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Design and developing of a privacy security mechanism using blockchain Hyperledger fabric in health care management system

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Abstract
Blockchains are tamper evident and tamper resistant digital ledgers implemented in a distributed fashion and usually without a central authority. At their basic level, they enable a community of users to record transactions in a shared ledger within that community, such that under normal operation of the blockchain network no transaction can be changed once published. This document provides a high-level technical overview of blockchain technology. The purpose is to help readers understand how blockchain technology works.
Hyperledger Fabric is a modular and extensible open-source system for deploying and operating permissioned blockchains. Fabric is currently used in more than 400 prototypes and proofs-of-concept of distributed ledger technology, as well as several production systems, across different industries and use cases. Starting from the premise that there are no "one-size-fits-all" solutions, Fabric is the first truly extensible blockchain system for running distributed applications. It supports modular consensus protocols, which allows the system to be tailored to particular use cases and trust models.
Fabric is also the first blockchain system that runs distributed applications written in general-purpose programming languages, without systemic dependency on a native cryptocurrency. This stands in sharp contrast to existing blockchain platforms for running smart contracts that require code to be written in domain-specific languages or rely on a cryptocurrency.
Furthermore, it uses a portable notion of membership for realizing the permissioned model, which may be integrated with industry-standard identity management. To support such flexibility, Fabric takes a novel approach to the design of a permissioned blockchain and revamps the way blockchains cope with non-determinism, resource exhaustion, and performance attacks.
This paper describes Fabric, its architecture, the rationale behind various design decisions, its security model and guarantees, its most prominent implementation aspects, as well as its distributed application programming model. We further evaluate Fabric by implementing and benchmarking a Bitcoin-inspired digital currency. We show that Fabric achieves end-to-end throughput of more than 3500 transactions per second in certain popular deployment configurations, with sub-second latency.

Keywords: Hyperledger fabric, healthcare management system, privacy protection, security mechanisms, access control, smart contracts

1. Introduction
Blockchain technology has emerged as a key technology recently in the digital revolution of the healthcare sector and several research studies have identified blockchain potential for the healthcare ecosystem. It is ready to transform the way traditional medical systems and businesses have been engaged in the healthcare sector for the last several decades. Information and Communication Technologies and blockchain are key enabling technologies for the decentralization and digitalization of healthcare institutions and provides modern and digitalized healthcare ecosystem to patients as well as service providers. Blockchain applications for healthcare data management create utilities for patient, doctors and healthcare institutes in the directions of patient record access and control, claims and payments management, management of medical IoT security and research data verification and exchange for financial auditing and transparency.
In these applications, real-time updates to an encrypted, decentralized blockchain ledger are done to understand, monitor, and control medical information. This also facilitates the healthcare institutions to restrict the unauthorized person to access sensitive information.

Hyperledger Fabric is a permissioned distributed ledger technology. Basically, if you want to make our own blockchain and not hop onto Ethereum or some other existing blockchain, then you can do that with Hyperledger Fabric.

It's modular, which means that we can choose a change aspect of it depending on our particular needs. For example, the consensus protocol, the database management service, the ordering service can all be configured. The smart contracts can be written in some popular programming languages, such as Java, Go, and NodeJS/

Java script. The Fabric blockchain is permissioned, meaning that only invited people can participate and view the blockchain. We don't need cryptocurrency for the mining of blocks, which can sometimes enable simpler and safer contracts and transactions. This all sounds pretty good. (1. Journal of Big Data).

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.

This work presents a healthcare smart contract system for medical data management and to streamline complex medical procedures. We discussed the state-of-the-art blockchain research in the healthcare field and implemented Hyperledger fabric-based solution for the healthcare management. (Agbo, C.C., Mahmoud, Q.H. and Eklund, J.M.) [18] The purpose of this paper is also to indicate the potential use of blockchain in healthcare and to show blockchain research's challenges and possible directions. This systematic review includes only research that introduces a new healthcare solution, algorithm, method, methodology, or architecture. Review type research, discussion of potential blockchain uses and applications, and other non-relevant publications are excluded. Using realistic clinical databases, the paper then studies the blockchain applicability to these healthcare workflows and the feasibility of current adoption of blockchain in different use cases.

Traditional healthcare practices have often been influenced by the usage of paper-based medical records and these have evolved into electronic patient records. Thus, electronic health records often contain highly sensitive medical information, which is shared among healthcare providers, pharmacies and patients. Current EHR management approaches include distributed or cloud server data storage; this practice can lead to diverse functionalities and financial complications. Further, according to Coventry and Brinley, healthcare organizations are vulnerable to a number of cyber security threats, including malware and ransom ware. (", Transforming Government: People) Successful compromise of EHR management and storage providers can be achieved by deploying ransomware, which encrypts data until a ransom is paid, or by hacking the EHR repository. The WannaCry ransomware crypto worm, used in the WannaCry cyber-attack that resulted in a loss of £92 million, infected vulnerable servers and computers of the National Health Service and encrypted medical data at 80 out of 236 NHS foundations. Further, the Med jack Medical Device Hijack cyber-attack used malware that infected multiple unprotected medical devices, compromised network defenses, breached user anonymity and accessed medical records Healthcare information is often substantially more valuable than other data sources for trading on the black market: the average cost of a hijacked medical record is approximately $380; this is twice as large as the average cost across all industry-related data breaches. Incidents such as the above demonstrate that the healthcare Sensors 2020, 20, 6587. DOI:10.3390/s20226587 www.mdpi.com/journal/sensors Sensors 2020, 20, 6587 2 of 14 sector can suffer substantial financial loss as a result of common attack vectors against traditional EHR databases. With the increasing drive towards EHR, there is a certain urgency for a scalable, immutable, transparent and secure solution to be implemented in order to address the aforementioned challenges. A state-of-the-art approach, invulnerable to common attack vectors, could handle medical data in a decentralized manner in order to avoid the possibility of a single point-of-failure or a single point-of-attack. A key driver is to achieve general agreement amongst the co-operating healthcare providers in order for weak security and insider threats to be prevented or properly responded to. Current EHR storage and distribution approaches utilize certain solutions in the context of challenging the aforementioned security threats. In particular, they use access control policies such as role-based access control and attribute-based access control, which restrict system access to unauthorized users according to specific preassigned roles and attributes. Moreover, a secure and anonymous three-factor authentication protocol could be deployed in the context of privacy-preserving healthcare-oriented wireless sensor networks. Additionally, encryption combined with pseudonymization techniques is deployed to conceal users' identities and preserve anonymity. However, access control policies may leak private information and encryption mechanisms could potentially affect system performance. (Agbo, C.C., Mahmoud, Q.H. and Eklund, J.M., 2019) [18].

1.1 Objectives

- To employment a privacy security mechanism using blockchain Hyperledger fabric in health care management system.

1.2 Justification of Study

Without trusted intermediaries, the needed trust within a blockchain network is enabled by four key characteristics of blockchain technology, described below:

- **Ledger:** The technology uses an append only ledger to provide full transactional history. Unlike traditional databases, transactions and values in a blockchain are not overridden.
- **Secure:** Blockchains are cryptographically secure, ensuring that the data contained within the ledger has not been tampered with, and that the data within the ledger is attestable.
- **Shared:** The ledger is shared amongst multiple participants. This provides transparency across the node participants in the blockchain network.
- **Distributed:** The blockchain can be distributed. This allows for scaling the number of nodes of a blockchain

network to make it more resilient to attacks by bad actors. By increasing the number of nodes, the ability for a bad actor to impact the consensus protocol used by the blockchain is reduced.

For blockchain networks that allow anyone to anonymously create accounts and participate is called permission less blockchain networks, these capabilities deliver a level of trust amongst parties with no prior knowledge of one another; this trust can enable individuals and organizations to transact directly, which may result in transactions being delivered faster and at lower costs. For a blockchain network that more tightly controls access is called permissioned that trust blockchain networks, where some trust may be present among users, these capabilities help to bolster.

1.3 Scopes of Study

This document provides a high-level technical overview of blockchain technology. It looks at different categories of implementation approaches. It discusses the components of blockchain technology and provides diagrams and examples when possible. It discusses, at a high-level, some consensus models used in blockchain networks. It also provides an overview of how blockchain technology changes affect the blockchain network. It provides details on how blockchain technology was extended beyond attestable transactions to include attestable application processes known as smart contracts. It also touches on some of the limitations and misconceptions surrounding the technology. Finally, this document presents several areas that organizations should consider when investigating blockchain technology. It is intended to help readers to understand the technologies which comprise blockchain networks. (Brothers) [39].

1.4 Potential Benefits of Hyperledger fabric in the Healthcare Industry

Hyperledger fabric technology provides numerous benefits to medical researchers, health care providers, and individuals. 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.

