissionless, and anyone can buy bitcoins. (ii) permissioned blockchains where only pre-verified users shall have access which is vital for some

enterprise-based systems in order to protect the business affairs. Ethereum and Hyperledger Fabric framework are two widely known blockchain-based approaches, where Hyperledger is a fully permissioned network designed for operations involving sensitive and confidential data, whereas Ethereum is a public network that enables permissioned networks.

Improving quality of care and better access to healthcare facilities is important for the society and more so for the elderly population. Especially in pandemic times, when normal lifestyle is disrupted, and the population is expected to stay home, the need for remote patient monitoring has increased and the necessity is larger than ever before. Towards solving the existing problem in healthcare, researchers from different fields proposed different schemes by adopting blockchain technology. After reviewing several studies and systems of blockchain and smart contracts, we identify two frameworks, Ethereum and Hyperledger Fabric. Also, improving quality of care and better access to healthcare facilities is important for the society and more so for the elderly population. Especially in pandemic times, when normal lifestyle is disrupted, and the population is expected to stay home, the need for remote patient monitoring has increased and the necessity is larger than ever before. Towards solving the existing problem in healthcare, researchers from different fields proposed different schemes by adopting blockchain technology. After reviewing several studies and systems of blockchain and smart contracts, we identify two frameworks, Ethereum and Hyperledger Fabric. But in this paper, we will discuss about Ethereum blockchain.

Ethereum represents a blockchain with built-in decentralized transactions and a Turing-complete execution environment where the system can perform any computations. However, all nodes must have access to the whole records in blockchain. A Merkle Patricia Tree (MPT) is being used to improve the state. MPT is a special type of data structure that may store cryptographically authenticated data as keys and values. Depicts the block structure of Ethereum and its Merkle Tree in which the hash of the root node (the tree's initial node) is dependent on the hashes of all sub-nodes. Blockchain has the ability for addressing significant health care

concerns while also providing unique chances to leverage the power of other emerging technologies. Despite interoperability challenges including the lack of an existing standard for developing blockchain-based healthcare application, enabling blockchain to solve many complex problems found in today's healthcare industry that shall allow a transformation with the help of researchers and practitioners from different fields towards improving and innovating methods for viewing the health care industry.

Healthcare management involves many processes such as managing finances, staff, patients, legal issues, logistics, inventory, etc. Medical workflows often involve repetitive tasks related to the actual patient treatment that can be plotted out as a series of conditional steps. These are designed to provide better internal controls and improved efficiency, compliance, productivity, and reduce risk, work cycles and overhead within hospitals and other healthcare service providers. In this paper, multiple medical workflows are designed for different healthcare management application domains.

Emerging blockchain-based healthcare innovations, including data sources, blockchain technology, healthcare applications, and stakeholders, are conceptually divided into several layers. Gordon and Catalini published a review on healthcare blockchain where they concluded their discussion on how blockchain technology can enable patient-centric control of healthcare data sharing over institution centric control. In their study they examined how blockchain technology transforms the healthcare sector by enabling digital access rights, patient identification across the network, handling a large volume of healthcare data and data immutability. This paper presents a project that is built on deep-learning algorithms, i.e., convolutional neural networks, and some machine learning libraries. The dataset used contained more than a thousand videos of a person speaking random sentences. Features are extracted from the cropped video, which contains only lips and the area near the lips. Custom videos were also included in the dataset to give the model more robustness. This model has got accuracy far better than previous findings.

Blockchain technology provides numerous benefits to medical researchers, health care providers, and individuals [60,61]. It would serve research as well as personalized medicine to create a single storage location for all health data, track personalized data in real-time and set data access permissions at a granular level.

## II. LITERATURE REVIEW

Zhang et al. [1] wrote a book chapter proposal where they have discussed different use cases of healthcare blockchain. They have highlighted the importance of the blockchain-based system for healthcare and how blockchain technology provides effective healthcare design.

Siyal et al. [2] discussed how blockchain technology and smart contracts are beneficial for the healthcare sector by streamlining the overall process. In their work, they have stated that managing healthcare record are crucial and blockchain has the potential to reduce the loss and to prevent fabrication of data by securing the information on the ledger.

Jamil et al. discussed the issues regarding drug regulations and how to standardized drugs using blockchain. In their work, they have highlighted the difficulties to detect falsified drugs and proposed blockchain as a way to detect counterfeits [3]

Agboetal.[4] They have selected 65 papers to address their research question. Their study shows that blockchain could be a potential technology for different healthcare use cases which includes drugs supply chain, biomedical research, managing electronic healthcare records. However, they have also analyzed the fact that there is still needs to develop more understanding of blockchain technology and how it could be a best fit for different healthcare related challenges.

Zhang et al. [5] discussed about blockchain and smart contracts how blockchain based smart contracts has the potential to address different healthcare issues. In their work they took some initial steps to adopt blockchain technology for different healthcare use cases and pointed towards different challenges in the implementation of blockchain technology. They have elaborated that developing blockchain based apps can address healthcare issues in more efficient ways.

Philippe et al. [6] presented consent management in the E-health environments and proposed blockchain as a secure and most reliable solution to handle healthcare data. Access to personal data has become a concern in this era of digital world, with challenging aspects of security and privacy. Digital security is a major challenge due to hacking motives and violations of privacy. This is possible in the eHealth area where patient's health information management system must comply with many, while remaining accessible to healthcare professionals who are duly authorized. Because of its most popular use-Bitcoin-most will have heard of blockchain in the payment region. Nonetheless, the features of blockchain make it possible to meet the consent management criteria as demonstrated in an application within a case for use in a health domain.

## III. PROPOSED METHODOLOGY

This section provides a formal description of the proposed frameworks, elucidating the software platform employed in crafting this framework and delineating its advantages. The subsequent section delves into a detailed exploration of the pivotal components integral to the framework's implementation, namely Ethereum and the Interplanetary File System (IPFS).

### A. Fundamental Framework

*a. Ethereum:* Ethereum, operating as a decentralized network, is constructed upon blockchain technology, initially deployed on the widely used cryptocurrency Blockchain. Its inception aimed to establish an open-source platform featuring smart contract capabilities within a blockchain framework. Utilizing peer-to-peer networking, Ethereum distributes itself

and employs its native cryptocurrency, Ethers. Facilitating programmers, Ethereum provides a language known as Solidity, enabling the design of custom blockchains.

At the core of Ethereum's functionality are smart contracts, serving as a distinctive feature. Transactions act as the conduit for external entities to engage with Ethereum, allowing users to modify the status of documents or data on the Ethereum blockchain network. Key components of an Ethereum transaction include the sender-author, identifiable by a 20-byte address, and the recipient, similarly possessing a 20-byte address.

Despite incurring a cost involving the quantity of money transferred and gas, each blockchain transaction mandates payment by the author. Gas, representing this cost, encompasses gas limitations and associated expenses within every transaction. The price of gas denotes the amount the transaction author is willing to pay for this essential component.

