SMART CONTRACTS DEPLOYMENT WITH SECURITY ENHANCEMENT OF HEALTHCARE DATA USING ETHEREUM BLOCK CHAIN TECHNOLOGY

Y. Pratapa Reddy[1*], Dr. Ch. Aruna[1]

[1-] Department of Computer Science and Engineering, KKR & KSR Institute of Technology and Sciences (A), Vinjanampadu, Vatticherukuru (Md), Guntur District-522 017, Andhra Pradesh, India.

ABSTRACT

The safety and security of the medical information included in electronic health records (EHR) continues to be a major concern. Individual 'healthcare' is everyone's first priority, regardless of gender or age, and it affects everyone's daily life, which includes various components like Doctor, prescriptions, chemists, clinics, medical reports, etc. Everyone could not keep / maintain or adopt their personnel doctor in the society. This emphasises the importance of every person memorising and disclosing their own medical history. Whenever necessary, the person should reveal their medical history to a doctor without hesitation so that the patient can receive an immediate support and proper medical care and also the doctors can make a quick decision. In the present study, a secured web application, 'MediConnect' is proposed, where every registered person can access their health records by entering their unique "Individual Patient Medical Identity" (IPMID or MC XXXXX), which is created when they register in web application, and stores in a database. Block Chain Technology (BCT), which is powered with environments like node.js, npm, and github etc., and the tools like MetaMask and Ethereum, will further encrypt the massive database, making it impossible for hackers or unregistered individuals to change, delete, or otherwise tamper the existing records. This ensures that all citizens can easily and securely upload their medical records to a secure internet platform.

Keywords: HER, Healthcare, IPMID, Data integration, Blockchain Technology, Ethereum, MetaMask

1. INTRODUCTION

Satoshi Nakamoto introduced "Blockchain Technology" (BCT) in his 2008 white paper "Peer-to-Peer Electronic Cash System" (PEPCS). In 2009, Satoshi Nakamoto built a Bitcoin, the first Blockchain application. A distributed, replicated, noble network of databases, where the BCT, allows a numerous non-trusting party to trade without a trusted intermediary while maintaining an ever-growing, append-only, tamper-resistant list of time-sequenced records. BCT wants to develop a decentralised, uncontrolled digital currency so that the two people can interact directly without intermediaries.

Block chain Technology (BCT) is opted by many academics and researchers to work on it in the present days in various industries like transportation, supply chain management, and medical care. and so on. Ledger of Me (LoM) argues that event-driven smart contracts, medical record data, and patient control are required for blockchain-based Patient Health Records (PHR) systems. [1].

Dimitrov, (2019) [2] surveyed and suggested that blockchain technology may find use in healthcare for patient outreach apps, medical records, and data ownership, with the help of digital systems built on the blockchain. The systems help and allows the data producers including patients, to connect quickly, easily, and seamlessly. The integration of blockchain with Internet of Things (IoT) networks to protect data integrity while minimizing privacy and security concerns is smart contracts, which manage data, authenticate devices, authorize users, and regulate access. [3]. Many ledgers and applications (Apps) are developed by researchers, academicians, and industrialists to work with BCT. Some of them are A hyper-ledger blockchain-enabled secure medical data management system (HBESDM-DLD) equipped with a deep learning (DL) diagnosis model [4], which can address encryption, efficient key creation, hyper-ledger blockchain data management, and diagnosis with the help of the SIMON block cypher technique.

Allam et al., (2024), [5] reviewed about the IoT applications in eHealth and how BCT might help solve healthcare management concerns using consensus algorithm.While designing a ledger or a database the Health Insurance Portability and Accountability Act (HIPAA) standards must be followed, which enhances the protecting patient privacy through BCT and increase healthcare inter-system communication while.

By combining the Cyber-physical Systems (CPS) with blockchain technology encompasses distributed ledger technology, secure conventions, and consensus computations and specialists can enhance the robustness, dependability, and security of these frameworks. The two primary parts of our blockchain-based deep learning method for medical cyber-physical systems (CPS) are a security framework to safeguard medical data and a classifier to conduct deep learning-based anomaly scans. [7].

A BCT e-Learning architecture is used in Higher Education Systems (HES), highlighting the benefits such as security, anonymity, longevity, integrity, transparency, immutability, and global ecosystem simplification [8]. A ‘Block-ED' was designed to assist the educational community in managing their resources in such a way that no unauthorised manipulations or alterations to the documents occur [9].