Health researchers need comprehensive data sets to advance understanding of disease, accelerate biomedical discovery, track the development of drugs quickly, and design individual treatment plans based on genetics, lifecycle, and environment. By including patients of different ethnic and socio-economic backgrounds and from different geographic areas, the shared data system of Blockchain would provide a wide range of data set. It provides perfect information for longitudinal studies because blockchain collects health data over the lifetime of a person. (Brodersen, 2016) [2].

A health care Hyperledger fabric will extend the collection of health data to include data from groups of people currently under-served by the medical community or not typically involved in science.

The shared data environment of blockchain makes it easier for “hard-to-reach” audiences to be interested and for the general public to produce results more reflective.

A health care Hyperledger fabric will likely encourage the development of a new breed of “smart” health care provider apps that would circumvent the latest medical research and develop customized treatment pathways. The health care provider and patient would have access to the same information and could be involved in a cooperative, educated discussion of research-based treatment options rather than intuition-based best case.

(6. “Digital twins in health care: Ethical implications of an emerging engineering paradigm”).

2. Literature Review

2.1 Review of relevant literature

In principle, a blockchain should be considered as a distributed append-only time stamped data structure. Blockchains allow us to have a distributed peer-to-peer network where non-trusting members can verifiably interact with each without the need for a trusted authority. To achieve this one can, consider blockchain as a set of interconnected mechanisms which provide specific features to the infrastructure, as illustrated in Fig. 1. At the lowest level of this infrastructure, we have the signed transactions between peers. These transactions denote an agreement between two participants, which may involve the transfer of physical or digital assets, the completion of a task, etc. At least one participant signs this transaction, and it is disseminated to its neighbours. Typically, any entity which connects to the blockchain is called a node. However, nodes that verify all the blockchain rules are called full nodes. These nodes group the transactions into blocks and they are responsible to determine whether the transactions are valid, and should be kept in the blockchain, and which are not. (Burniske, 2016) [4].

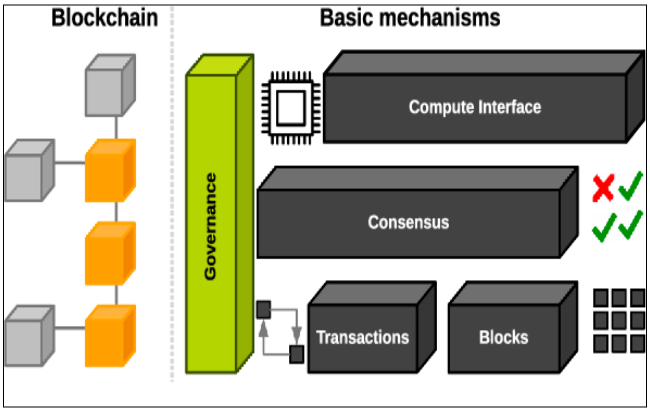

Fig 1: An overview of blockchain architecture.

A valid transaction means, for instance, that Bob received one bitcoin from Alice. However, Alice may have tried to transfer the same bitcoin, as it is a digital asset, to Carol. Therefore, nodes must reach to an agreement on which transactions must be kept in the blockchain to guarantee that there will be no corrupt branches and divergences. This is actually the goal of the second Consensus layer. Depending on the blockchain type, different Consensus mechanisms exist. The most well-known is the Proof-of-work. PoW requires solving a complicated computational process, like finding hashes with specific patterns, a leading number of zeroes, to ensure authentication and verifiability. Instead of splitting blocks across proportionally to the relative hash rates of miners, Proof-of-Stake protocols split stake blocks proportionally to the current wealth of miners. This way, the selection is fairer and prevents the wealthiest participant from dominating the network. Many blockchains, such as

Hyperledger fabric, are gradually shifting to PoS due to the significant decrease in power consumption and improved scalability. Other consensus approaches include Byzantine Fault Tolerance and its variants (Buterin, 2014) [5].

An additional layer, the Compute Interface, allows blockchains to offer more functionality. Practically, a blockchain stores a state which consists e.g., of all the transactions that have been made by the users, thereby allowing the calculation of each user's balance. However, for more advanced applications we need to store complex states which are updated dynamically using distributed computing, e.g., states that shift from one to another once specific criteria are met. This requirement has given rise to SCs which use nodes of the blockchain to execute the terms of a contract. Finally, the Governance layer extends the blockchain architecture to cover the human interactions taking place in the physical world. Indeed, although blockchains protocols are well defined, they are also affected by inputs from diverse groups of people who integrate new methods, improve the blockchain protocols and patch the system. While these parts are necessary for the growth of each blockchain, they constitute off-chain social processes. Therefore, blockchain governance deals with how these diverse actors come together to produce, maintain, or change the inputs that make up a blockchain. (Caulfield, 2008) [6].

Current literature categorizes blockchain networks in several ways. These categories are formed according to the network's management and permissions as public, private and federated. In public blockchains anyone can join as a new user or node miner. Moreover, all participants can perform operations such as transactions or contracts. In private blockchains; which along with the federated belong to the permissioned blockchain category, usually, a whitelist of allowed users is defined with particular characteristics and permissions over the network operations. Since the risk of Sybil attacks is almost negligible there, private blockchain networks can avoid expensive PoW mechanisms. Instead, a wider range of consensus protocols based on disincentives could be adopted. A federated blockchain is a hybrid combination of public and private blockchains. Although it shares similar scalability and privacy protection level with private blockchain, their main difference is that a set of nodes, named leader nodes, is selected instead of a single entity to verify the transaction processes. This enables a partially decentralized design where leader nodes can grant permissions to other users. In this article, we provide a more fine-grained blockchain network classification than current the state-of-the-art because, in addition to classical features such as the ownership and management of the information shared in the blockchain, we consider features such as transaction approval time, or security aspects such as anonymity. Table 1 summarize the main characteristics of each blockchain network regarding efficiency, security and consensus mechanisms. (Checkland, 1995) [8].

Table 1: Classification and main characteristics of blockchain networks

Property	Public	Private	Federated
Consensus	Costly PoW	Light PoW	Light PoW
Mechanism	All miners	Centralized organization	Leader node set
Identity	(Pseudo) Anonymous	Identified users	Identified users
Anonymity	Malicious?	Trusted	Trusted
Protocol Efficiency &	Low efficiency	High efficiency	High efficiency
Consumption	High energy	Low energy	Low energy
Immutability	Almost impossible	Collusion attacks	Collusion attacks
Ownership &	Public	Centralized	Semi-Centralized
Management	Permission less	Permissioned whitelist	Permissioned nodes
Transaction Approval	Order of minutes	Order of milliseconds	Order of milliseconds

Well-known implementations of public blockchains include Bitcoin, Hyperledger fabric, Litecoin and, in general, most cryptocurrencies. One of their main advantages is the lack of infrastructure costs: the network is self-sustained and capable of maintaining itself, drastically reducing management overheads. In private blockchains, the main applications are database management, auditing and, in general, performance demanding solutions is an example of an open platform for building and deploying private blockchains. Finally, federated blockchains are mostly used in the banking and industry sectors. This is the case of the Hyperledger project which develops cross-industry permission-based blockchain frameworks. Recently, Hyperledger fabric has also provided tools for building federated blockchains. (Checkland, 2000) [9] Other projects such as cardanol are rather ambitious trying to provide more functionality. For more on blockchain categorization, the interested reader may refer to Waldport, Swanson.

2.2 Hyperledger is a set of open-source tools aiming to build a robust, business-driven blockchain framework.

One of the biggest projects in the blockchain industry, Hyperledger, is comprised of a set of open-source tools and subprojects. It's a global collaboration hosted by The Linux Foundation and includes leaders in different sectors who are aiming to build a robust, business-driven blockchain framework.

There are three main types of blockchain networks: public blockchains, consortiums or federated blockchains, and private blockchains. Hyperledger is a blockchain framework that aims to help companies build private or consortium permissioned blockchain networks where multiple organizations can share the control and permission to operate a node within the network. (Checkland) [10].

Since a blockchain is a transparent, immutable, and secure decentralized system, it is considered a game-changing solution for traditional supply chain industries. It can support an effective supply chain system by:

- Tracking the products in the entire chain
- Verifying and authenticating the products in the chain
- Sharing the entire chain's information between supply chain actors
- Providing auditability

This article uses the example of a food supply chain to explain how a Hyperledger blockchain can transform a traditional supply chain. (Checkland, 1999) [11].

2.3 Citation of Hyperledger fabric in the Healthcare management system

Network is controlled using Hyperledger modelling and access control languages. Hyperledger Fabric is a platform for distributed ledger solutions underpinned by a modular architecture delivering high degrees of confidentiality, resilience, flexibility and scalability. Medical information is often highly sensitive, in both a social and legal sense, so a closed blockchain such as Hyperledger Fabric helps to retain the necessary privacy required for such an application. Hyperledger Fabric is a better solution for managing access to health records, as it accommodates for multiple layers of permission, meaning the owner of a set of data can control which parts of their data is accessed.

