Towards Blockchain-Based Secure Data Management for Remote Patient Monitoring

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***Abstract*—Traditional data collection, storage and processing of Electronic Health Records (EHR) utilize centralized techniques that pose several risks of single point of failure and lean the systems to a variety of external and internal data breaches that compromise their reliability and availability. Blockchain is an emerging distributed technology that can solve these issues due to its immutability and architectural nature that prevent records manipulation or alterations. In this paper, we discuss the progress and opportunities of remote patient monitoring using futuristic blockchain technologies and its two primary frameworks: Ethereum and Hyperledger Fabric. We also discuss the possible blockchain use cases in software engineering for systematic, disciplined, and quantifiable application development. The study extends by introducing a system architecture for EHR data management using Ethereum as a model. We discuss the challenges and limitations along with the initial evaluation results of the proposed system and draw future research directions in this promising area.**

***Index Terms*—Electronic Health Records, Blockchain, Ethereum, Hyperledger Fabric**

I. Introduction

Health can be defined as “a state of physical, mental, and social well-being and not merely the absence of disease or infirmity.” Having proper healthcare is a demand of human beings in the modern world [1]. Good quality of care and better access to healthcare facilities are of paramount importance for society and elder population. Statistics show the average life expectancy at birth has increased from 73.7 to 78.6 years between 1980 and 2016 [2]. As a result, the healthcare industry is an important sector that seems to emerge as one of the essential part of human lives. The current transformation of the digital health landscape is not only technological, but also social, cognitive, and political; the end goal is participatory health– a partnership with digital devices collecting data and generating insights, with new models of care, evolving through partnerships of clinicians, patients, and carers [3].

The term of health informatics, also known as medical informatics, is the study and application of methods to improve the management of patient data, clinical knowledge, population data, and other information relevant to patient care and community health [4]. Health informatics is not only tied to the application of computers, but more generally to the entire management of information in healthcare including the development and assessment of methods and systems for the acquisition, processing, and interpretation of patient data [5]. According to a study by Hassan Aziz [6], health informatics is a wide-ranging science incorporating the complex mixture of people, organizations, illnesses, patient care, and treatment closely tied to modern information technologies, notably in the areas of computing and communication [6].

In the past, health records were written on paper, maintained in folders divided into sections based on the type of note, and only one copy was available. This changed in the 1960s and 1970s when new computer technologies were developed to support Electronic Medical Record (EMR) [7]. EMRs, grew in popularity because their multiple benefits including the ability to easily collate and track sets of information, monitor changes in patient outcomes after implementation of a new practice or procedure, and determine which patients are due for physical exams, procedures, immunizations [8]. Correspondingly, the use of EHRs has not only made patients’ medical information easier to read and available from almost any location in the world, but also changed the format of health records, and thus changed health care [7]. However, all the records in the conventional computing approach can be manipulated or altered easily, which creates concerns in terms of security and privacy of patients [9]. This is where an approach called “blockchain” emerged to introduce a revolutionary computer protocol used for the digital recording and storing of information in a decentralized and distributed ledger [10, 11].

Data should never store as writing in pencil that could deface anytime rather ensure immutability to protect the transparency of data transaction, stressed by H. Jobair. Data in current telehealth and telemedicine systems use centralized techniques for data storage and processing; however, this poses the risk of a single point of failure and leans the systems to a variety of external and internal data breaches compromising their reliability and availability [12]. In order to reform the traditional healthcare practices, blockchain technology can be a model that helps to address such crucial problems [12, 13]. Blockchain is potentially a solution due to its immutability and architectural nature, where every block has a particular summary of the preceding block that is arranged using a

978-1-6654-1685-6/21/$31.00 ©2021 IEEE
DOI 10.1109/ICDH52753.2021.00054

secure hash value, string order, timing, content, and order of trades that can not be manipulated or altered. [14]. The key contributions of this paper are summarized below:

- We discuss existing progress and the potential opportunities for Remote Patient Monitoring using Blockchain technology.
- We provide a comprehensive review on the blockchain technology and its two widely frameworks, (i) Ethereum and (ii) Hyperledger Fabric.
- We contribute by imparting an adequate overview of the concept of blockchain technology in software engineering and its inter alia interaction.
- We propose a system architecture for data management of remote patient monitoring using Hyperledger Fabric as a model

The remainder of the paper is organized as follows: we present a synopsis of blockchain technology and its associated frameworks in Section II followed by reviewing the relevant literature and proposed systems in Section III. Section IV presents an ethereum-based prototype for remote patient monitoring. We draw a discussion on architectural challenges and limitations in Section V. Finally, Section VI provides some concluding comments and future research directions.