Fang, et al., (2020) [10,11] discussed about a focus on record, credential issuance and management, and the decentralized education ecosystem. An architecture ‘HEDU-Ledger’ was designed with BCT enabled hyper-ledger fabric Apps to facilitate the ‘HEC-University’ with direct

channel attestation, validation, and traceability, and after endorsing attestation records, the hyper-ledger fabric confirms the degree and safely tracks stakeholder peer nodes.

Alshahrani (2022)[12] investigated the use of smart contracts (SC) and blockchain technology in online education, which provides an Innovative Enhanced Elliptic Curve Cryptography (IECCA) technique for encrypting and decrypting the data in order to boost the confidence in the evaluation. The behaviour analysis of the IECCA method proves that the strategy will improve the confidence in online learning platforms, evaluation procedures, academic records, and credentials.

Alhumayzi et al., (2023)[13], suggested a BCT related EHR data security App, 'AFPDSM' to safeguard data with an increased security of 98% and access limitation by 97%. Which is better than other applications like HCA-ECC, EHRCHAIN, IBE-DLM, and SPAKE.The market growth and demand of BCT in other potential fields are explored, and the employment prospects for students from various disciplines are analysed [14].

Yu et al., 2024, [15] developed and tested a BCT based platform for the collaborative sharing of educational resources from multiple angles including HEIs training output index, scientific research output index, social service index, and coordination degree of resource.

Dwivedi & Vig (2024),[16] discussed various difficulties that arise in the technological-organizational-environmental (TOE) barriers to BCT deployment in Indian higher education institutions (IHEI). It uses semi-structured interviews with private university higher administration and IT teams in Delhi-NCR, and identified ten significant difficulties under the three TOE framework dimensions.

Rejeb et al., 2019, [17,18] used both the IoT and BCT to improve the effectiveness and efficiency of current supply chains management (SCM) in tandem with IoT infrastructure. A framework was developed by conducting semi-structured interviews with four firms that utilized BCT, and concluded that SCM with an ideal application of BCT for financial and traceability purposes, to lighten the digitization of transactions, integration of the supply chain, and standards compliance.

Tokkozhina et al., 2023,[19] identified the influential dimensions of BCT adoption in SCM and investigate their synergetic and counter-synergetic effects which impacts 'operations and processes', 'supply chain connections', and 'innovation and data access'.

An artificial intelligence (AI) powered decentralised healthcare architecture that connects and authenticates the IoT devices is built on AI-enabled smart contracts. Data combination, time, and connection value outlined with a BCT was developed which enables a decentralised personal health data ecosystem that will revolutionise medication discovery, biomarker research, and preventative healthcare using blockchain and deep learning (DL) [20].

[20]. The focus on IoMT benefits from cloud computing (CC), edge computing(EC), and AI technology, the reduction in healthcare costs while maintaining patient privacy was studied [21].

The importance of healthcare services (HCS) and issues that have emerged during COVID-19 period was addressed with a decentralised, patient-centred healthcare system [22]. A Doctor Appointment System (DAS) which is an online application using JavaScript, HTML, CSS, Bootstrap, and MySQL on the backend was developed [23].

The comprehensive analysis has been studied under AI applications includes theoretical foundations, case examples, and major themes such as scalability, security, and ethical considerations, which contribute to the development of strong, intelligent decentralised systems (Hammad et al., 2024)[24]. Machine learning (ML) algorithms has been studied about the user-submitted health data to measure symptom intensity and provide preliminary medical advice, at the system's architecture, severity prediction ML models, which shows impact on rapid healthcare treatment (Aysha M, 2025)[25].

ML implementation challenges in relation to non-adoption, abandonment, health and care technology scale-up, dissemination, and sustainability (NASSS) with clinical, operational, and epidemiological use cases shows ML's core health care function [26].

Kelly et al., (2020)[27] was studied related to IoT health care challenges, barriers to market acceptance by health care professionals and patients, confidence and acceptability, privacy and security, interoperability, standardisation and remuneration, data storage, and control and ownership, policy support, cybersecurity standards, strategic planning, and transparency.

Session-based, service-based, rule-based, and profile-based encryption and access controls make protecting the EHR data difficult. Multiple datasets are safeguarded by AFPDSM uses data taxonomy analysis to categorise relevant EHR data. The ciphertext of a polynomial function and feature values encrypt data in a BCT implementation of Healthy Trust Access Restriction(HTAR), and stops unauthorised access [28]. Wenhua et al., (2023)[29] investigated about the security challenges and problems of BCT with cryptography, decentralisation, and consensus algorithms.