3. Methodology

3.1 Methodology

With changing times and emerging technologies, software development has become far more dynamic. Customers have become increasingly smart and are demanding a quick and easily adaptive approach and strategy while developing a software.

Agile is an incremental & iterative approach that promotes continuous and simultaneous development and testing of a software product. Typically, Agile and Scrum frameworks emphasize on rapid application development where the project is segregated into multiple timeframes called as sprints. Each sprint is a duration of a couple of weeks and additional features are kept adding at every sprint. It consists of creating a Minimum viable product (MVP) with features just enough for the working of the product with concurrent development and testing processes. The project is divided into multiple functional components which execute simultaneously alongside each other. There is a lot of customer involvement in Agile processes for continuous evaluation, review & feedback. Based on customer response, product requirements can be changed, re-planned and re-developed to satisfy newer client specifications.

Agile provides flexibility in terms of allowing change in requirements at any point of time in the project, thus making it the most sought-after methodology. The processes of planning, design, development and testing appear multiple times in Agile, given its parallel execution approach. Since the customer is involved in every process, Agile promises thorough customer satisfaction, as the customer is completely aware of the product right from its conception. Testing and bug fixing is an easy process since there is a constant defect identification and rectification process. (Clohessy, 2019) [2].

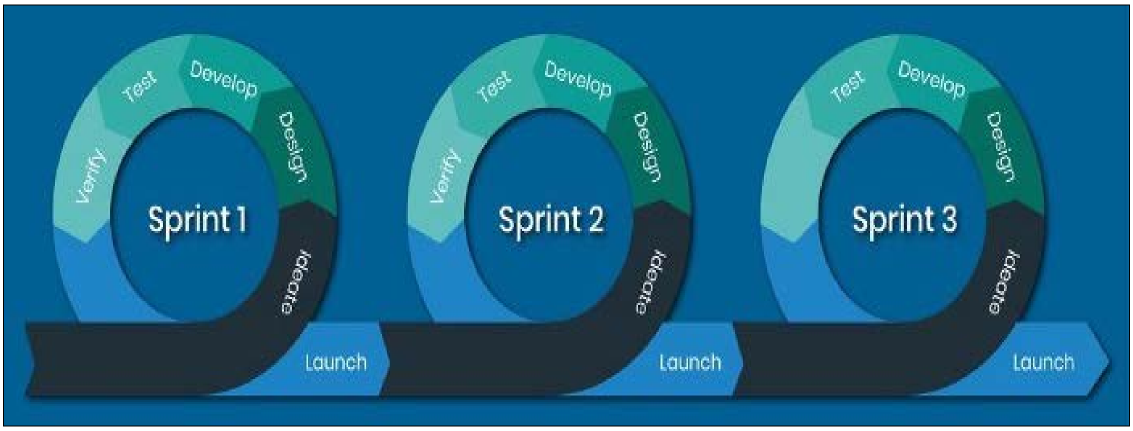

Fig 2(a): Agile Methodology

While Agile is the go-to methodology for projects where there are frequent requirements changes which often is the case nowadays considering dynamic applications, there are a few drawbacks it has as well. Dedicated timeframes for sprints sometimes may be a hindrance during development. A delay in the process may cause allotted time frames to exceed thereby increasing cost and time overhead. Agile requires regular refactoring due to changing requirements without which the overall structure and design can go for a toss.

Blockchain technology provides numerous benefits to medical researchers, health care providers, and individuals. 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.

Health researchers need comprehensive data sets to advance understanding of disease, accelerate biomedical discovery, track the development of drugs quickly, and design individual treatment plans based on genetics, lifecycle, and environment. By including patients of different ethnic and socio-economic backgrounds and from different geographic areas, the shared data system of Blockchain would provide a wide range of data set. It provides perfect information for longitudinal studies because blockchain collects health data over the lifetime of a person. (Colijn, 2017) [13].

A health care blockchain will extend the collection of health data to include data from groups of people currently under-served by the medical community or not typically involved in science. The shared data environment of blockchain makes it easier for “hard-to-reach” audiences to be interested and for the general public to produce results more reflective.

A health care blockchain will likely encourage the development of a new breed of “smart” health care provider apps that would circumvent the latest medical research and develop customized treatment pathways. The health care provider and patient would have access to the same information and could be involved in a cooperative, educated discussion of research-based treatment options rather than intuition-based best case.

In this section, we present our general methodology where a blockchain architecture is used to visually show how data are shared by users as it moves among various nodes in the network. The architecture uses two web applications: one to create the data for the blockchain and the other to visualize the network to improve transparency and build trust. The application supports the sharing of data files between different nodes, so that a user will have the ability to visually see the files as they are sent and received, ensuring the existence, order, and immutability of these files. (Das, 2016) [14] Specifically, we will illustrate the process used when permission is granted for some data by the patient Sustainability 2020, 12, 6768 5 of 20 and the subsequent movement of these data along the network to support transparency. To achieve the stated objectives, the methodology uses two features: blockchain technology and visualization techniques. This methodology is technology agnostic, different blockchain technologies can be used for application implementation. The methodology can be summarized as follows:

1. Create the blockchain with the different network nodes, where each node corresponds to different users who will participate in data sharing. In our case study the nodes correspond to patients who decide to share their files as well as the buyers of information from these files.
2. Manage the transactions generated by different nodes. Here, we will focus on authentication, file transfer, and visualization. These transactions are combined with other transactions to create a new block.
3. Configure and customize the information to be visualized after choosing a tool for the network visualization.
4. Connect or integrate the blockchain with the visualization tool.
5. Demonstrate the visualization of how nodes are interacting during a transaction. Figure 2(b) shows at a high level how the transactions are managed within the blockchain network. (Dorussen, 2005) [15].

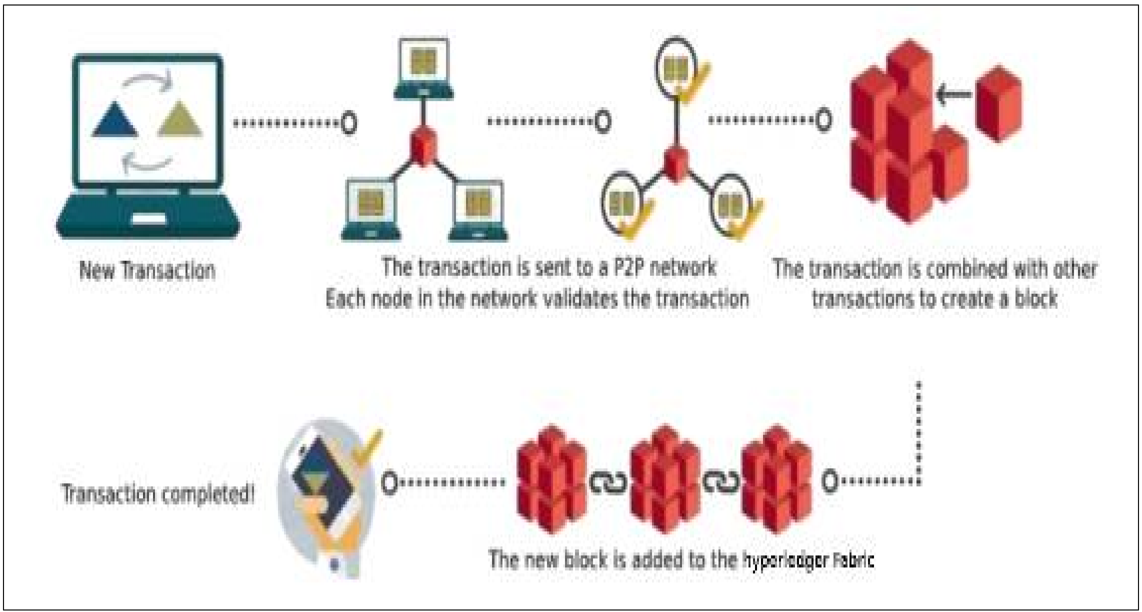

Fig 2(b): Methodology for transactions management in the blockchain network.