*b. The Smart Contract:* A smart contract serves as a set of instructions capable of executing transactions on the blockchain. When users initiate transactions, this code segment is executed, functioning directly on the blockchain, thereby making it resistant to manipulation and alterations. Solidity, the programming language utilized by smart contracts, enables the programming of various activities on the blockchain. Programmers can compile the programmed operations, which can subsequently be executed and deployed on the Ethereum blockchain. JavaScript, a programming language, implements Ethereum's Solidity language for writing the code of smart contracts.

#### B. Software Required:

*a. Ganache:* Ganache serves as a local Ethereum blockchain, facilitating the swift development of decentralized programs. It provides a predictable and secure environment for deployment, development, and testing throughout the entire development cycle. Ganache is versatile, functioning both as a desktop program and a command-line tool for Ethereum.

*b. MetaMask:* This serves as a gateway, enabling you to experience the decentralized web of the future directly through your browser. It grants the capability to run Ethereum decentralized applications without the necessity of running a complete Ethereum node within your browser.

*c. Web3:* Transaction verification within the chain is essential for seamless interaction with the chain's modules. To generate and validate a transaction, a participant in another offline framework's network must relay it to the peer-to-peer (p2p) connection, constituting an actual network. Additionally, there is a library collection that facilitates communication between Ethereum nodes and in-chain components, primarily utilized on the server side for Node.js.

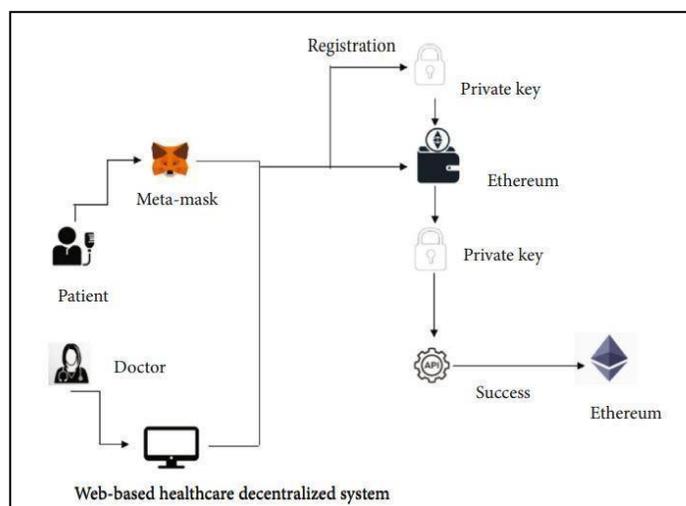
Web3 utilizes the Hypertext Transfer Protocol (HTTP) connection to establish a link with the Ethereum network through an Ethereum node, potentially residing within ETH wallets on the local system. MetaMask, an in-browser extension, enables operations from Ethereum accounts and facilitates integration with websites. Functioning as a browser-based Ethereum wallet, MetaMask establishes a connection between the browser and a Web3 provider class. This provider is a data structure offering access to publicly available Ethereum nodes. Users can manage public and private keys unique to their accounts using MetaMask. The collaboration of Ethereum, MetaMask, web3.js, and a web interface facilitates seamless backend-front-end communication

*d. VS Code:* Visual Studio Code by Microsoft is a versatile editor compatible with Windows, Linux, and macOS. It encompasses a range of features such as troubleshooting, Git management, GitHub integration, syntax highlighting, intelligent code completion, code samples, and bug fixes.

*e. Languages:* The website's front-end design is crafted with HTML (Hypertext Markup Language), CSS (Cascading Style Sheets), and React.js. Managing the server and back-end functions is accomplished through the Solidity programming language and Node.js. Two essential tools, Truffle and Ganache, play a pivotal role in generating local Ethereum blockchains for system development. The system relies on various components including the Ethereum virtual interface, MetaMask (serving as a wallet), Truffle (functioning as an integrated development environment), Yarn (command-line interface), Ganache (for account creation), and Local Web3 (for web interface), collectively employed to establish the blockchain and facilitate system usage.

*f. Protocol Layout:* Figure 1 illustrates the system layout when a patient opts to access their medical records through MetaMask or the healthcare system's decentralized website. Upon retrieving the private key from the Ethereum wallet, the user is automatically authenticated. The Ethereum wallet, functioning as a cold storage wallet, offers heightened security with a lower risk of compromise compared to hot wallets. In the event of a lost device, patients can seamlessly receive a replacement without facing penalties for the loss of their medical records.

This wallet extends its utility beyond record access, as it can be employed for document signing and various verification requirements. Furthermore, it supports multiparty patient verification and contributes to the establishment of a role-based access control system for records within the blockchain-based Journal of Sensors.



**Fig 1: The protocol layout of the BlockcareX system.**

In case of a medical emergency, a comparable multiparty permission mechanism can be enacted to secure access to the patient's records within the distributed property identification system.

#### C. Block Diagram:

Figure 2 depicts the block diagram of our proposed design, featuring four key components: a user application, a blockchain handshake protocol, a cloud, and a public blockchain network. This system, presented as a virtual representation, serves a dual purpose. Firstly, it offers users access to application interfaces, catering to distinct roles such as doctors and system administrators. Secondly, the user application generates an initial transaction based on user-entered data, submitting it to the blockchain handshake protocol for confirmation. The user interface then establishes the connection between users and the blockchain handshake protocol.

At the core of our proposed architecture is the blockchain handshake (BH) protocol, linking the database server, the blockchain network, and the cloud-based health record system functioning as a wrapper. Leveraging the Ethereum blockchain network, the public blockchain network serves as a distributed ledger connecting blockchain nodes—miners responsible for updating the blockchain through decision methods or authenticating transactions using smart contracts.

visible to all. Executing a transaction entails utilizing the private keys to unlock the associated addresses.

In our design, the cloud delivers two essential services akin to existing cloud-based EHR administration systems. The initial service hosts the EHR administration system, while the subsequent service involves data storage, allowing all health records to be securely stored in a cloud database. The EHR administration system, interacting with transactions from the blockchain handshake protocol, fulfills its duties and stores the processed data in the cloud database. In response to user access requests, the cloud furnishes the necessary data

#### D. Use Case Diagram of Proposed System:

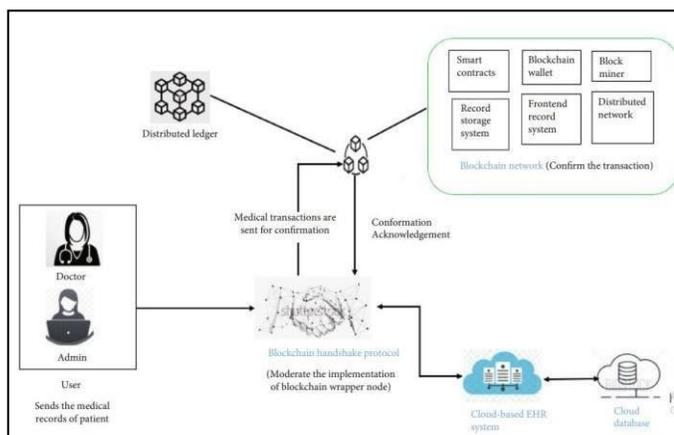
The use-case diagram, as presented in Figure 3, outlines three primary entities for this application: an administrator, a patient, and a doctor. An exclusive feature involves inputting profile details, providing access across all three organizations. The patient is granted access to three out of ten operations, while the doctor has access to a distinct set of three out of ten operations. The administrator, uniquely, possesses access to all ten actions, affording them the ability to examine and monitor comprehensive information. Notably, the sole operation capable of altering block data post-retrieval is the writing of a patient's record, a task reserved solely for the doctor.