Shahnaz et al., (2019) suggested framework aims to integrate blockchain technology for EHR and safeguard EHR with granular access rules, and addresses the scalability issue with BCT, including off-chain record storing which offers EHR systems the benefits of a scalable, secure, and integrated blockchain solution [30].

2. DEVELOPMENT ENVIRONMENTS

2.1 BLOCK CHAIN TECHNOLOGY

Improved security and anonymity are two benefits that many sectors can reap from blockchain technology. Numerous social and corporate spheres are currently making use of blockchain

technology. Among the many subjects covered in these parts are e-governance, logistics, transportation, social media, and online commerce. Digital records can be made secure with blockchain technology. Because there are no middlemen or administrators in the digital ledger, all records are completely verifiable. Since each transaction in the blockchain is dependent on the ones that came before it, any additions or deletions to the blockchain must be documented in the ledger. The blockchain is thus impenetrable to cybercriminals. A single block of BCT is revealed in Figure-1.

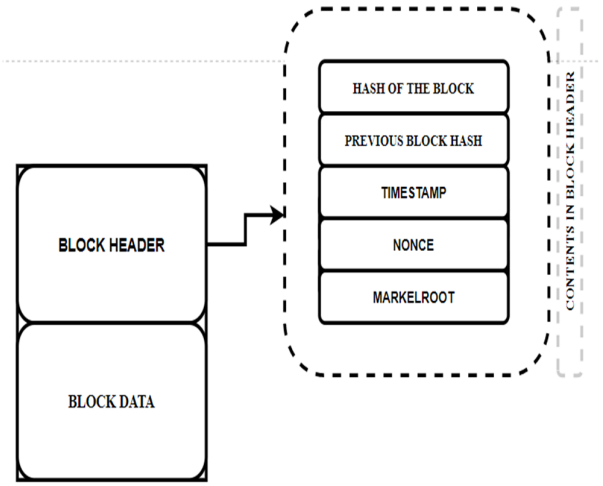


Figure 1: Components of a Single Block of Block Chain Technology

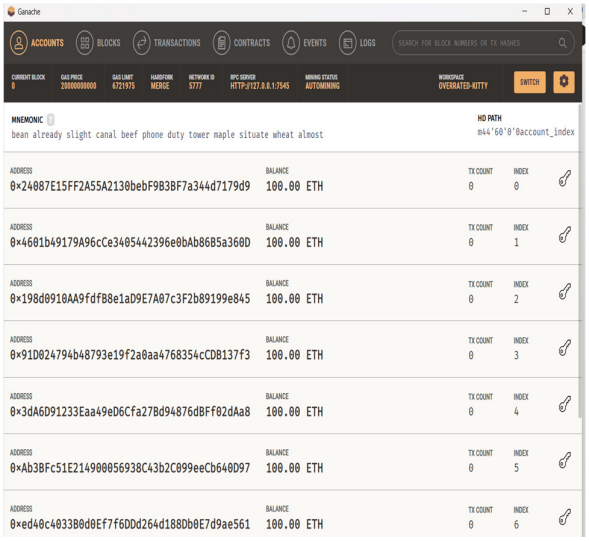


Figure 2: Ganache interface with default accounts

Figure -1 reveals the details of an individual block, which contains two major parts termed as ‘block header’ and ‘block data’. The second or lower part of the block always contains the original data related to transaction carried out. And the sub components of the ‘block header’ will change accordingly to the conditions of the new block creation., ie., when the block is generated, its time schedule, hash address, link with previous block and the effect of overall hash (Markel root) are updated.

2.2 GANACHE

“Ganache” is a personal blockchain for Ethereum, which can be used to deploy smart contracts, develop applications and run tests. Both desktop applications and command line tools are available on various operating systems. After the Ganache is downloaded and installed, the accounts page will be shown with a default account in Ganache is shown in Figure 2, it contains 10 default rows which indicates the transactions, and each transactions have 100 Ethereum (ETH). The transactions will be carried out in the form of ‘Gas’. Each transaction will facilitate with its own ‘address’ and ‘private key’ which makes the transactions easier.