II. Blockchain Technology

The application of blockchain in healthcare is a recent addition in trusted sharing of sensitive healthcare information. It is defined as a distributed, incorruptible database of records or digital events which is executed, validated, and maintained by a network of computers instead of a single central network among participating parties around the world [15, 16]. The Organization for Economic Cooperation and Development (OECD) [17] describes blockchain as a combination of already existing technologies that together can create networks by utilizing distributed ledger technology (DLT). These networks can store information that has been verified by cryptography tools among a group of users and agreed through a predefined network protocol, often without the control of a central authority. The concept of blockchain is quite opposite to the conventional approach; 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. In Fig. 1, proposed by Seyednima Khezr et al. [18] depicts a workflow of blockchain-based healthcare applications.

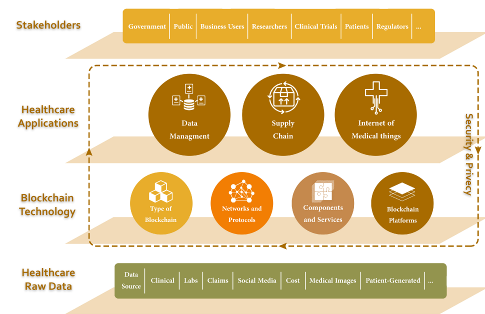

Fig. 1. represents blockchain-based workflow consists of primary layers including raw data, and stakeholders [18]

Blockchain technology allows the creation of a tamper-evident, shared, and trusted ledger that sequentially appends cryptographically secure data transactions. The ledger would only be accessible to trusted parties. The cryptographic techniques used to record information to a blockchain guarantee that once a transaction has been added to the ledger, it cannot be modified; thereby assuring participants that they are working with data transactions that are up-to-date, accurate, and nearly impossible to manipulate. The blockchain thus functions as the single source of truth.

By narrowing the focus of the research to immutable data storing, implementation of telehealth and 21st-century patient data management, blockchain technology is crucial. And the immutable nature of said technology could lead to reduced cost of regulatory compliance with greater transparency, improved traceability, increased speed, and efficiency.

Multiple blockchain infrastructures have emerged, (i) permissionless blockchain that focuses on "trustless" networks used by any individuals. 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 [19, 20]. Ethereum and Hyperledger Fabric framework are two widely known blockchain-based approaches, where Ethereum is public and supports permissioned networks, and Hyperledger is a fully permissioned network designed for operations involving sensitive and confidential data [21].

A. Ethereum

Ethereum was introduced as a platform in 2013 as a project which attempts to build a generalized blockchain technology in where all transaction-based state machine concepts may be built with aims to provide to the end-developer a tightly integrated end-to-end system. This allows building software on a hitherto unexplored compute paradigm in the mainstream: a trustful object messaging compute framework [22]. 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 kind of data structure that can store cryptographically authenticated data in the form of keys and values [23]. Fig. 2

depicts the block structure of Ethereum and its Merkle Tree where the hash of the root node (the first node in the tree) depends on the hashes of all sub-nodes.

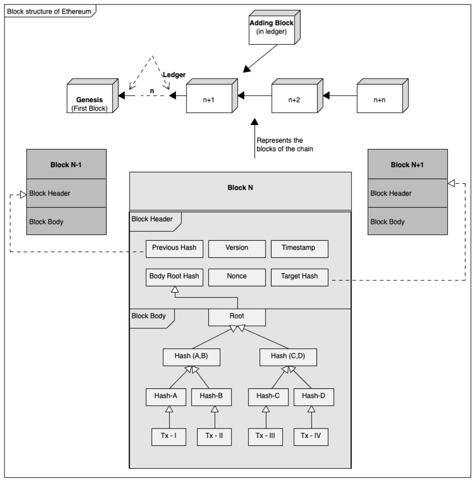

Fig. 2. Ethereum's Block structure and Merkle Root [18]

Fig. 2 also illustrates the block where the block header contains block versions that validate block rules; the "Previous Block" hash represents the value of the previous block while the "Timestamp" represents the creation time of the current block. The "Body Root Hash" is a value of the Merkle tree root built by transactions in the block body, and the "Target Hash" is a threshold of a hash value of a new valid block. On the other hand, the "Block Body" contains validated transactions, and the "Merkle Tree" is used to store all the valid transactions. The "Genesis Block" is assigned automatically when the network is started, with hash default values, and other blocks are inserted in the ledger following the genesis [24]. In addition, the "Ethereum State" is one of the key parts of the network consists of accounts, where has a 20-byte address and state transitions that are assigned for a single account [25]. The "World State" is responsible for mapping between addresses and account states while the "Consensus" in the Ethereum network is based on modified Greedy Heaviest Observed Subtree (GHOST) protocol.