#### E. Flowchart of the Proposed System:

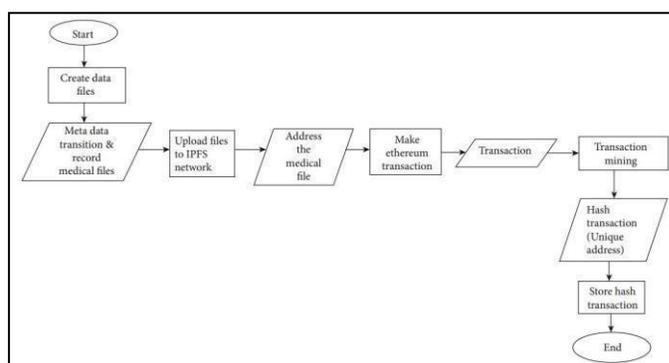
Figure 4 illustrates the process of creating a medical record within the system. The initial step involves the first doctor generating a medical record and subsequently recording the examination results for each patient. The metadata transaction associated with this medical record is then processed, where a segment of data known as transaction metadata is appended to the transaction post-processing. Regardless of the transaction's outcome, all ledger-recorded transactions include metadata, offering a detailed account of the transaction's resolution.

Following this, the medical file undergoes upload to the IPFS network, known as the Interplanetary File System, a decentralized document system designed for efficient transactions with minimal resource utilization and time requirements. Upon uploading, a content address is obtained for the file.

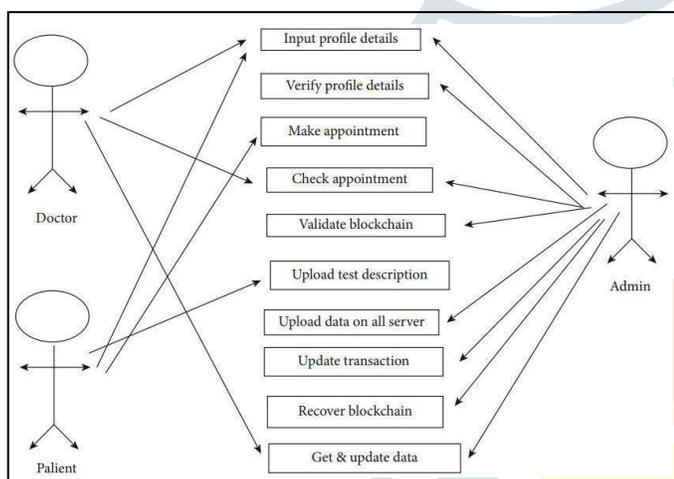
The subsequent stage involves an Ethereum transaction, for which Ganache is necessary as it provides addresses and private keys. These addresses are stored, and the transactions are made



**Figure 2: Block diagram of the blockchain based BlockcareX system.**



**Figure 4: Flowchart of explaining the process of creating a medical record.**



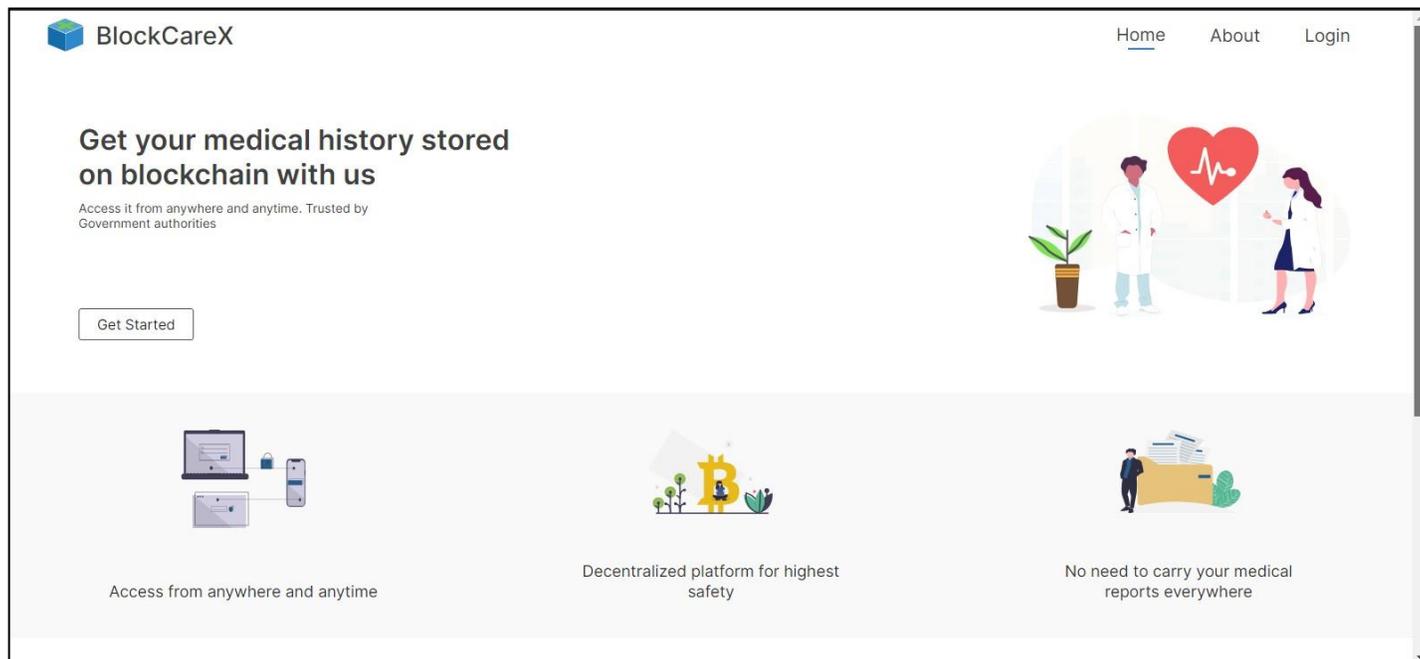
**Figure 3: Use case diagram of the BlockcareX system.**

The Ethereum Virtual Machine (EVM) plays a crucial role in processing Ethereum transactions, particularly in facilitating smart contract interactions. For each interaction with a contract, all nodes within the network must reach a consensus confirming the occurrence of the transaction. Subsequently, the EVM executes an immediate post-contract process in adherence to the transaction's rules.