'Ethereum' is the second largest cryptocurrency after bitcoin. Vitalik Buterin and a few others founded Ethereum in 2015. Vitalik is a cryptographer, worked on developing a decentralised network that may increase the value of society's other services, many of which are currently centralised. Voting, real estate transfer records, and social networks like 'Facebook' and 'Twitter' all rely on specialised servers that handle the majority of the data that works. Ethereum uses the proof of Stake (PoS) based Consensus Mechanism (CM) to deploy a smart contract. These things can be decentralised using the technology that powers Bitcoin, known as Blockchain. Ethereum enables decentralised solutions for a variety of sectors, including crowd-sourcing, democratic voting, and a public movie review engine etc.,

2.3 METAMASK

To access an Ethereum network, a Google Chrome bowser extension 'MetaMask' which is acts as a wallet is to be enabled, and enabling the user should get registered with MetaMask wallet account.

2.4 TRUFFLE SUITE

First, install the Truffle for Visual Studio (VS) code which is useful to create, debug, and deploy the smart contracts on Ethereum based blockchains. It describes the local IDE Solidity debugging support.

Solidity is a high-level object-oriented programming language which is created developed by Ethereum led by Christian Reitwiessner in 2015, which is designed for smart contracts using cryptocurrency. It is an Ethereum Virtual Machine (EVM) used as a run time environment to make smart contracts using BCT. This Ethereum uses a byte code.

A sample solidity program to develop a smart contract in REMIX.IDE is described in Figure -3.

```
1  // SPDX – License-Identifier:MIT
2
3  pragma solidity 0.8.19;
4
5  contract receiveMoney Contract {
6
7      function receiveMoney () public payable {
8      }
9  }
```

Figure-3: Basic smart contract program in Solidity interface

In the solidity program (Figure -3), various functions, variables are used where '**MIT'** indicates the license, 'pragma solidity' is the compiler, '0.8.19' is the version of compiler, 'contract' indicates the smart contract, 'public' indicates the usage to public where anyone can receive. The other required development tools are preinstalled in the device like 'Node.js', 'npm', 'github', etc.,

3. METHODOLOGY

In the present work, an object-oriented programming language, 'remix.ethereum' is used as a environment to develop a smart contract with the help of 'MetaMask' wallet added with Ganache, an Ethereum Blockchain. The working procedure to deploy a smart contract in Remix is mentioned in the Table 3.1.

3.1 Stepwise Procedure to develop a smart contract

Table-1: Steps to follow to generate a smart contract

Step No.	Procedure step to do
Step:1	Install 'Ganache' blockchain Ethereum from truffle.com From the installed App, 'Quick Start' is selected, then the Ganache interface opened and is shown in Figure -2. It contains the details of URL as http:// 120.0.0.1:7545. The default Chain ID is 1337.
Step:2	Open Google Chrome Browser and add an extension of MetaMask to it Create an account by registering into the MetaMask. It creates a wallet account as Account 1, Account 2, …so on with each account will have 0 ETH of credited amount.
Step:3	Add the ganache account to MetaMask Wallet through 'Add custom network' To add a 'custom network', copy the 'URL' and 'chain ID' of Ganache through entering the private key details of ganache in the MetaMask. It creates an account.
Step:4	Install the development environments like 'truffle version' for windows with 'visual studio' (VS) code, 'node.js', 'npm', 'github' for creating a smart contract.
Step:5	Open remix.ethereum.org and run online object-oriented programming language under solidity platform.
Step:6	Connect the MetaMask to remix platform to initiate a smart contract
Step:7	Further, the smart contracts can be developed.

3.2 Smart Contract for proposed work

The procedure mentioned in Table-1 is followed and installed all required software to generate a smart contract for the proposed work. In the proposed work the health records of the individual patient will be secured.

The steps involved in the development of data in the proposed web application (MediConnect) includes various steps like ‘Register now’, ‘Patient login’ and ‘Doctor login’.

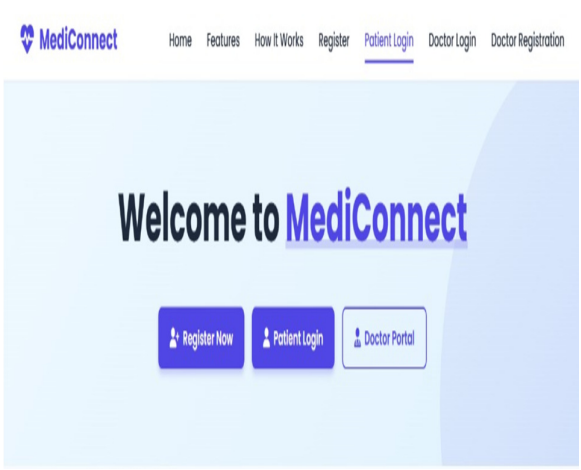
In the first ‘Register now’ step, a new person or individual can register by providing the details like Name, date of Birtthe, email, personnel mobile number, alternate / emergency contact number and address. Later, it generates login credentials as username as MS-XXXXX, and a random password. This can be connected to the blockchain network.