3.2 Justification of methodology

The framework implementation will be a decentralized application (DApp) that supports a private blockchain network with a back-end distributed file system (DFS). Hyperledger fabric Hyperledger fabric blockchain has been used for the implementation of the healthcare blockchain smart contract system. This is an open-source network and currently one of the largest public blockchain networks with an active community and a large public DApp repository. Currently, the platform uses a proof-of-work (PoW) consensus algorithm but we are working towards changing it to a proof-of-stake (PoS) scalability algorithm in the near future. Ideally, a Delegated Proof-of-Stake (DPoS) or a Practical Byzantine Fault Tolerance (PBFT) consensus algorithm is suitable for the design of distributed applications. (Frey, 2014) [16] By comparing DFS content with ledger records, the DApp would have the ability to detect anomalies, unauthorized data insertions and missing entities. Each step is marked with a timeline for auditing. The main elements of the smart contracts are functions, events, state variables, and modifiers and been written in the high-level programming language known as solidity. Remix and Kuvan test network have been used to deploy smart contracts on the test net and test net ethers for paying the transaction fee. In smart contract creation, three stages are involved, which are writing, compiling, and announcing by using Solidity programming. The bytecode is generated by Solidity real time compiler. For announcing smart contracts to the blockchain, Hyperledger fabric Wallet has been utilized. Illustrates the operation of smart contracts with Hyperledger fabric, where the mining process is excluded for simplification. This smart contract is compiled into byte code at the machine level where each byte represents an operation and then uploaded to the blockchain as a transaction. It is picked up by a miner and confirms in block. Once a user sends the request through the web interface, the queries web-based data and embeds it into Transaction Tx and deploys it to the blockchain. The status of transaction Tx is updated in block. If node 3 wants to check the states that are stored in the contract, later on, it must synchronize up to at least Block -2 to see the changes that Tx causes.

3.3 Description of Methodology

We use smart contracts from Hyperledger fabric to create smart representations of existing medical records that are stored on the network within individual nodes. We build contracts to contain record ownership metadata, permissions, and data integrity. Our system's blockchain transactions carry cryptographically signed instructions for managing these properties. State-transition functions of the contract carry out policies, only by legitimate transactions enforcing data alternation. (Gauld, 2016) [17] These regulations can be structured to enforce any set of rules re gelatin a specific medical record as long as it can be computationally represented. For example, a policy may impose sending separate consent transactions from both patients and healthcare professionals before granting a third-party viewing permission. We designed a system based on blockchain smart contracts for complex healthcare workflows. Smart contracts have been designed for different medical workflows and then managing data access permission between different entities in the healthcare ecosystem.

A smart contract, stored on blockchain technology, could be designed which can have all the conditions from managing different permissions to accessing of data as shown in Figure 2 and it can be seen that a number of stakeholders are involved in this scheme carrying out different activities. This will help in creating better interaction between doctors and patients. Data authorization rules are embedded in smart contracts. It can also help in tracking all the activities with unique id from its origin to its surrender. Different scenarios have been designed and explained alongside all the functions and processes are well described embedded in the smart contracts. There will be no need to have a centralized entity to manage and approve the operation as it can be directly managed through the smart contract which will significantly reduce the administration cost of managing process. All of the medical record data is stored in local database storage to maintain the performance and economic viability and the hash of the data is the data element of the block committed to the chain. (Halamka, 2017) [19].

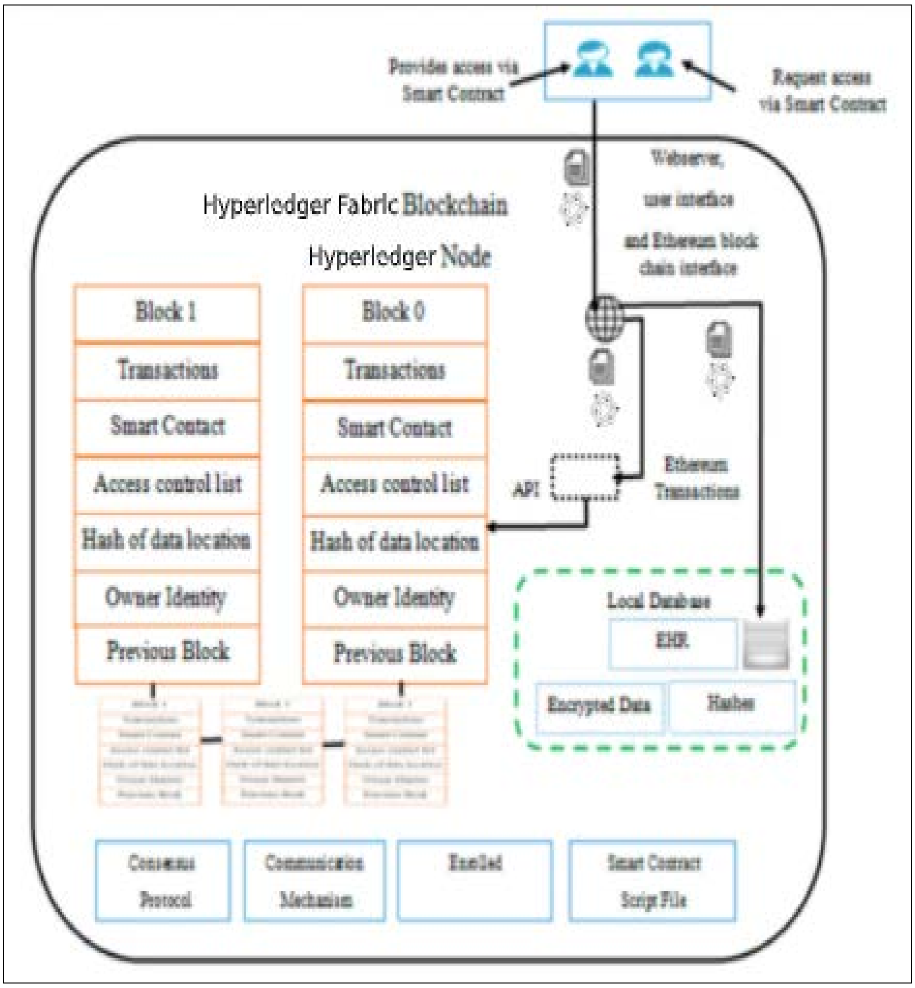

Fig 3: System workflow with smart contract-controlled access.

The data transactions are signed with the owner's private key like patient or doctor. The block content for the system represents data ownership and viewership permissions shared by members of a peer-to-peer private network. Blockchain technology supports the use of smart contracts that enable us to automate and track certain state transitions such as a change in viewing rights or the birth of a new system record. We log patient-provider relationships via smart contracts on a Hyperledger fabric blockchain that associate a medical record with viewing permissions and data retrieval instructions essentially information pointers for external server execution to ensure against tampering, we include a cryptographic hash of the record on the blockchain, thus ensuring data integrity. (Halim,:

www.healtheuropa.eu/shivom-precision-medicine/90476/ (accessed 8 August 2018).) [20].
Providers can add a new record associated with a specific patient, and patients can allow record sharing between providers. The party receiving new information receives an automated notification in both cases and can verify the proposed record before the data is accepted or rejected. This keeps participants in the evolution of their records informed and engaged. This system prioritizes usability by also offering a designated contract that aggregates references to all patient-provider relationships of a user, thus providing a single point of reference to check for any medical history updates. We use public key cryptography to manage identity verification and use a DNS-like implementation that maps an already existing and widely accepted form of ID such as name or social security number to the fabric address of the user. After referring the blockchain to confirm permissions via our database authentication server, a syncing algorithm handles "off-chain" data exchange between a patient database and a provider database

3.4 Use case diagram

Modern healthcare systems are characterized as being highly complex and costly. However, this can be reduced through improved health record management, utilization of insurance agencies, and blockchain technology. Blockchain was first introduced to provide distributed records of money-related exchanges that were not dependent on centralized authorities or financial institutions. Breakthroughs in blockchain technology have led to improved transactions involving medical records, insurance billing, and smart contracts, enabling permanent access to and security of data, as well as providing a distributed database of transactions. One significant advantage of using blockchain technology in the healthcare industry is that it can reform the interoperability of healthcare databases, providing increased access to patient medical records, device tracking, prescription databases, and hospital assets, including the complete life cycle of a device within the blockchain infrastructure. Access to patients' medical histories is essential to correctly prescribe medication, with blockchain being able to dramatically enhance the healthcare services framework. (Hallwright, 2019) [21]. In this paper, several solutions for improving current limitations in healthcare systems using blockchain technology are explored, including frameworks and tools to measure the performance of such systems, e.g., Hyperledger Fabric, Composer, Docker Container, Hyperledger Caliper, and the Wireshark capture engine. Further, this paper proposes an Access Control Policy Algorithm for improving data accessibility between healthcare providers, assisting in the simulation of environments to implement the Hyperledger-based electronic healthcare record (EHR) sharing system that uses the concept of a chain code. Performance metrics in blockchain networks, such as latency, throughput, Round Trip Time (RTT). Have also been optimized for achieving enhanced results. Compared to traditional EHR systems, which use client-server architecture, the proposed system uses blockchain for improving efficiency and security. (Hanafizadeh, 2018) [22].