Ethereum maintains an exhaustive record of all past transactions and the complete history of the blockchain, ensuring transparency and validation through consensus. Node operators within the Ethereum network meticulously monitor and record all smart contract interactions. In certain scenarios, miners can transform into bots, automating the processing of transactions whenever a transaction is received.

## V. RESULTS AND DISCUSSION

This section details the procedure for gaining access to the proposed system. The system is constructed utilizing Truffle and Ganache, user-friendly tools designed for the creation of local Ethereum blockchains. The server and back-end operations of the system are managed through the Solidity language and Node.js. The process of establishing a blockchain and accessing the system involves the utilization of the Ethereum virtual interface, MetaMask (serving as a wallet), and Local Web3 (functioning as a web interface).



(a)

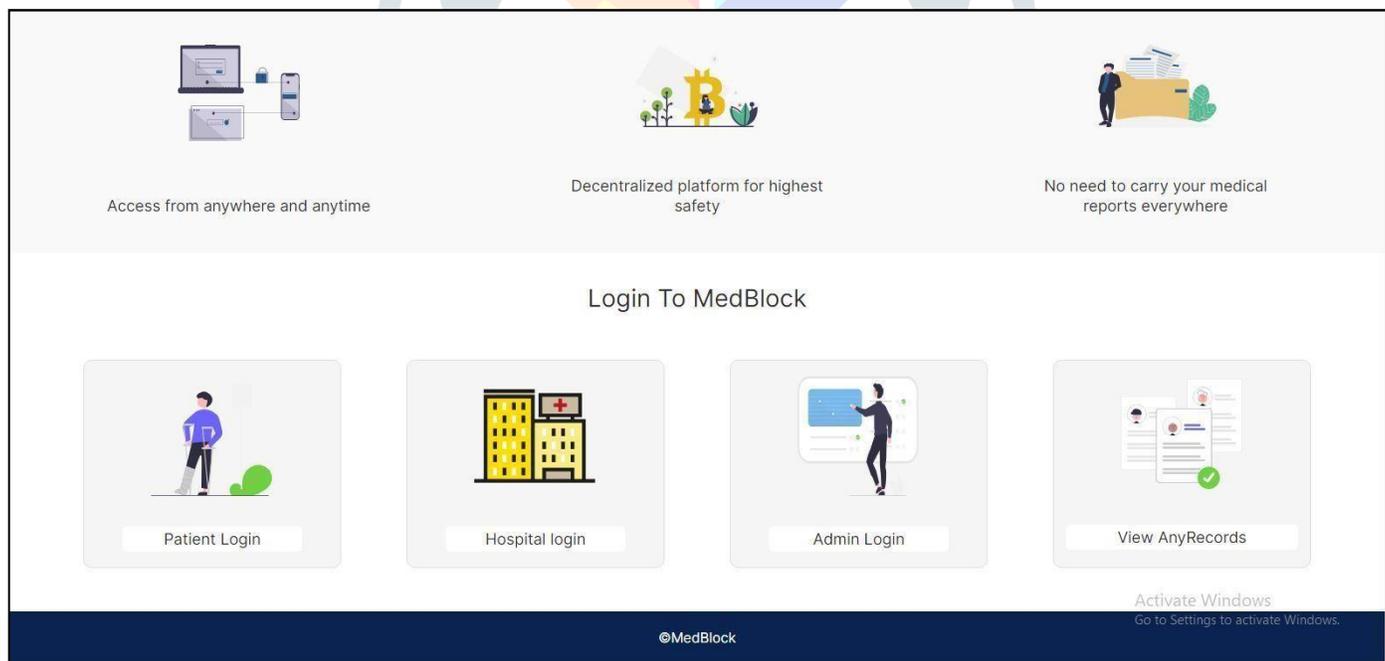


Figure 1: Homepage of the proposed system.

This image shows the homepage or landing page of the BlockcareX healthcare platform. It has a clean and modern design with a navbar at the top, a hero section showcasing the platform's features and benefits, and some sections below highlighting key aspects like security, transparency, etc.

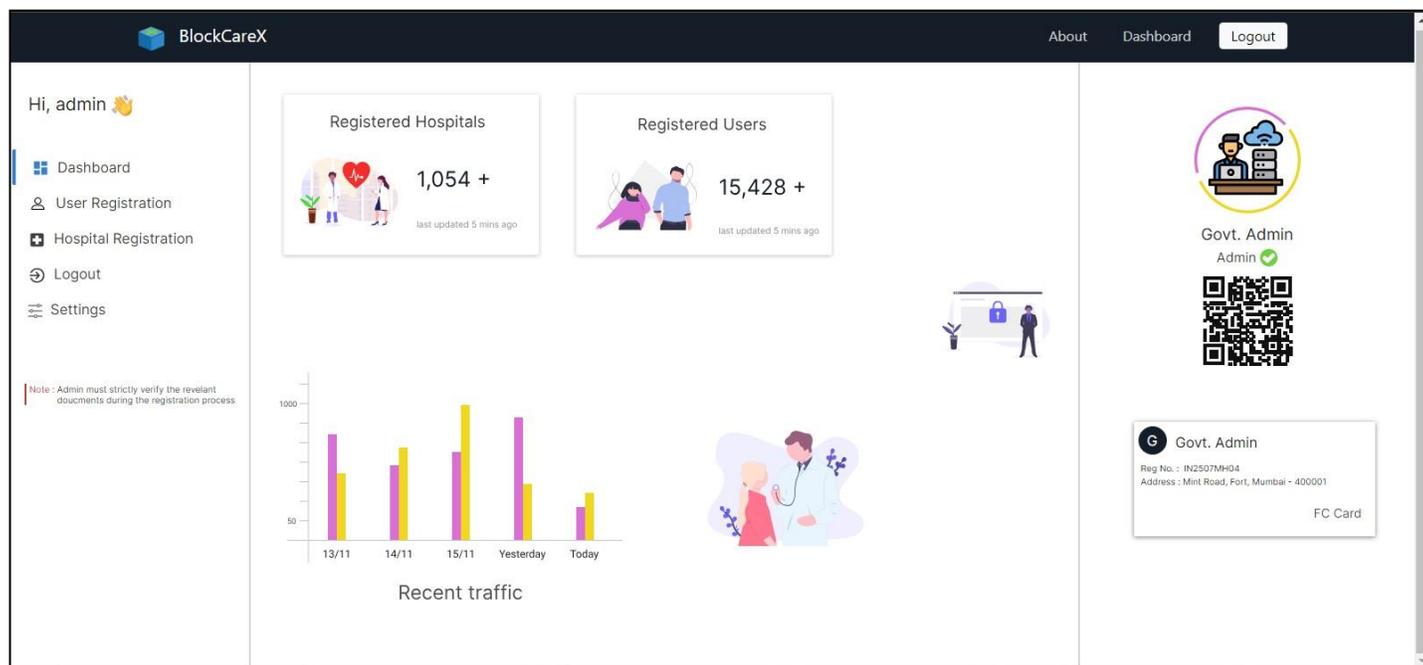


Figure 2: Admin Dashboard

This screenshot displays the admin dashboard interface of the platform. It seems to have various sections and options for the admin to manage different aspects like hospitals, patients, doctors, and potentially other administrative functions.