Later, in the second level, from the ‘Patient login’ interface, the registered patient can view his/her record data by connecting the Ganache and MetaMask wallet to the account. Further, they can add the records in the form of text messages which are accessible through online by them or any registered Doctors, pharmacists, clinical staff, etc.

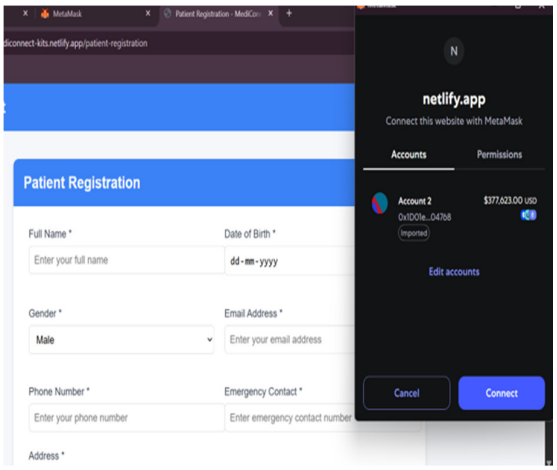
In the ‘MediConnect’ web application, the ‘Doctor login’ interface is meant for ‘Doctors login’ purpose to check the previous health records, reports, prescribed medicines etc., of details of the registered patients

4. RESULTS AND DISCUSSIONS

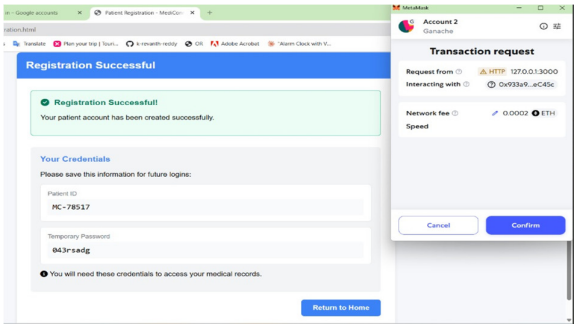
After the development of a smart contract in the remix.ethereum blockchain environment, the transactions are performed to test the program, where patient registration, patient login and doctor login has been development and the obtained results are shown in images from Figure:5(a) to 5(i).



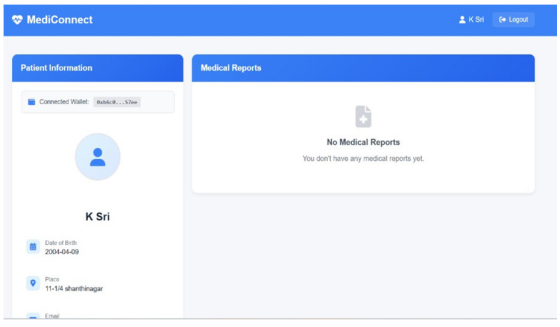
(a)



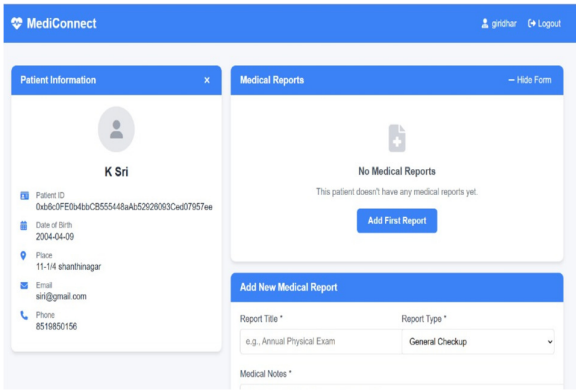
(b)



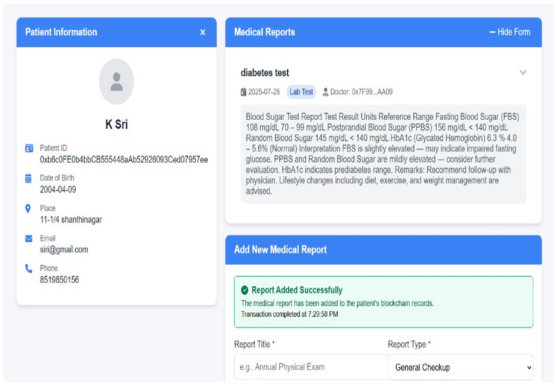
(c)