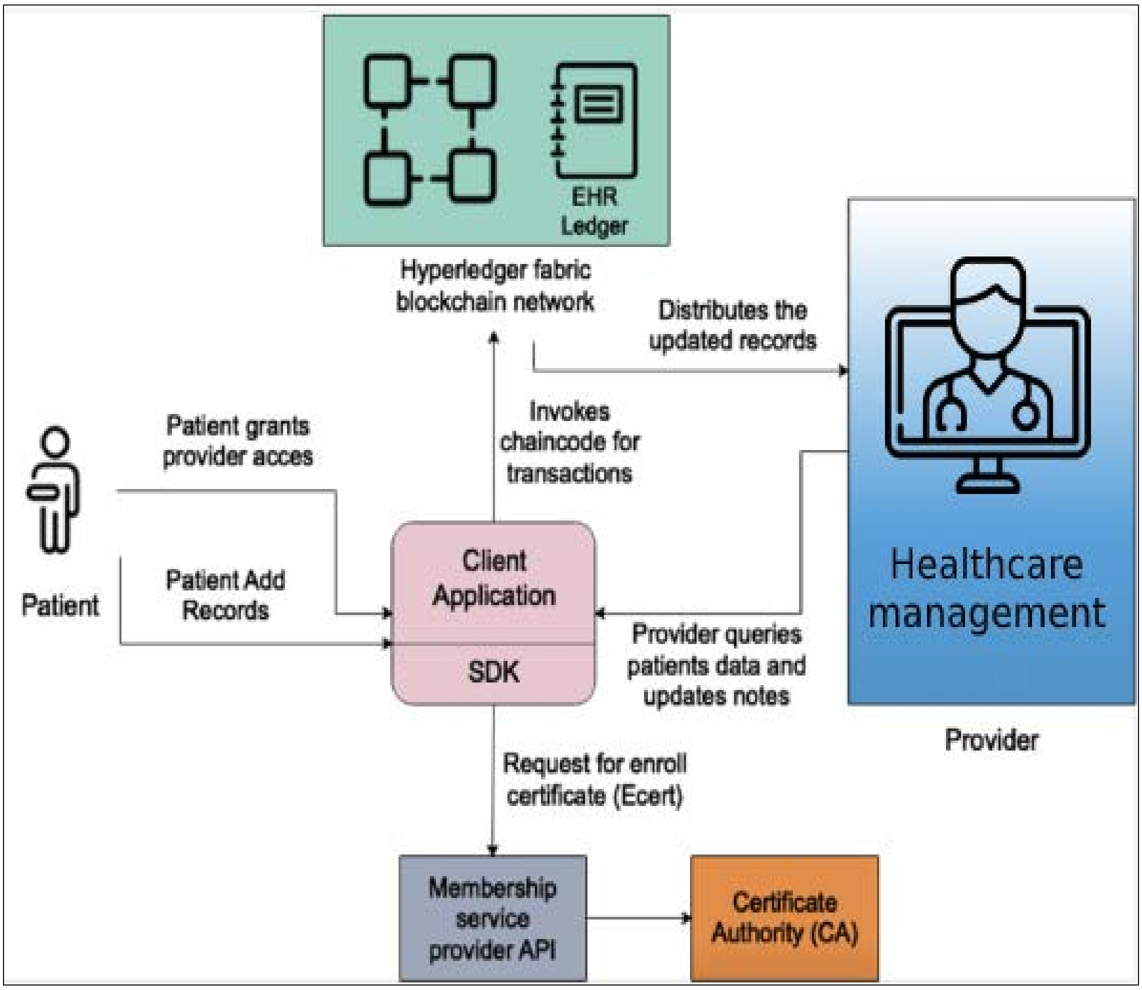

Fig 4: System architecture for healthcare management

3.6 Implementation Details
Different medical workflows involving specific medical procedures have been designed and implemented via blockchain smart contract system. These includes issuing basic medical prescription to the treatment of complex diseases and their procedure like treatment procedure for the surgery patients. The purpose of designing these medical smart contracts is to facilitate the patients, doctors and the healthcare organization to overcome the administrative inefficiencies. (Hevner, (2004) [23]. This system will help in medical data retrieval, analysis and management of complex healthcare data and procedures.

3.7 The Process for Issuing and Filling of Medical Prescriptions
The main goal is to streamline the medical prescription handling process by eliminating the long waiting time process, removing the fraud element from the system and reducing the error rate made by doctor misinterpretations. A doctor writes a prescription for the patient and puts it to the patient's healthcare records via a smart contract. The pharmacy then accesses this prescription through the smart contract on the Hyperledger fabric blockchain via permission granted by primary doctor and a patient. After accessing the prescription, pharmacy then issues the medicine along its expiry date and dosage use posted on to the patient healthcare records via smart contracts and then the medicine is ready for the collection by the patient. (Huang) [24] The smart contract features generally organize medicine satisfaction among doctors and drug stores. Doctors spend fewer times the time in explaining medicines requests or generally speaking with drug stores following a patient's visit.

Data flow for issuing a medical prescription involves patient, primary doctor (GP) and pharmacy as shown in Figure 5. It also contains the details of prescription which include medicine id, expiry date, patient id etc.

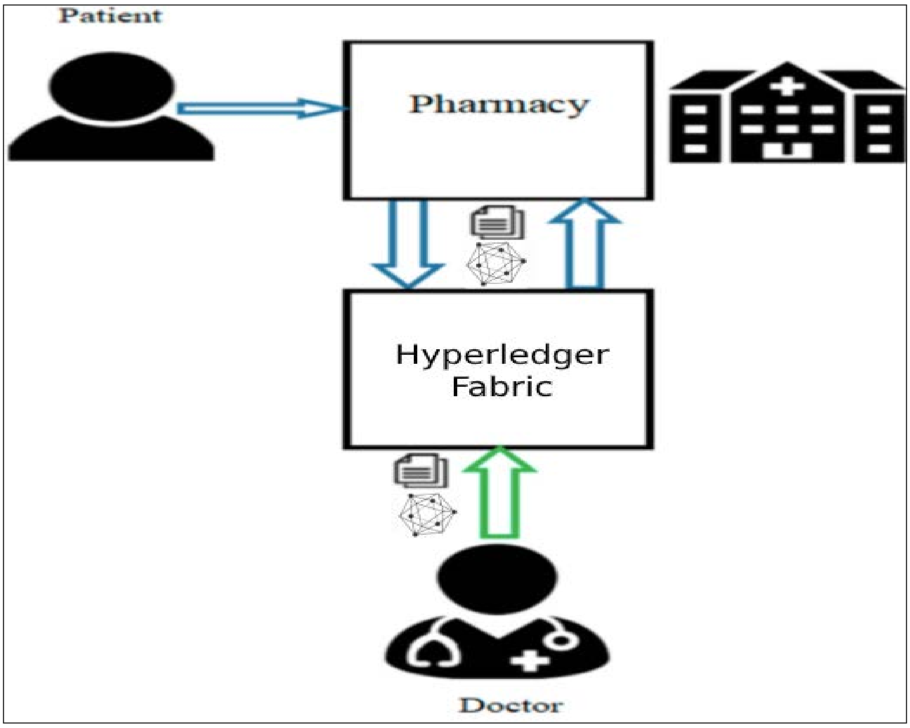

Fig 5: Smart contract for issuing and filing of medical prescriptions.

3.8 Analysis of Requirement
Ubuntu version 16.04

- **Step 1:** Install cURL
- **Step 2:** Install golan-go
- **Step 3:** GOPATH=$HOME/go
- **Step 4:** PATH =$PATH:$GOPATH/bin
- **Step 5:** Install note js
- **Step 6:** Install npm
- **Step 7:** Install Python
- **Step 8:** Install Docker
- **Step 9:** curl –fsSL
- https://download.docker.com/linux/ubuntu/gpg | sudo apt-key add -
- **Step 10:** add-apt-repository "deb [arch=amd64]
- https://download.docker.com/linux/ubuntu $(lsb_release -cs) stable
- **Step 11:** apt-get update
- **Step 12:** cache policy docker-ce
- **Step 13:** apt-get install -y docker-ce
- **Step 14:** apt-get install docker-compose
- **Step 15:** apt-get upgrade
- **Step 16:** curl -sSL https://goo.gl/6wtTN5 | sudo bash -s 1.1.0
- **Step 17:** chmod 777 -R fabric-samples
- **Step 18:** cd fabric-samples/first-network
- **Step 19:** byfn.sh generate
- **Step 20:** byfn.sh up

4. Analysis of Results
4.1 Sharing Laboratory Test/Results Data
The main objective is to share the information via blockchain smart contracts by permitting labs, doctors, emergency clinics, and different partners to effectively access and share a patient's therapeutic information among different stakeholders as it can be seen in Figure 6.