B. Hyperledger Fabric

Hyperledger [26] is a distributed peer-to-peer ledger forged by consensus. Hyperledget is a blockchain combined with a system for "smart contracts" and other assistive technologies that can be used to build a new generation of transactional applications that establishes trust, accountability, and transparency at their core, while streamlining business processes and legal constraints. Hyperledger encourages a collaborative approach to develop blockchain technologies throughout a community process with intellectual property rights and the adoption of key standards [27]. It also embraces the full spectrum of use cases that are crucial for enterprise-based systems. On the same venue, healthcare industries need to focus on the issue of privacy and security of medical records of patients and Hyperledger Fabric introduces unique security mechanisms such as private data collections that allow certain authorized participants to access only specific data [19, 28]. Unlike open permissionless systems that allow unknown identities to participate in the network, the members of a Hyperledger Fabric network enroll through a trusted Membership Service Provider (MSP). MSP is the mechanism that allows an identity to be trusted and recognized by the rest of the network without ever revealing the member's private key [26]. On another venue, the Hyperledger framework allows the execution of up to 3,500 transactions per second while Ethereum can execute 15 transactions only.

Consensus is a primary feature of Hyperledger Fabric. This is defined as a distributed process by which a network of nodes provides a guaranteed unique order of transactions and validates the block of transactions [29]. It enables to predetermine the number of channels and peers and consensus rules that are required for developing and testing the proposed approach. Such features provide another layer of security ensuring that only members of the network have access to the resources and transactions of the network. As a result, the administrator controls who is able to join the network and what roles they can perform as well as remove nodes from the network if needed.

C. Analogy Between Hyperledger Fabric and Ethereum

Hyperledger Fabric is one of the most popular blockchain frameworks which is hosted by the Linux Foundation. It offers plug–and–play components such as consensus and membership services as a basis for the solutions with a modular architecture. On the other side, Ethereum is a decentralized platform running smart contracts and applications without any possibility of downtime, censorship, fraud, or interference from third parties [30]. Hyperledger Fabric intends to provide a Business-to-Business (B2B) platform with a modular and extendable architecture that can be employed in various industries, from banking and healthcare over to supply chains. However, Ethereum is mostly Business-to-Commerce (B2C) that presents itself as utterly independent of any specific field of application [31]. An analogical summary is given in Table II-C.

Both Ethereum and Hyperledger come with their unique advantages for different business scenarios and challenges. However, based on our extensive investigation, we conclude that Ethereum serves well for public applications; Hyperledger's capabilities seem more appealing in enterprise-based blockchain development. Therefore, Hyperledger Fabric shall be adopt for healthcare-based applications due to its suitability for managing health records compared to Ethereum. Hyperledger provides a confidential, scalable, and highly flexible infrastructure solution with explicit anonymity and privacy of transactions [20].

TABLE I
ANALOGICAL ILLUSTRATION BETWEEN HYPERLEDGER FABRIC AND ETHEREUM

Blockchain		
Category	Hyperledger Fabric	Ethereum
Purpose and Confidentiality	Hyperledger Fabric is designed for B2B businesses with Confidential transactions	Ethereum is designed for B2C businesses and generalized applications with transparent transaction
Modularity and Extendibility	Hyperledger Fabric provide a modular and extendable architecture that can be employed in various enterprise based environments	For Modularity and Extendibility, different approaches need to be adopted for Ethereum
Cost-Effective	Hyperledger Fabric is a native platform that enables to create self-contained private ledger and manage contracts without fees engaged	Ethereum based blockchains network require a fee for each transaction
Scalability	Hyperledger Fabric allows more scalability when organizations are added or removed from a channel	Ethereum's scalability bottleneck is notable since each node in the network has to process each transaction
Plug and Play API	Hyperledger Fabric provides SDKs in Node.js and Go that can be used to interact with the blockchain efficiently	Ethereum's plug-and-play modularity allows you to customize privacy and permissions on a single platform
Consensus	Hyperledger Fabric consists of multiple stages of checking consensus and all peers on the network do not have to come to some agreement before a transaction is successful	Ethereum adopt a consensus protocol called Proof-of-work (PoW) that allows the nodes of the Ethereum network to agree on the state of all information recorded on the Ethereum blockchain
Security and Privacy	Fabric is a permission network, all nodes that participate in the network have an identity, as provided by a modular membership provider (MSP)	Ethereum uses transparency as part of its security but potential problems with data exposure are being arisen
Transaction Speed	Hyperledger Fabric's transaction speed capacity vary from 3000 transactions per second to 20000 which is impressive	Ethereum network can only support approximately 30 transactions per second which are quite narrow as of today