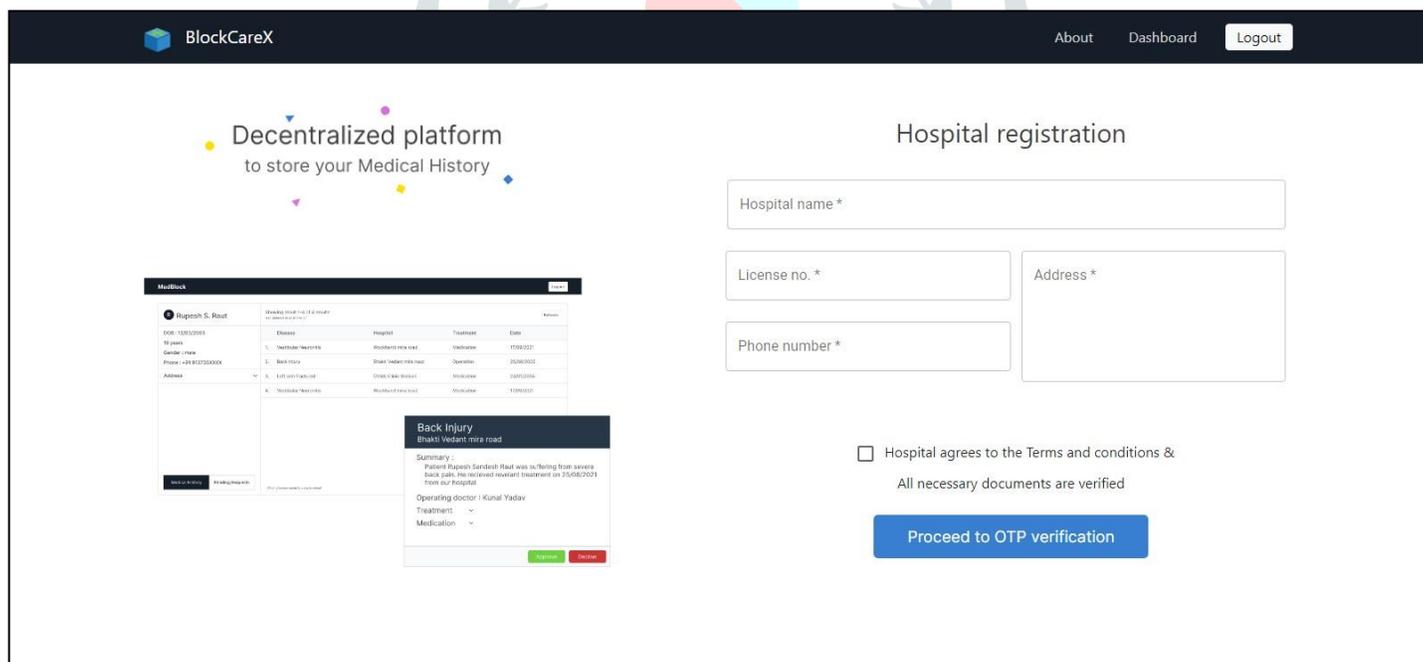


Figure 3: Hospital Registration Dashboard

This is likely the interface where hospitals or healthcare providers can register themselves on the BlockcareX platform. The UI shows fields to enter details like hospital name, address, and other relevant information required for registration.

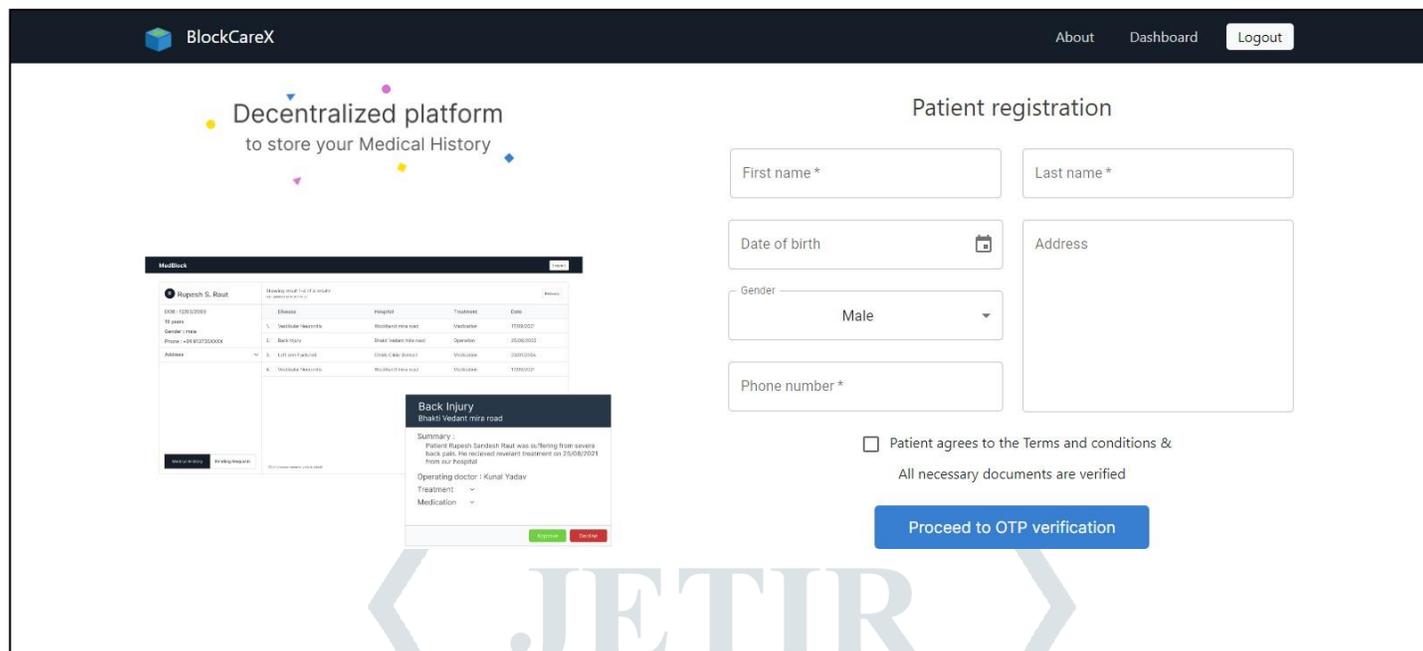


Figure 4: Patient Registration Dashboard

This screenshot presents the patient registration dashboard, which allows new patients to sign up and create their accounts on the BlockcareX system. It likely includes fields for entering personal details, contact information, and other necessary patient data.