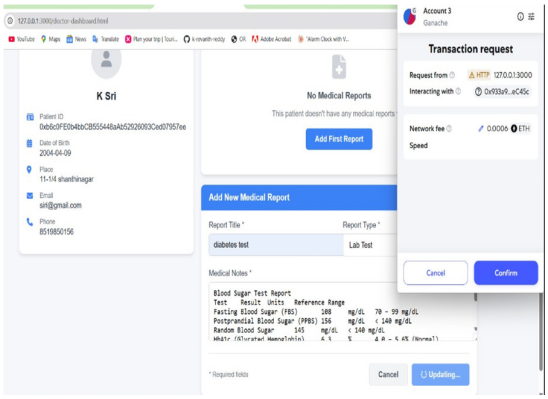
(d)



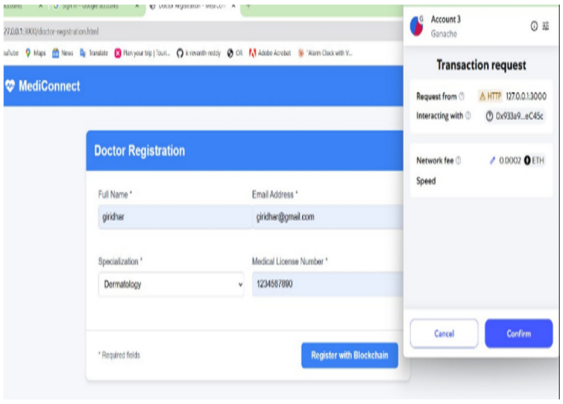
(e)



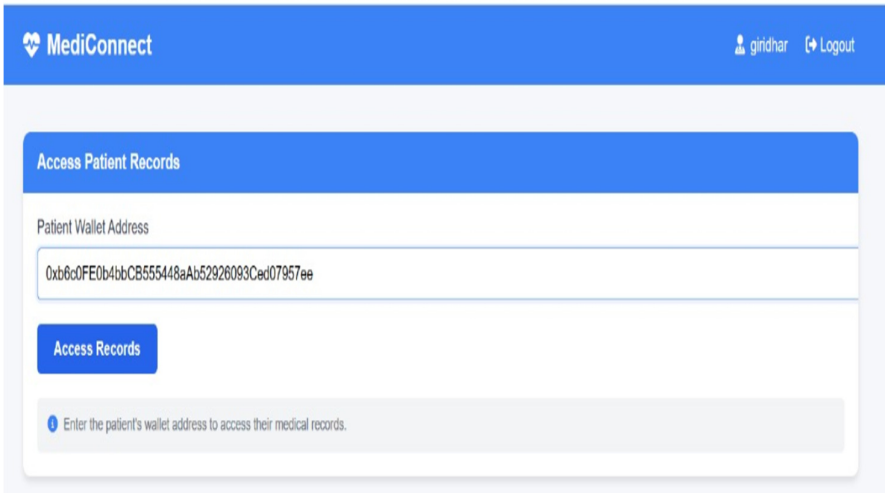
(f)



(g)



(h)



(i)

Figure -5: Outcomes of the medical record development in MediConnect

The Figure:5 (from 5(a) to 5(i)) describes the outcomes of various levels of while development of a smart contract in MediConnect web application.

First, the ‘MediConnect’ application has been initiated and from the ‘Register now’ tab, a new patient registration is completed which it develops a unique medical ID as MC-XXXXX, with provided ‘user ID’ and ‘password’.

Later, from the ‘patient login’ tab, the account is connected to blockchain through MetaMask wallet and a new block has been created in the Ganache interface with an unique private and public keys. Due to this unique key generation, the Ethereum blockchain is considered as a highly secured database. By entering the unique record private key details, the medical records of the patient can be uploaded and can be accessed through online.

Further, whenever, any registered medical practitioner / doctor / specialist needs to verify any patient record, the registered doctor can access the patient record by entering the private key of the patient.

Through this application, any person/ patient can upload and store their health record in the database, which are accessible through online from anywhere with high security. It provides the complete and perfect medical history of patient which improves the treatment conditions.