D. Blockchain in Software Engineering

Blockchain is growing at a staggering rate with intrinsic potential in the domain of software application. However, an ad hoc approach to adopting blockchain may lead to not better, but worse, situations and results, and with severe disappointments [32]. For instance, blockchain is high on energy consumption along with scalability, lack of interoperability, stand-alone projects, difficult integration with legacy systems, complexity issues [33]. To overcome such issues, systematic frameworks have been proposed by inheriting the software engineering approach which is a systematic, disciplined, quantifiable approach to the development, operation, and maintenance of software; that is, the application of engineering to software [34]. These frameworks are using practices of a newly developed approach called Blockchain-Oriented Software (BOS) engineering, which is relatively new [35].

A significant example of inheritance of the concept of software engineering and blockchain is the known as "Smart Contract" where Ethereum is typically written using "Solidity". Solidity is an object-oriented language that consists of data structure, public and private functions, and can inherit from other contracts along with concepts like events and modifiers [35]. M. Marchesi et al. [36] an Agile Software Engineering method to design Blockchain applications depicts in Fig. 3.

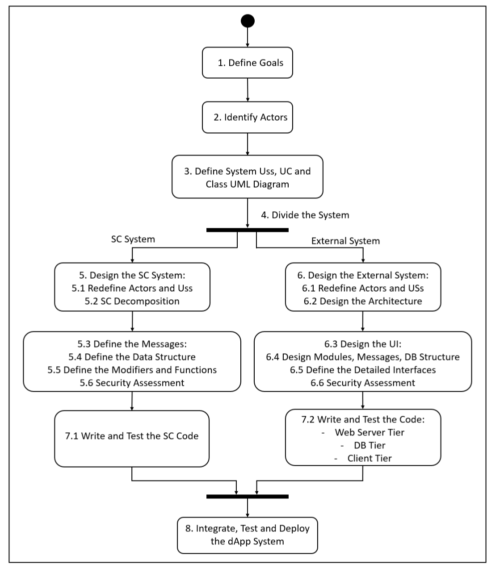

Fig. 3. Proposed Blockchain-Oriented Software development process [36]

Software Engineering provides absolute guidelines in every phase of the software development life-cycle, not only for conventional software development but also shall be extended to blockchain-based applications. Challenges in the implementation of such concepts into blockchain shall be broad due to the emergence of new technologies; however, adopting the domain including requirements, process, testing, security, maintenance, configuration management, and verification and validation is a new demand for the blockchain-based software application. Research efforts devoted to this topic can encourage practitioners to contribute more prototypes and proofs-of-concept in order to enhance the understanding of blockchain-oriented SE applications [37].

E. Blockchain in Healthcare

Blockchain was first largely applied in financial industry as the technology that allowed Bitcoin to operate, however, efforts have been made to adapt the technology for many industries including healthcare, insurance, pharmacy, manufacturing, e-voting, energy, and many more [38]. The healthcare industry is particularly challenge as it has a complex mechanism with various influential stakeholders and a need to disrupt through innovative solutions. Blockchain has applications that can potentially address healthcare issues including public health management, remote monitoring, electronic health records (EHR), medical data management, data security, and drug development. Remarkably, blockchain can mitigate concerns about data ownership and share by allowing patients to own data and choose with whom it is shared [39]. Gaynor, Mark et al. [40] graphically depicts some opportunities provided by blockchain for exchanging health care data in Fig. 4, where these applications could allow the health care industry to improve data exchange across all industry processes, including exchange, storage, and record tracking.

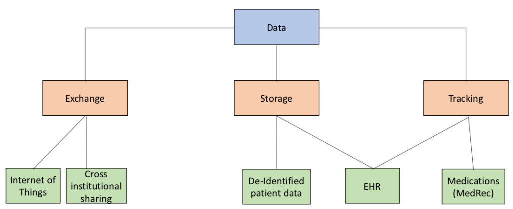

Fig. 4. Data (electronic health record) exchange tree [40]

Blockchain has the potential for addressing significant healthcare issues and provides unique opportunities to harness 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 issues that the health care industry encounters today 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 [40, 41].