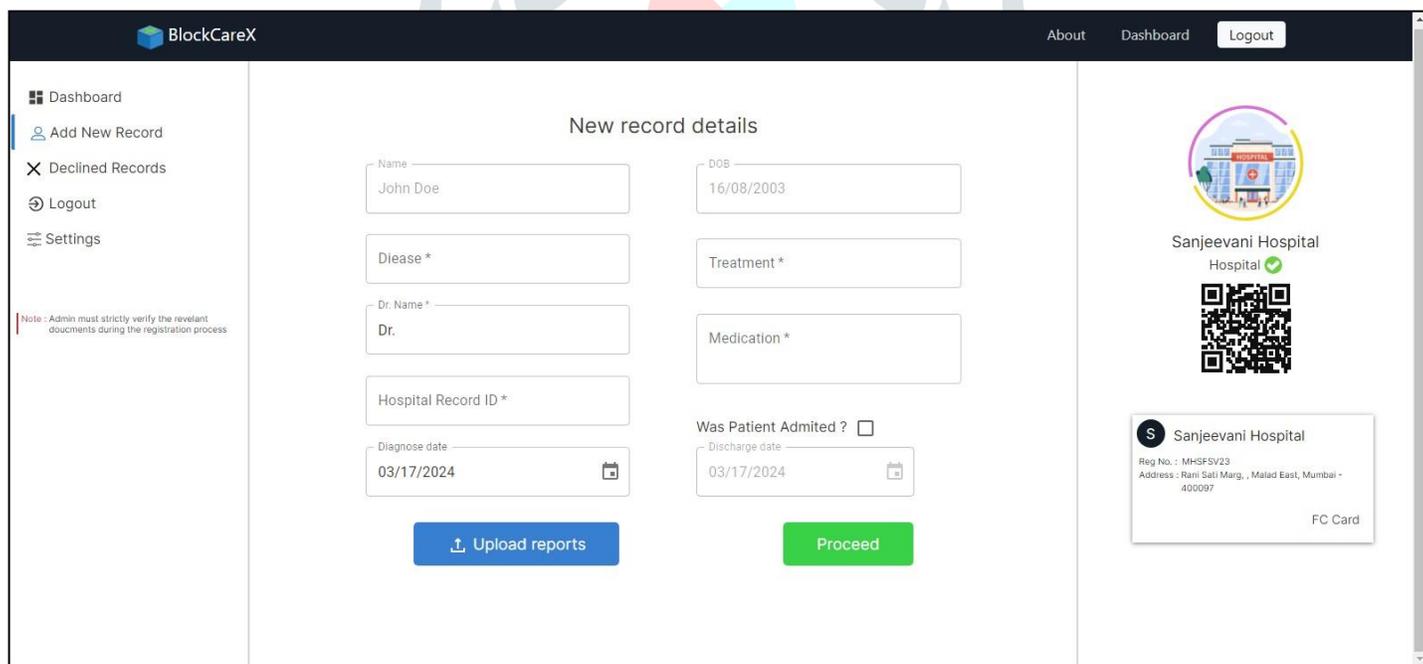


Figure 5: Add New Patient Records

This image displays the interface for adding new patient records to the BlockcareX platform. It probably has fields or sections for entering various types of medical data, test results, diagnoses, and other relevant information related to a patient's health records.

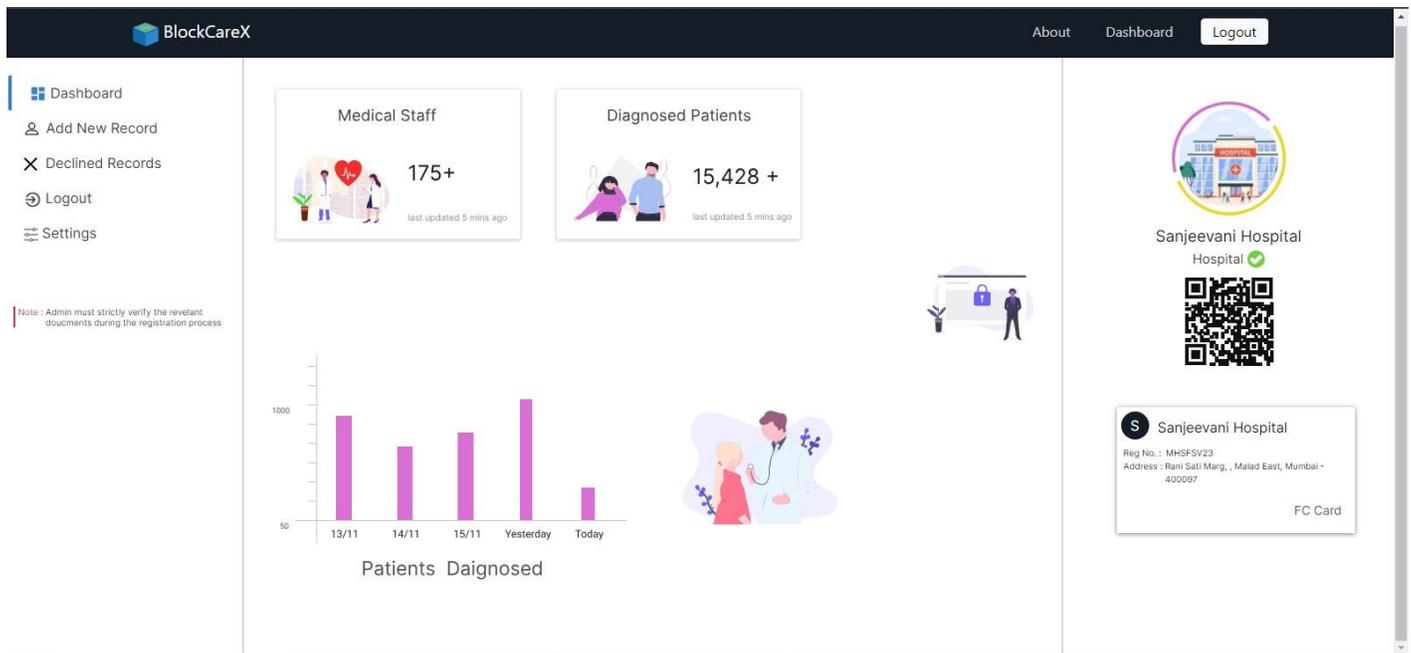


Figure 6: Hospital Dashboard

This screenshot shows the hospital dashboard view of the BlockcareX system. It likely provides healthcare facilities with an overview of their operations, patient records, staff management, and other hospital-specific functionalities within the platform.