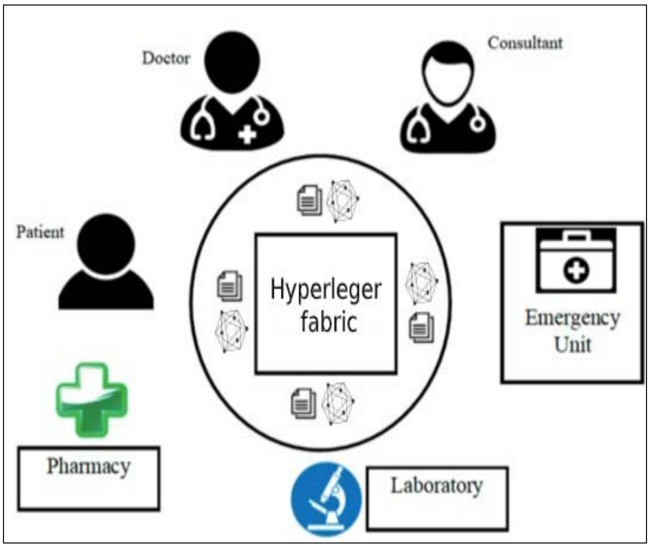

Fig 6: Smart contract for sharing lab results.

Consider a use case where a patient visits a lab for a blood test. After being processed, the lab will put the results into the patient records, the patient gets these notifications via Hyperledger fabric blockchain, a notice that the processed results of the test are accessible, and can pick whether to enable the lab to encode the information and put them on Hyperledger fabric blockchain. The patient grants permission for the information to be posted on the blockchain. (Bryatov & Borodinov, 2019) [25] If there is an emergency with the patient and he is unresponsive, the emergency department would be able to access patient information quickly via Hyperledger fabric blockchain and would be able to provide customized treatment.

By allowing patient's medical records to be posted on healthcare blockchain, a patient avoids having to carry the results of the laboratory on their own or arrange for records to be faxed to different care providers. He also ensures that all of his health care providers have the necessary information to provide the best possible care. Laboratories reduce the regulatory expenses of printing and mail or fax each test result to singular suppliers. Furthermore, labs and patients access the healthcare blockchain, where they may get installments from protection firms that counsel the transferred information to process claims or from pharmaceutical organizations that select the information for use in contemplates. (Bocek, Rodrigues, Strasser, & Stiller) [26] Specialists and emergency clinics get access to brought together restorative information on their patients at no cost, decreasing authoritative work and costs.

4.2 Enabling Effective Communication between Patients and Service Providers

In this scenario, the patient submits a request for a medical condition as shown in Figure 7. It automatically sends this request to the primary doctor through the smart contract system. A doctor must consider the request and reply with a recommendation and refer the patients to the specialist for further care where appropriate. Any patient information about the history of treatment should be reported on the EHR. Please note that patient record is maintained by a local database where there are specific rules who can have access to the record to what extent and these rules are govern by the smart contracts on Hyperledger fabric blockchain. (Decker & Wattenhofer, 2013) [27].

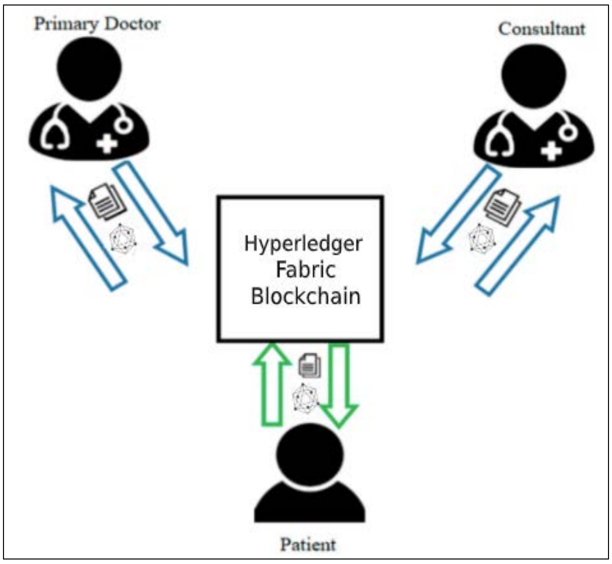

Fig 7: Smart contract for enabling communication between patient and service provider.

Another case where the patient submits a request for a specific medical treatment. Consequently, it sends this application to the appropriate specialist through the strict structure of the agreement. A doctor understands the demand and responds with a recommendation and where patients are simply traded for further care with the specialist. Any patient data regarding the history of treatment must be reported on the EHR. Note that a nearby database keeps patient records where there are explicit principles that can approach the record to what degree and these guidelines are administered through the knowledgeable contracts on Hyperledger fabric blockchain.

Patients seeking health information on a specific subject receive a recommendation that is far more personalized than those provided by a web search. Senior physicians gain a new way of monetizing their expertise without having to overbook their schedules, while junior physicians can access a new potential patient market and build their brand within their specialty. Payments encourage patients to receive recommendations from junior doctors. Dennis & Owen, 2015) [28].

4.3 Data Flow for Healthcare Reimbursement

The main objective is to speed up the process of reimbursement for the health care system. In this, physicians will be able to proceed quickly with care instead of having to put on hold the treatment of their patient while waiting for the payer to respond. The execution of automated smart contracts will monitor the whole process. Reducing- and ultimately eliminating-the error-laden human effort to manually review and respond to requests for prior authorization, and reducing appeals triggered by incorrect interpretation of manually written prior authorization forms.

Health Insurance Company posts their policies via blockchain smart contracts containing the policies used to determine authorization. A supplier then submits to the blockchain an application for prior authorization for a specialist appointment, treatment or prescription. The smart contract for a medical policy of the payer determines automatically authorization using the medical information of the patient stored via Hyperledger fabric blockchain and the information in the request. Authorization data will then be returned to the provider immediately. (Puthal, Malik, Mohanty, & Kougianos, 2018) [29] Also, the patient-as well as any laboratories, pharmacies, specialists and other stakeholders to whom the patient has delegated access–could verify the insurance authorization in real-time.

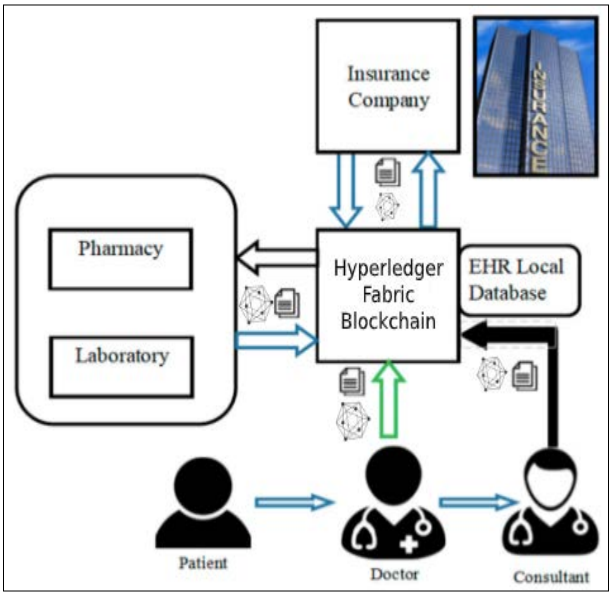

Fig 8: Smart contracts for healthcare reimbursement.

The automated process of prior authorization would result in significant cost savings for payers, which currently spends substantial amounts on manually reviewing and responding to requests. Doctors will be able to proceed quickly with treatment instead of having to stop the care of their patient while waiting for the payer's response. Furthermore, patients will be spared concerned as to whether their insurance will cover the treatment recommended by their doctor. With immediately available prior authorization information, doctors and patients can work together easily with a care plan tailored specifically to the needs of the patient and the appropriate insurance coverage.

4.4 Hyperledger fabric blockchain Based Smart Contracts for Clinical Trials

Providing drug and medical device manufacturers with a simpler and more cost-effective alternative to the current recruitment of clinical trials, which often requires considerable expenses to buy patient contact information from independent data providers and to execute comprehensive pull-marketing campaigns.

The main goal is to allow users to run clinical trial-related smart contracts on a Hyperledger fabric blockchain network resulting in safer medicines and increased public interest in medical research. In this process, we will handle metadata, including protocol registration, preset study details, screening and enrolment logs via smart contracts. (Liang, Zhao, Shetty, Liu, & Li) [30].

A pharmaceutical company looks for metadata stored on the Hyperledger fabric blockchain to identify potential patients for inclusion in clinical trials as shown in Figure 9. The organization then sends a message to selected patients, including an application to read access to their medical records, including any relevant results from the laboratory study. If the patient allows access, a pharmaceutical company bill would be processed via smart contracts, awarding part of the received fee to the patient, and another section to the labs that reported the appropriate test results for the patient.