F. ONC's Requirements

The Office of the National Coordinator for Health Information Technology (ONC) introduced the "Cures Act", also referred to as "21st-century cures act" to give patients and their healthcare providers seamless and secure access, exchange, and use of electronic health information. It aims to increase innovation and competition by fostering an ecosystem of new applications to provide patients with more choices in their healthcare [42, 43]. ONC act provides not only the right to electronically access all of their electronic health information and records (EHI, EHR), structured and/or unstructured, at no cost, but also ensure that physicians use technology to offer and exchange electronic health information with patients efficiently [44]. The new provisions certify the third party to access health information in a fair and consistent manner with the permission of the respective stakeholder(s). The applicability of ONC's rules shall be in effect by 2023 as illustrated in Fig. 5; it shall comply by health care providers, health IT developers, and related stakeholders.

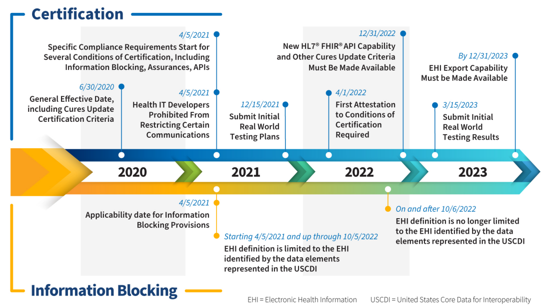

Fig. 5. ONC's Cures Act Final Rule Highlighted Regulatory Dates [40]

One of the primary purposes of ONC is to provide a mandatory guideline for the health IT developers that need to be followed for establishing secure standards [45]. The new standards and implementation require IT professionals to be certified as health IT developers in order to adequate the newly established technical requirements to provide better connection and user experience of next-generation health modules for providers and to support a patient's access to core data in their electronic health record.

III. Related Work

According to a report of the Health System Tracker [2], the number of aging/older adults is set to augment by 69% (from 56M to 94.7M) in the next 35 years. Hence, 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. We first carried out a "Search Process" to identify potential studies related to our research using the keywords Blockchain, Telehealth, and Remote Patient Monitoring in order to construct the search string. We used three digital database sources including (i) IEEE Xplore (ii) Research Gate and (iii) Springer Link.

We filtered a specific time period to search studies published between 2016 to 2021 as well as publication topics including health care, and blockchains for IEEE access and computer science discipline (Springer Link). The initial search process returned a set of 1,384 studies. We analyze the title, abstract and conclusion for research paper in order to apply the inclusion and exclusion criteria illustrates in Table II - III.

A. Applications

- Gem Health Network: In collaboration with Philips Blockchain Lab, a company named "Gem" devel-

TABLE II
GENERALIZED TABLE FOR SEARCH CRITERIA

Database	Initial Search	Total Inclusion
IEEE Xplore	120	10
Research Gate	25	2
Springer Link	35	8
Total	180	20

TABLE III
OVERVIEW OF EXCLUSION AND INCLUSION

Condition of Exclusion and Inclusion		
Category	Condition (Inclusion)	Condition (Exclusion)
Type	Blockchain, Healthcare, and telehealth based	Based on framework other than said approaches
Approach	Studies or Systems that that	that do not discuss or propose approaches
Similarity	Research and System provide similar aspects	Studies that does not depict expected aspects
Language	Studies that are available in English	Any other languages than English

ops enterprise health care applications networks using blockchain technology [46, 47]. The network includes wellness apps and global patient ID programs that create a healthcare ecosystem using the Ethereum approach. The applications would be connected to a universal data infrastructure in order to address the trade-off between patient-centric care and operational efficiency [48]. As a result, different healthcare operators can access the same information using the Gem Health network that shall include identity schemes, data storage, and smart contracts. In conclusion, the systems solve important operational problems in healthcare industries.