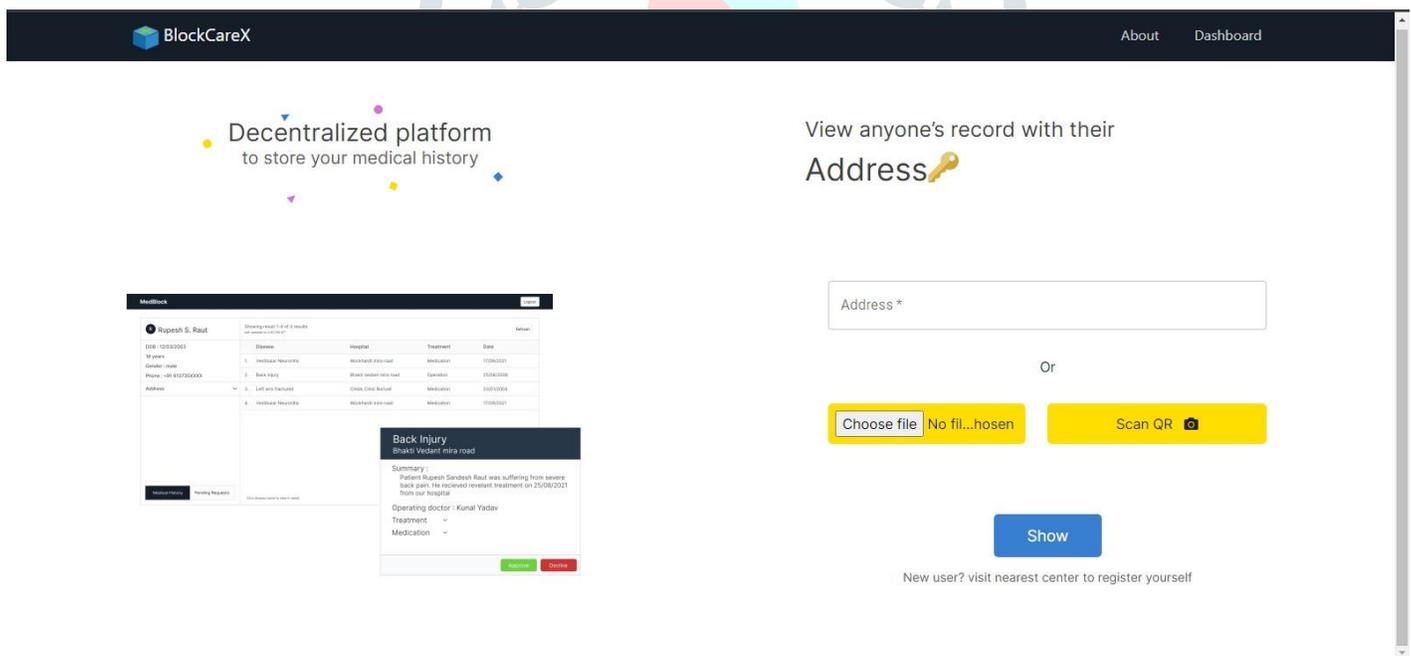


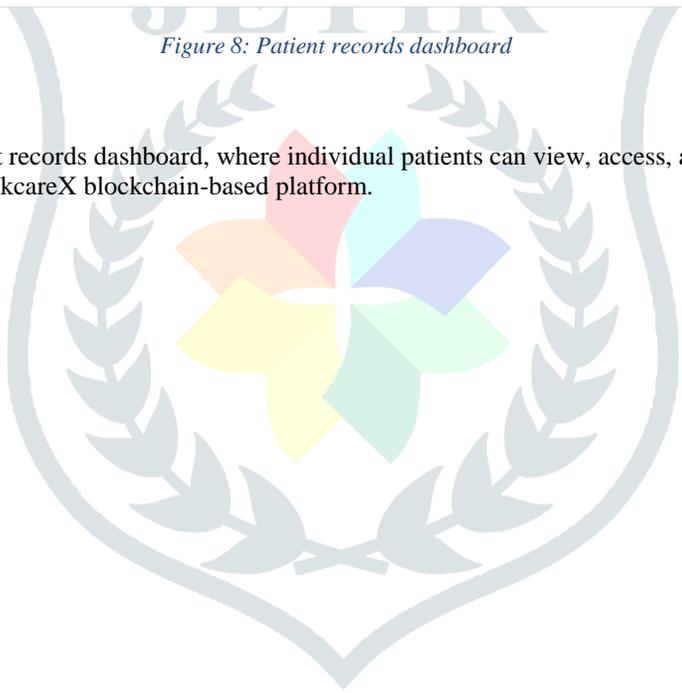
Figure 7: Public patient records access dashboard

This image presents the public patient records access dashboard, which seems to be an interface for authorized individuals or entities to access and view patient medical records stored on the BlockcareX platform, likely with appropriate access controls and permissions.

<b>J Rohan Waware</b>		Showing result 1 - 17 out of 17 results <small>last updated at: 4:30 PM IST</small> <span style="float: right;">Refresh</span>																																													
DOB : 16/08/2003 21 years old Gender : Male Phone : +91 7045270840 Address <input type="checkbox"/>	<table border="1"> <thead> <tr> <th>Disease</th> <th>Hospital</th> <th>Treatment</th> <th>Date</th> </tr> </thead> <tbody> <tr> <td>1. Diabetes</td> <td>Jupiter Hosp</td> <td>Controlling blood sugar through di...</td> <td>29/06/2022</td> </tr> <tr> <td>2. Metacarpal fracture of the ring finger</td> <td>Sanjeevani Hospital</td> <td>Surgical Treatment</td> <td>29/06/2022</td> </tr> <tr> <td>3. Metacarpal fracture of the index finger</td> <td>Sanjeevani Hospital</td> <td>Surgical Treatment</td> <td>29/06/2022</td> </tr> <tr> <td>4. Fatty Liver</td> <td>Sanjeevani Hospital</td> <td>Medications</td> <td>29/06/2022</td> </tr> <tr> <td>5. test</td> <td>Sanjeevani Hospital</td> <td>test</td> <td>17/07/2022</td> </tr> <tr> <td>6. gunfan</td> <td>KEM Hospital</td> <td>ereft</td> <td>06/08/2022</td> </tr> <tr> <td>7. advszdv</td> <td>KEM Hospital</td> <td>dvszdv</td> <td>17/08/2022</td> </tr> <tr> <td>8. Anxiety</td> <td>KEM Hospital</td> <td>Antibiotics may be given orally (pil...</td> <td>17/08/2022</td> </tr> <tr> <td>9. Muerte cerebral</td> <td>Sanjeevani Hospital</td> <td>De conducto</td> <td>30/08/2022</td> </tr> <tr> <td>10. jbnbskjb</td> <td>KEM Hospital</td> <td>kjnbndjk</td> <td>02/09/2022</td> </tr> </tbody> </table>	Disease	Hospital	Treatment	Date	1. Diabetes	Jupiter Hosp	Controlling blood sugar through di...	29/06/2022	2. Metacarpal fracture of the ring finger	Sanjeevani Hospital	Surgical Treatment	29/06/2022	3. Metacarpal fracture of the index finger	Sanjeevani Hospital	Surgical Treatment	29/06/2022	4. Fatty Liver	Sanjeevani Hospital	Medications	29/06/2022	5. test	Sanjeevani Hospital	test	17/07/2022	6. gunfan	KEM Hospital	ereft	06/08/2022	7. advszdv	KEM Hospital	dvszdv	17/08/2022	8. Anxiety	KEM Hospital	Antibiotics may be given orally (pil...	17/08/2022	9. Muerte cerebral	Sanjeevani Hospital	De conducto	30/08/2022	10. jbnbskjb	KEM Hospital	kjnbndjk	02/09/2022		
Disease	Hospital	Treatment	Date																																												
1. Diabetes	Jupiter Hosp	Controlling blood sugar through di...	29/06/2022																																												
2. Metacarpal fracture of the ring finger	Sanjeevani Hospital	Surgical Treatment	29/06/2022																																												
3. Metacarpal fracture of the index finger	Sanjeevani Hospital	Surgical Treatment	29/06/2022																																												
4. Fatty Liver	Sanjeevani Hospital	Medications	29/06/2022																																												
5. test	Sanjeevani Hospital	test	17/07/2022																																												
6. gunfan	KEM Hospital	ereft	06/08/2022																																												
7. advszdv	KEM Hospital	dvszdv	17/08/2022																																												
8. Anxiety	KEM Hospital	Antibiotics may be given orally (pil...	17/08/2022																																												
9. Muerte cerebral	Sanjeevani Hospital	De conducto	30/08/2022																																												
10. jbnbskjb	KEM Hospital	kjnbndjk	02/09/2022																																												
<input type="button" value="Medical History"/> <input type="button" value="Pending Requests"/>	Click the record to view the details																																														