5. CONCLUSIONS

As a result of advancements in BCT, a distributed and secure ledger of patient personal health record is generated. This will allow patients to have more intervention over their data, as well as better oversight of various treatments they have undergone at various levels added with proof of reports. Patients can gain real benefits from sharing their data with specialists of healthcare sector like pharmacists, specialist doctors, researchers, clinical level staff, and other insurance companies, to get a flawless treatment.

A decentralised healthcare management is attractive because it protects the patient data with transparency, trust, security, and privacy. The distributed and shared blockchain structure prevents a single point of failure. BCT is used to collect distant patient medical data and maintain patient Health record (PHR) in this decentralised healthcare data management architecture. Real-time testing of the proposed framework ‘MediConnect’ evaluates the patient credentials and generates the IMPID as MC-XXXXX to access them with high security by using SHA-256 consensus algorithm of Ethereum blockchain.

REFERENCES

[1] G. Leeming, J. Cunningham, and J. Ainsworth, “A Ledger of Me: Personalizing Healthcare Using Blockchain Technology,” *Front. Med.*, vol. 6, no. July, pp. 1–10, 2019, doi: 10.3389/fmed.2019.00171.

[2] D. V. Dimitrov, “Blockchain applications for healthcare data management,” *Healthc. Inform. Res.*, vol. 25, no. 1, pp. 51–56, 2019, doi: 10.4258/hir.2019.25.1.51.

[3] K. P. Satamraju and B. Malarkodi, “Proof of concept of scalable integration of internet of things and blockchain in healthcare,” *Sensors (Switzerland)*, vol. 20, no. 5, 2020, doi: 10.3390/s20051389.

[4] N. Sammeta and L. Parthiban, “Hyperledger blockchain enabled secure medical record management with deep learning-based diagnosis model,” *Complex Intell. Syst.*, vol. 8, no. 1, pp. 625–640, 2022, doi: 10.1007/s40747-021-00549-w.

[5] A. H. Allam, I. Gomaa, H. H. Zayed, and M. Taha, “IoT-based eHealth using blockchain

technology: a survey," *Cluster Comput.*, vol. 27, no. 6, pp. 7083–7110, 2024, doi: 10.1007/s10586-024-04357-y.

[6] Y. Y. Ghadi *et al.*, *The role of blockchain to secure internet of medical things*, vol. 14, no. 1. Nature Publishing Group UK, 2024. doi: 10.1038/s41598-024-68529-x.

[7] B. F. Balogun, K. Tripathi, S. Tiwari, S. M. J S, and A. K. Tyagi, "A blockchain-based deep learning approach for cyber security in next-generation medical cyber-physical systems," *J. Auton. Intell.*, vol. 7, no. 5, p. 1478, 2024, doi: 10.32629/jai.v7i5.1478.

[8] K. Palanivel, "Blockchain Architecture to Higher Education Systems," *Int. J. Latest Technol. Eng. Manag. Appl. Sci.* , vol. VIII, no. II, pp. 124–138, 2019.

[9] S. Irshad, M. N. Brohi, and T. R. Soomro, "Block-ED: The Proposed Blockchain Solution for Effectively Utilising Educational Resources," *Appl. Comput. Syst.*, vol. 25, no. 1, pp. 1–10, 2020, doi: 10.2478/acss-2020-0001.

[10] Y. Fang, "Current Status , Issues , and Challenges of Blockchain Applications in Education Blockchain Technology and its Characterize," pp. 20–31, 2020.

[11] A. A. Khan, A. A. Laghari, A. A. Shaikh, S. Bourouis, A. M. Mamlouk, and H. Alshazly, "Educational blockchain: A secure degree attestation and verification traceability architecture for higher education commission," *Appl. Sci.*, vol. 11, no. 22, pp. 1–22, 2021, doi: 10.3390/app112210917.

[12] M. Y. Alshahrani, "Implementation of a blockchain system using improved elliptic curve cryptography algorithm for the performance assessment of the students in the e-learning platform," *Appl. Sci.*, vol. 12, no. 1, 2022, doi: 10.3390/app12010074.

[13] M. Alhumayzi, L. Batista, and V. Benson, "Factors Affecting Employees' Acceptance of Blockchain in the Higher Education Institutions," *Int. Conf. Enterp. Inf. Syst. ICEIS - Proc.*, vol. 2, no. Iceis, pp. 297–303, 2023, doi: 10.5220/0011833500003467.