- MedRec: MedRec is a decentralized record management system to handle EMRs, developed using blockchain technology designed by Ariel Ekblaw and Asaph Azaria [49, 50]. The system was developed using Go-Ethereum (Geth) and Solidity; however, it was not built on the live Ethereum network, instead, it creates a small-scale private blockchain with extensive, specific APIs [51]. MedRec allows patients easy access to their medical information across providers and treatment sites [50].
- Carechain: A Swedish startup company Carechain, led by IT pioneers Johan Sellström and Stefan Farestam initiated a blockchain-based personal healthcare data management system that intends to focus on protocol level and create a new infrastructure that no one owns, but everyone can control [52]. The Carechain adopted the Ethereum approach with the aim of creating a national blockchain for health data where the system allows individuals ownership and control over their own health information [53]. The system shall assign a universal digital ID owned and controlled by the individual in order to put the individual at the center. The system shall ensure integrated information integrity, built-in policy guarantees with traceability.
- Dovetail: Dovetail is a blockchain-based digital consent application using Hyperledger Fabric approach that allows the sharing of patient data to improve healthcare systems, healthcare products, and healthcare services [54]. The system provides a fully audited ledger of medical data interactions and harnesses certain unique qualities of distributed ledger technology to verify identity, store consent and create tamper-proof audit records of every data exchange [19]. Dovetail system stores old medical records and adds new using traditional high-encryption channels with sophisticated data interpolation to transmit patient data and store patient consent for data sharing, and to make sure that that consent is respected by everyone in the process.
- Axuall: Axuall introduces a blockchain-based national digital network powered by the Sorvin Network and Hyperledger Indy to verify identity, credentials, and authenticity in real-time. The system shall enable clinicians, healthcare systems, and primary source institutions to share and manage authenticated credentials, all while meeting regulatory standards [55]. The platform automatically aggregates and verifies credentials that can be shared between clinicians and organizations in real-time by ensuring the highest standards of compliance and security. The physicians will be able to present fully compliant credential sets while healthcare organizations will be able to verify the validity of a physician's credentials [56].
- MedHypChain: MedHypChain is a privacy-preserving, patient-centered interoperability hyperledger-based medical healthcare and data sharing system, where each transaction is secured via an Identity-based broadcast group signcryption scheme [57]. The system allows secure implementation of patient-centered interoperability (PCI) data sharing between the patient and medical server remote diagnosis of a patient, interoperability, and malicious participant tracing. The demonstration indicates that the system achieves significant confidentiality, anonymity, traceability, and unforgeability.

IV. SYSTEM OVERVIEW

We propose research into the establishment of a decentralized, peer-to-peer network of participants wherein transactions are recorded on a shared distributed ledger for the purpose of patient data management and secure accessibility. Participants in the network would govern and agree by consensus on the updates to the records in the ledger. Also, every record would contain a timestamp and unique cryptographic signature. Thus, making the ledger an auditable, immutable history of all transactions in the network to ensure data security and integrity, while allowing the choice for patients and providers to access data from anywhere, anytime.

A. System Architecture

Our primary goal is to demonstrate the structure of both blockchain-based frameworks for telehealth and healthcare based application. As part of our scratch, we initially develop a demo prototype in order to provide a clear visualization of the proposed blockchain-based healthcare application. We adopt Ethereum framework towards a better understanding of how the system mechanism shall function within a Ethereum-based blockchain environment. The developed prototype consists of (i) a secure Application Programming Interface (API) that is compliant with requirements of the Office of the National Coordinator for Health Information Technology (ONC) to facilitate access, exchange and use of patient Electronic Health Records and (ii) Ethereum based data repository. For demonstration purposes, we focus on Electronic Health Record (EMR) that shall be created in a secure data repository to enable secure upload, storage, analysis, retrieval, and transmission of patient data at direction of the patient, or assign, when it is needed and where it is needed.

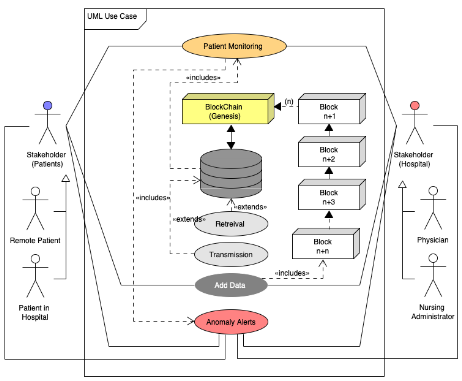

Fig. 6. UML Use Case for Blockchain-Based Health Application

We followed a variety of guidelines from different organizations and approaches– ONC and the concept of software engineering is included. In accordance to SE, we analyze the existing problem, elicit the requirements and identify the research questions by adopting the most suitable standards Agile methodology in blockchain. We develop an UML use case (80%) to scratch down the sequence of actions towards identifying objects and constituting a complete task or transaction in proposed application during requirements analysis or creation process for current research. The use case initializes as a method to capture primary functional objectives with the motivation of establishing a system's architectural foundation, and subsequently supporting requirement coverage [58]. We display four types of stakeholders including (i) Hospital and (ii) Patients in the use case depicted in Fig. 6. The use case also illustrates scores of functions; for instance, patient monitoring and anomaly alert which shall extend in continuous research.