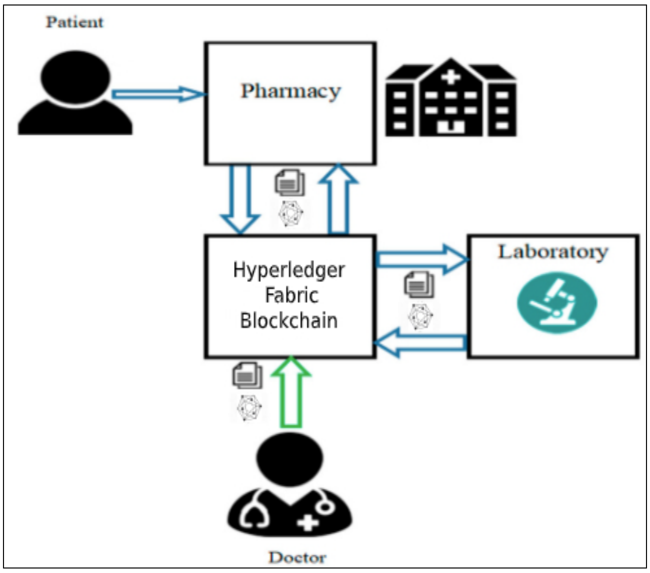

Fig 9: Smart contracts for conducting clinical trials.

Through directly targeting qualifying customers, drug and medical device manufacturers will significantly reduce spending on data purchases and marketing efforts. Patients, meanwhile, in addition to receiving compensation for participating in trials, would gain access to new treatment options. Laboratories that were involved in posting results would have a new way of monetizing their data.

4.5 Basic Outpatient Surgical Procedure

The process associated with surgery can be a huge burden in a busy clinic. The EHR Surgical Workflow System meets the needs of busy practices and turns a complex process into an all-in-one step-by-step, streamlined workflow. The practice can be made fully integrated via Hyperledger fabric blockchain smart contracts EHR Surgical Workflow system. This allows administrators, billing, front desk and other tasks to complete tasks to support the workflow from pre-operative patient management to post-operative patient management. The details are then inserted seamlessly into the prior surgical record of the patient. Through the smart contract features it would be possible to record patient consent and initial assessment of the patient. Our workflow consists of various activities that are involved throughout the surgical patient process. This includes pre-approvals, medical clearance, surgery scheduling, pre-operative testing and recording consent. Throughout the process, the visit is recorded, treatment is reported and paid. (Zhang, Walker, White, Schmidt, & Lenz) [31] This would be useful to review past surgical cases or surgeries that have been canceled. Algorithmic workflow and the solidity smart contract components can be seen respectively.

5. Project Description

5.1 Screenshots of different modules of the project and their description

It is well known that all patient data are stored in different formats in traditional healthcare delivery models, providers, laboratories, payers (i.e., insurance companies) and drug companies, and there is no standardization of record keeping. This has led to infringements of data and the disarray we see today in the exchange of health records. Poor infrastructure for data sharing has also impeded the progress of drug discovery and research into public health. Efforts to address this issue have focused largely on forcing a new shared standard throughout the ecosystem. These attempts were unsuccessful because regulation, lobbying, and patient apathy quickly rejected them. Due to the lack of effective processing and exchange of health data has prevented the widespread adoption of the practice of adjusting medical treatment to the attributes, desires and expectations of a patient. Personalized medicine–or precision –has long been recognized as the future of health care, and industry operators have devoted substantial resources to the development of personalized health care options, only to be stymied by the current system.

In this article, we discussed the current needs of the healthcare industry, the shortcomings of the current system, and proposed Hyperledger fabric-based solutions for healthcare management. Giving an overview of the state of personalized medicine, detailing concerns with the current healthcare system that hinder the implementation of personalized medicine and demonstrating how our designed system offers solutions to these problems. (Yue, Wang, Jin, Li, & Jiang) [32] We also analyzed the practical cost of deploying smart contracts for different health care scenarios and found that the cost increases linearly with outpatient numbers. For these reasons, health care departments like pediatrics and general surgery costs are higher than others. However, quantitatively it is seen that the cost of deployment of smart contracts is quite reasonable and therefore such a Hyperledger fabric-based system for maintenance of health records is feasible in realistic scenarios.

- **Step 1:** Press Ctrl + Alt + T to open a terminal
- **Step 2:** Installing curl using this comment in terminal: $ apt-get install curl
- To show version of curl use this comment: $ curl - -version
- **Step 3:** Installing Google golang using this comment:
- sudo apt-get install golang-go
- For select home directory:
- export GOPATH=$HOME/go
- export PATH=$PATH:$GOPATH/bin
- **Step 4:** Installing Google node js using this comment:
- sudo apt-get install nodejs
- **Step 5:** Installing Google node npm using this comment:
- sudo apt-get install npm
- **Step 6:** Installing python using this comment in terminal:
- sudo apt-get install python
- **Step 7:** Installing docker using this comment in terminal:
- sudo apt-get install docker
- **Step 8:** Installing curl using this comment in terminal:
- apt-cache policy docker-ce
- **Step 9:** Installing -y docker-ce using this comment in terminal:
- sudo apt-get install -y docker-ce
- **Step 10:** Installing docker-compose using this comment in terminal:
- sudo apt-get install docker-compose
- **Step 11:** Installing apt-get upgrade using this comment in terminal:
- sudo apt-get upgrade
- **Step 12:** we're going to download the samples of Fabric that have already been prepared to test it out. Enter the following two commands in terminal:
- sudo curl -sSL https://goo.gl/6wtTN5 | sudo bash -s 1.1.0
- **Step 13:** Run fabric-samples using this comment in terminal:
- sudo chmod 777 -R fabric-samples
- **Step 14:** Creating genesis block using this comment in terminal:
- This will also create the genesis block (the first block on the blockchain), among other things.
- cd fabric-samples/first-network
- sudo ./byfn.sh generate
- **Step 15:** Now bring the blockchain network up with the following command:
- sudo ./byfn.sh up

5.2 Cost Estimation Method

In terms of deploying medical blockchain, there is a need to make estimation of the cost associated with deploying healthcare smart contracts. The ultimate goal is to propose a system which can give a feasible medical health system with all the benefits of blockchain. All programmable calculations in Hyperledger fabric blockchain cost some fees to avoid the abuse of network and overcome other computational related issues. The fee in Hyperledger fabric blockchain is specified as gas to run all sort of transactions. Gas refers to the payment or price value required for a successful transaction or execution of a contract on the Hyperledger fabric blockchain platform. The exact price of gas is determined by the network miners who may refuse to process a transaction if their limit is not met by the gas price. (Witchey) [33] Hence all the operations, computations, message call, creation/deployment of smart contracts and storage on Hyperledger fabric virtual machine needs gas to perform all these tasks. If someone wants to do any sort of operation on EVM, they must have specific amount of gas in their account to execute transactions on Hyperledger fabric virtual machine. There is a gas limit for every transaction, so if there is any unused gas it will return to the user account after the execution of transactions. If a user doesn't have valid balance account, he can't carry on any kind of operation and hence considered as invalid transaction. In EVM Ethers are used to purchase gas and the users who are running the transactions can set their account gas limit for the specific transaction. But again, it's on the miner if they tend to approve the transaction or not. If a sender chooses higher gas price, it will cost them high price to pay for the gas and miners will get great value for the transactions. A miner then executes the computation in order to add this transaction to a block. After the successful execution of transactions, a miner can then broadcast the new block into the network. (Rabah) [34].

5.3 Validating Workflows with Real Healthcare Datasets

We used our developed smart contract workflows to estimate the deployment cost using real healthcare datasets. Blockchain transaction details in Hyperledger fabric can be seen in Figure 10 Description of the datasets is provided in section A. In section B using the real datasets, the deployment cost is estimated and plotted for various factors. (Hölbl, Kompara, Kamisalic, & Symmetry 2018) [35].