[14] R. Patan, R. M. Parizi, M. Dorodchi, S. Pouriyeh, and A. Rorrer, "Blockchain Education: Current State, Limitations, Career Scope, Challenges, and Future Directions," pp. 1–25, 2023, [Online]. Available: http://arxiv.org/abs/2301.07889

[15] Y. Yu, L. Yan, and H. Sun, "Research on the Optimization and Coordination of Higher Education Resources Allocation Efficiency Based on Blockchain Technology," *Inf. Knowl. Manag.*, vol. 5, no. 1, pp. 27–38, 2024, doi: 10.23977/infkm.2024.050105.

[16] S. Dwivedi and S. Vig, "Blockchain adoption in higher-education institutions in India: Identifying the main challenges," *Cogent Educ.*, vol. 11, no. 1, 2024, doi: 10.1080/2331186X.2023.2292887.

[17] A. Rejeb, J. G. Keogh, and H. Treiblmaier, "Leveraging the Internet of Things and Blockchain in SC.pdf," *Futur. Internet*, vol. 11, no. 161, pp. 1–22, 2019.

[18] A. Batwa and A. Norrman, "A framework for exploring blockchain technology in supply chain management," *Oper. Supply Chain Manag.*, vol. 13, no. 3, pp. 294–306, 2020, doi: 10.31387/OSCM0420271.

[19] U. Tokkozhina, A. Lucia Martins, and J. C. Ferreira, "Uncovering dimensions of the impact of blockchain technology in supply chain management," *Oper. Manag. Res.*, vol. 16, no. 1, pp. 99–125, 2023, doi: 10.1007/s12063-022-00273-9.

[20] P. Mamoshina *et al.*, "Converging blockchain and next-generation artificial intelligence technologies to decentralize and accelerate biomedical research and healthcare," *Oncotarget*, vol. 9, no. 5, pp. 5665–5690, 2018, doi: 10.18632/oncotarget.22345.

[21] L. Sun, L. Sun, X. Jiang, H. Ren, H. Ren, and Y. Guo, "Edge-Cloud Computing and Artificial Intelligence in Internet of Medical Things: Architecture, Technology and Application," *IEEE Access*, vol. 8, pp. 101079–101092, 2020, doi: 10.1109/ACCESS.2020.2997831.

[22] M. Y. Jabarulla and H. N. Lee, "A blockchain and artificial intelligence-based, patient-centric healthcare system for combating the covid-19 pandemic: Opportunities and applications," *Healthc.*, vol. 9, no. 8, 2021, doi: 10.3390/healthcare9081019.

[23] Ezenwobodo and S. Samuel, "International Journal of Research Publication and Reviews," *Int.*

J. Res. Publ. Rev., vol. 04, no. 01, pp. 1806–1812, 2022, doi: 10.55248/gengpi.2023.4149.

[24] A. Hammad, "Applications of AI in Decentralized Computing Systems : Harnessing Artificial Intelligence for Enhanced Scalability , Efficiency , and Autonomous Decision- Applications of AI in Decentralized Computing Systems : Harnessing Artificial Intelligence for Enha," no. June, 2024.

[25] I. Introduction, "MEDICONNECT Abstract :," vol. 8, no. 2, pp. 2736–2739, 2025.

[26] J. Shaw, F. Rudzicz, T. Jamieson, and A. Goldfarb, "Artificial Intelligence and the Implementation Challenge," *J. Med. Internet Res.*, vol. 21, no. 7, 2019, doi: 10.2196/13659.

[27] J. T. Kelly, K. L. Campbell, E. Gong, and P. Scuffham, "The Internet of Things: Impact and Implications for Health Care Delivery," *J. Med. Internet Res.*, vol. 22, no. 11, 2020, doi: 10.2196/20135.

[28] H. Liu, R. G. Crespo, and O. S. Martínez, "Enhancing privacy and data security across healthcare applications using Blockchain and distributed ledger concepts," *Healthc.*, vol. 8, no. 3, 2020, doi: 10.3390/healthcare8030243.

[29] Z. Wenhua, F. Qamar, T. A. N. Abdali, R. Hassan, S. T. A. Jafri, and Q. N. Nguyen, "Blockchain Technology: Security Issues, Healthcare Applications, Challenges and Future Trends," *Electron.*, vol. 12, no. 3, 2023, doi: 10.3390/electronics12030546.

[30] A. Shahnaz, U. Qamar, and A. Khalid, "Using Blockchain for Electronic Health Records," *IEEE Access*, vol. 7, pp. 147782–147795, 2019, doi: 10.1109/ACCESS.2019.2946373.