We carried out a low-level architecture for a better understanding of the design of the proposed system where we present the overall flow of the application consists of four entities. The data shall be collected from the residents either remotely or home healthcare and shall be stored in a decentralized blockchain database. Each data shall be linked with a unique and unchangeable hash and timestamp and shall allow the assigned stakeholders in the retrieval and transmission of stored data using the designed API. An overview of the proposed system illustrates on Fig. 7 while Fig. 8 shows an overview of the interfaces to be provided.

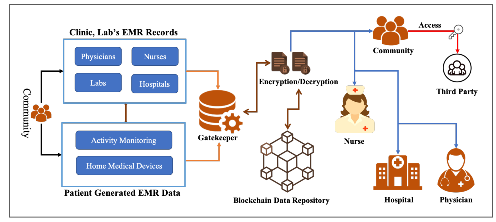

Fig. 7. A low-level architecture of proposed application

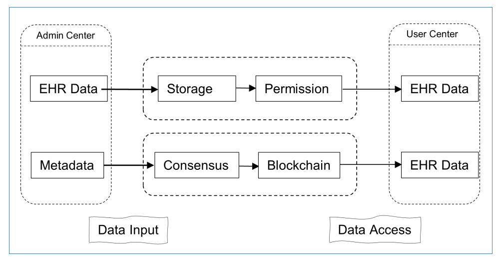

Fig. 8. An overview of metadata

The users act as peers and interact with the proposed platform through a simple web interface where the metadata has been separated but linked together by a unique identifier, so a metadata duple is considered an experiment, where each experiment has a name and an identifier. The system will validate metadata by the consensus algorithm that operates among peers within the consortium. Once the metadata is validated by consensus, the metadata is incorporated into a block and is appended in the open ledger, the ledger is composed of metadata entries in the form of blocks. The metadata shall be stored as an object with a timestamp. The peers within a consortium shall allow to search and retrieve the metadata and only be allowed to access that user has permissions. Each block of the proposed system is chained together in an append-only structure using a cryptographic hash function. As a result, altering and deleting previously confirmed data is impossible that shall lead to the new data being appended in the form of additional blocks chained with previous blocks. Meaning that, updating data of one of the transacted blocks shall generate a different hash value and different link relation towards achieving immutability and security.

The proposed system consists of two major modules, organizational and patients. The organizational section enables access to the permissioned stakeholders for adding, updating, retrieving, and monitoring EHR data information while second modules allow patient and assigned representative to access and update certain EHR records. The system was initially developed as a web application that may be extended to mobile applications in future research.

B. System Entities

- Blockchain Network: Blockchain network is one of the primary components of the proposed system designed to store Electronic Health Records (EHR) in a secure decentralized location. Stored EHR data with timestamp and hash shall be generated in the network. The network consists of two types of primary stakeholders responsible to add, update, retrieve data in a blockchain network.
- Cloud Database: We utilize a cloud-based platform named Etherscan, which is a decentralized smart contracts platform suitable for Ethereum. Etherscan allows the users to look up, confirm and validate transaction histories including token transfer and contract execution on the Ethereum decentralized smart contracts platform. Stored data on cloud can be remotely accessed by permissioned stakeholders from anywhere using internet.
- Healthcare Stakeholders: Blockchain can facilitate healthcare stakeholders including physicians, nurses, and patients in different forms. The proposed system enables said authorized stakeholders to access the network that can help to reduce the complexity and security issues.

C. System Implementation

We adopt Etherscan which is a block explorer for the proposed platform to discover, verify and approve transactions that have taken place on the Ethereum blockchain. We utilize the API service of Etherscan for developing decentralised network. Etherscan store data as hash (TxHash) into the block along with the timestamp of real-time based confirmed transaction and its fees. To access the transactions

D. System Evaluation

After contriving an initial prototype, we generally validate through experimental simulation approaches. There are several key considerations when designing any blockchain evaluation, including the test environment, observation points, transaction characteristics, workloads, and network size. These characteristics should be noted as part of the evaluation results, since revealing these details makes it easier to compare performance across platforms.