Figure 8: Patient records dashboard

This screenshot displays the patient records dashboard, where individual patients can view, access, and manage their own medical records stored securely on the BlockcareX blockchain-based platform.



## VI. FUTURE SCOPE

A blockchain, structured as a linked sequence of blocks, has revolutionized the creation and deployment of new programs, pivoting towards a distributed and decentralized paradigm as opposed to traditional cloud-based applications. The current smart contract is poised for expansion to enhance lookup functionality and incorporate advanced features essential for an Electronic Health Record (EHR) administration system. Future developments may focus on introducing real-time video conference communication features, particularly relevant in the context of the ongoing COVID-19 outbreak.

Another prospective enhancement involves integrating a payment module into the existing architecture. This integration can be seamlessly achieved through a decentralized blockchain-based framework, enabling patients to pay for specialist consultations using credit or debit cards, with the National ID (NID) number serving as a verification mechanism.

The incorporation of Ganache provides an opportunity to experiment with a similar technique utilizing a private blockchain. This experimentation aims to optimize lookup capabilities and support additional features necessary for an EHR management solution. Furthermore, the study will encompass a comparative analysis of present and future methodologies.

## VI. CONCLUSION

The conventional approach to medical record-keeping proves inefficient, demanding substantial storage space for preserving the results of all medical tests across various patients. Previous systems suffered from unstructured data, impeding seamless information transmission. Given the sheer volume of data generated by the healthcare industry, there is a pressing need to enhance data management methods while safeguarding data security and privacy. The evolving landscape, especially concerning confidential data, introduces additional complexities, necessitating solutions. Blockchain emerges as a robust mechanism adept at addressing these fundamental challenges.

Our system empowers patients to effortlessly grant and revoke record-specific authorizations to authorities with a simple tap. The automation of this process is significantly streamlined thanks to the capabilities of Ethereum and smart contracts. The proposed wallet serves as a secure bridge, facilitating convenient blockchain access and streamlined secret key management. It acts as a crucial link for patients hesitant about transitioning their information to electronic health records (EHRs). Leveraging cryptographic encryption methods that are highly resilient to cracking, the system ensures robust security and reliability.

Our assessment indicates that the system has successfully achieved the majority of the project's objectives, particularly concerning the secure authentication and data exchange of medical reports using blockchain technology. The project's implementation is anticipated to align with users' needs. Consequently, the successful integration of blockchain has addressed authentication, data exchange, and security challenges in medical reports. The system also addresses issues related to disease transmission in hospitals, such as the ongoing COVID-19 situation, mitigating risks associated with physical copies of medical records and minimizing the potential for human chain contamination.

## REFERENCES

- [1] Rajani, Aniket & Singh, Aashutosh & Kumar, Abhishek & Bandekar, Chirayu. (2023). Healthcare Management System using Blockchain with ML Integration. *International Journal of Advanced Research in Science, Communication and Technology*. 3. 96-101. 10.48175/IJARSC-8565.
- [2] Tan TL, Salam I, Singh M (2022) Blockchain-based healthcare management system with two-side verifiability. *PLoS ONE* 17(4): e0266916. <https://doi.org/10.1371/journal.pone.0266916>
- [3] Tan TL, Salam I, Singh M. Blockchain-based healthcare management system with two-side verifiability. *PLoS One*. 2022 Apr 14;17(4):e0266916. doi: 10.1371/journal.pone.0266916. PMID: 35421184; PMCID: PMC9009638.
- [4] Ben Fekih R, Lahami M. Application of Blockchain Technology in Healthcare: A Comprehensive Study. The Impact of Digital Technologies on Public Health in Developed and Developing Countries. 2020 May 31;12157:268–76. doi: 10.1007/978-3-030-51517-1\_23. PMCID: PMC7313278.
- [5] Khezr, Seyednima, Md Moniruzzaman, Abdulsalam Yassine, and Rachid Benlamri. 2019. "Blockchain Technology in Healthcare: A Comprehensive Review and Directions for Future Research" *Applied Sciences* 9, no. 9: 1736. <https://doi.org/10.3390/app9091736>
- [6] Vujičić, Dejan & Jagodic, Dijana & Randić, Siniša. (2018). Blockchain technology, bitcoin, and Ethereum: A brief overview. 1-6. 10.1109/INFOTEH.2018.8345547.
- [7] K. Tiwari, S. Kumar, and R. K. Tiwari, "SURAKSHIT: a blockchain-enabled healthcare model for privacy assurance and data security," *Journal of Critical Reviews*, vol. 7, no. 13, pp. 2493–2511, 2020.
- [8] A. Gharat, P. Aher, P. Chaudhari, and B. Alte, "A framework for secure storage and sharing of electronic health records using blockchain technology," *ITM Web of Conferences*, vol. 40, article 03037, 2021
- [9] M. Gupta, "PR wallet based blockchain access protocol to secure EHRs," in *Blockchain and IoT Integration*, pp. 65–76, Auerbach Publications, 2021.
- [10] M. D. Turjo, M. M. Khan, M. Kaur, and A. Zaguia, "Smart supply chain management using the blockchain and smart contract," *Scientific Programming*, vol. 2021, Article ID 6092792, 12 pages, 2021.
- [11] C. C. Agbo, Q. H. Mahmoud, and J. M. Eklund, "Blockchain technology in healthcare: a systematic review," *Multidisciplinary Digital Publishing Institute, In Healthcare*, vol. 7, no. 2, p. 56, 2019.
- [12] A. Sharma, G. Rathee, R. Kumar et al., "A secure, energy- and SLA-efficient (SESE) E-healthcare framework for quickest data transmission using cyber-physical system," *Sensors*, vol. 19, no. 9, p. 2119, 2019.
- [13] S. Pariselvam and M. Swarnamukhi, "Encrypted cloud based personal health record management using DES scheme," in *IEEE International Conference on System, Computation, Automation and Networking (ICSCAN)*, pp. 1–6, Pondicherry, India, 2019.