In Fig. 9, an API is depicted where stakeholders can create new patients profile by filling the preset form. Once submitted, the EMR data shall transact to the blockchain storage, details show in Fig. 11. Each EMR data consists of a unique hash and timestamp and the stored data is accessible using the authorized API, in Fig. 10. We consider the following criteria as input:

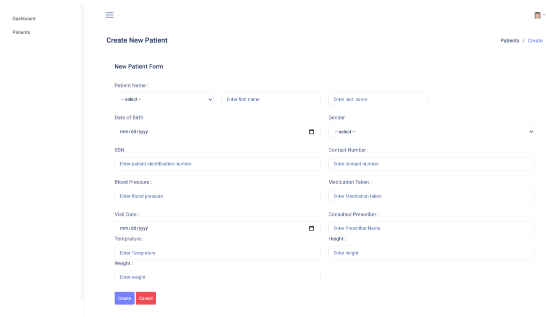

Fig. 9. Depicts a form to create patient data

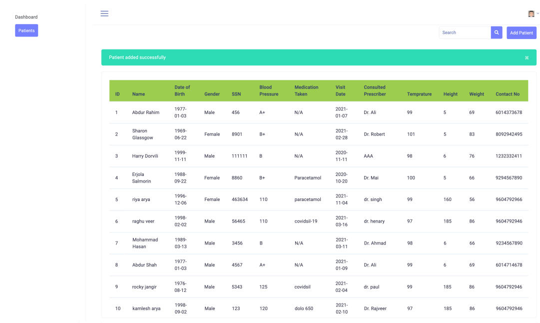

Fig. 10. An interface for accessing stored data using API

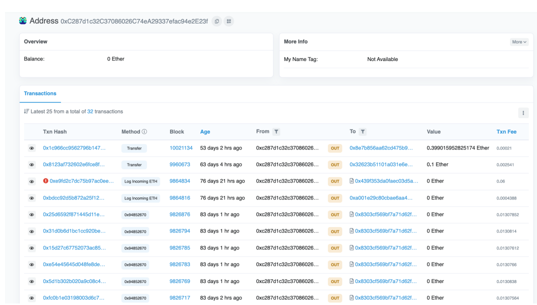

Fig. 11. Stored data saved in Ethereum-Based Blockchain Netwoek

V. Discussion

The outbreak reveals the dire need to invest and improve health infrastructure to better monitor and address the health records of patients. Looking back to the last half-century of computer technologies and architectures, we may observe a trend of fluctuation between the centralization and subsequent decentralization of computing power, storage, infrastructure, protocols, and code. Muneeb Ali asserts that we are currently witnessing the transition from centralized computing, storage, and processing to decentralized architectures and systems that allow us explicit control of digital assets to end-users and remove the need to trust any third-party servers and infrastructure [59]. The frameworks offer different aspects and methodology for every application and choosing the right framework shall depend on requirements specification. Unlike many other applications, healthcare systems' requirements are specific and the primary fundamental is to secure the EMR records in order to prevent manipulation; therefore, the application must embody a rich set of privacy features [60]. The demonstration indicates a positive result in Ethereum based healthcare and telehealth data management. Future research shall continue to facilitate and evaluate Hyperledger Fabric within practical boundaries.

Blockchain technology in software engineering is an emerging field and inheriting the concept of SE into Blockchain is indeed as of today's demand. In this study, we elaborate on some basic inter alia interaction between the aforementioned domain. The perusal indicates the importance of SE in the development of emerging blockchain technology in order to ensure proper guidelines, overcome conventional and security challenges along with the systematic framework for futuristic systems. Such illustrative study encourages researchers to contribute to enhancing the inheritance of software engineering into Blockchain.

VI. Conclusion

Blockchain is emerged to solve issues people are going through for conventional databases and related existing problems. In this study, we successfully discuss the progress of Blockchain along with an overview of the aspects of Software Engineering. An Ethereum-based system is introduced that has competency in storing Electronic Health Data within a secure and immutable blockchain network. System demonstration indicates that the prototype allows the permissioned stakeholders to add, update, and retrieve EHR data on a RESTful API environment. We recognize possible directions for future research, thus, conclude by outlining a framework for further empirical research that shall be conducted extensively to resolve issues raised in our analysis.

VII. Acknowledgement

This work was supported in part by research computing resources and technical expertise via a partnership between Kennesaw State University's Office of the Vice President for Research and the Office of the CIO and Vice President for Information Technology [61].

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