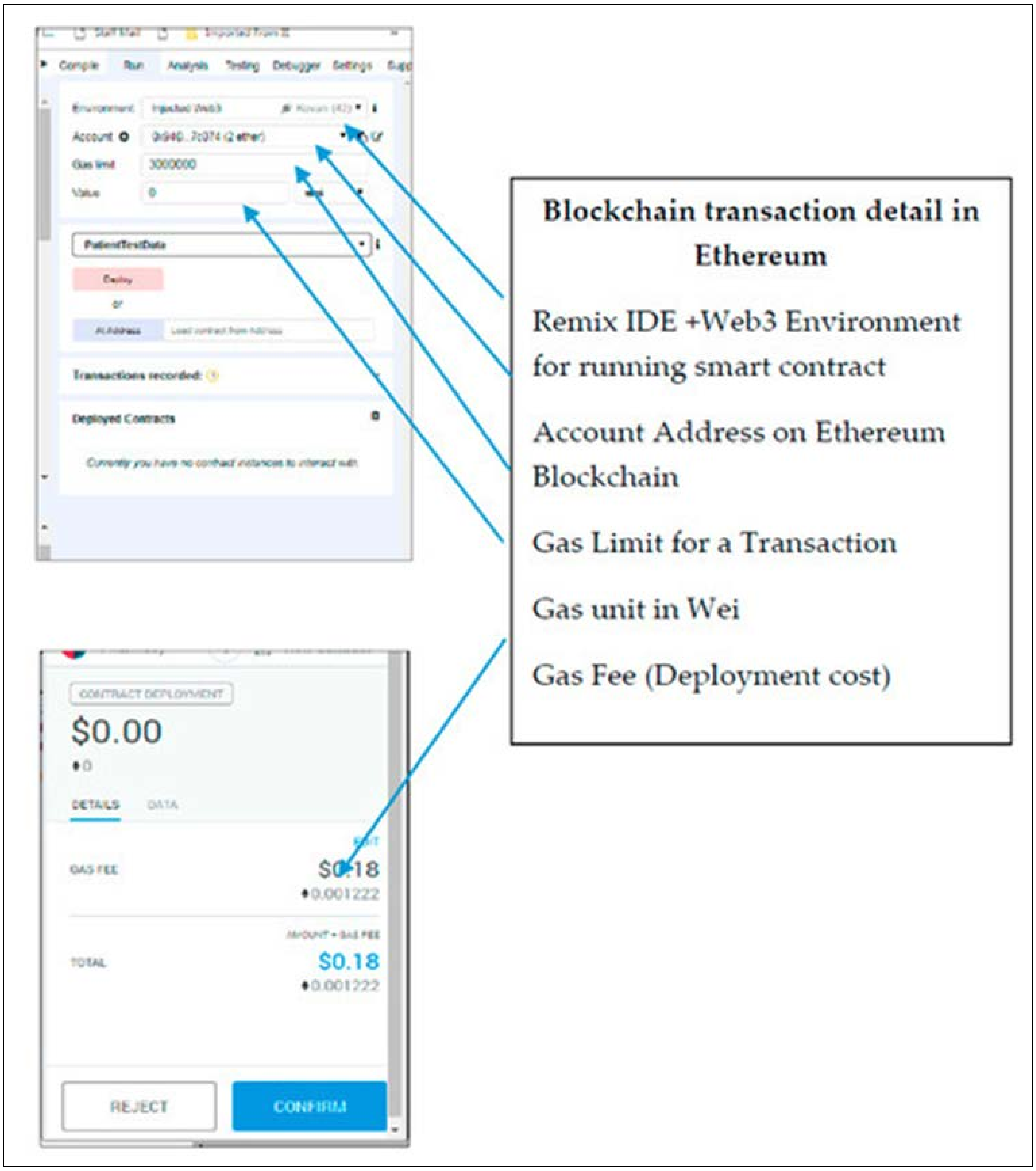

Fig 10: Metalmark extension for calculating smart contract cost.

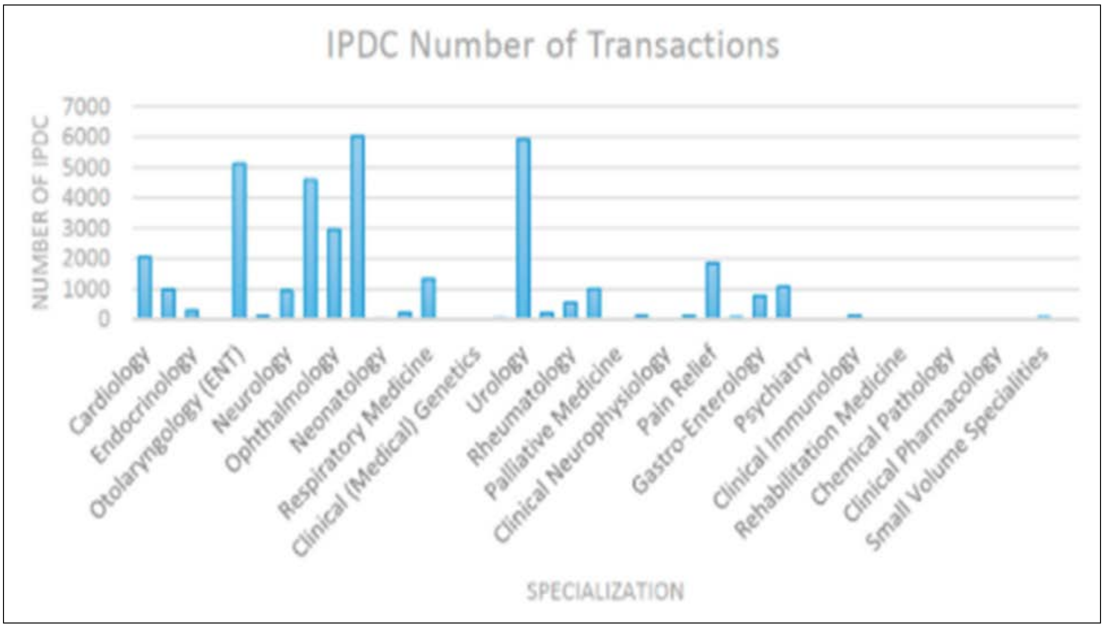

Fig 11(a): Plot showing county wise pharmacy list 1.

5.4 Dataset Description

Datasets are taken from HSE from its different archives. The Health Service Executive is responsible for providing health and personal social services with public funds for all people living in Ireland. All the outpatients, Inpatients waiting list across different departments/Hospital in Ireland has considered to be used in this work. The Outpatient, Inpatient and Day case waiting lists are managed by the National Treatment Purchase Fund from collection of data to its validation phase. (37. McGhin, Choo, Liu, & He) [36]

The Waiting List report for OP states the total number of patients who are waiting, across the various time bands, for a first appointment at a consultant-led Outpatient clinic. Every individual report consists of the numbers waiting per Hospital in each specialty. To protect individual's confidentiality, where there are <5 patients waiting in a particular specialty/hospital, the numbers have been aggregated under a 'Small Volume' heading. All report consists of data on a monthly basis over a year.

Figure 11(a) below shows the county wise number of pharmacies, Figure 11(b) shows the number of transactions for different departments.

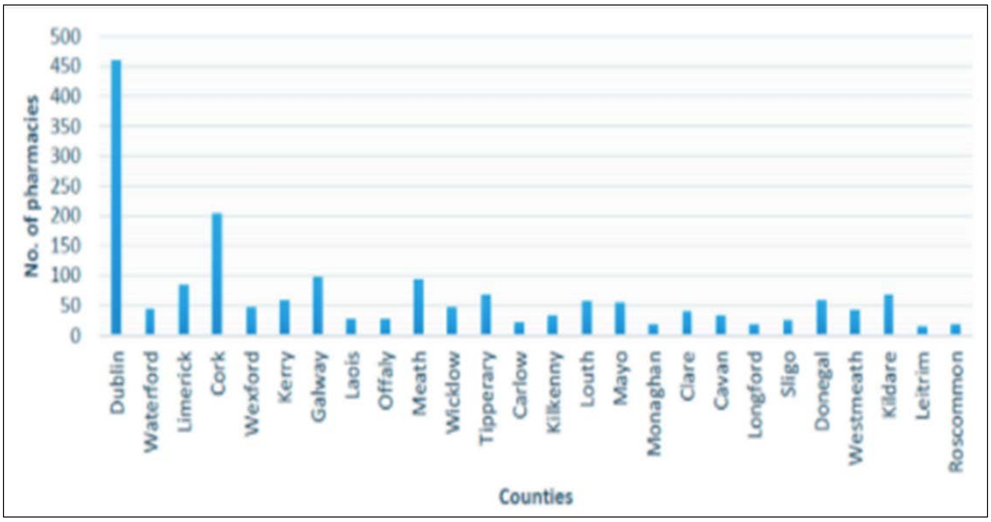

Fig 11(b): Number of IPDC and their transaction across different departments/specialty.

5.5 Cost Estimation Using Real Data

In terms of deploying healthcare blockchain, the cost associated with implementing smart contracts for healthcare needs to be calculated. The ultimate goal is to implement a system that can provide all the advantages of blockchain to a viable medical health system. In Hyperledger fabric blockchain, all programmable calculations cost some fees to avoid network abuse and to overcome other computational related issues. Therefore, all operations, computations, message calls, smart contract creation/deployment and storage on EVM require gas to perform all these tasks. (Esposito, De Santis, Tortora, Chang, & Choo?) [37].

The cost has been compiled for deploying smart contracts for healthcare management system. In order to run an operation on the Hyperledger fabric blockchain, there is cost known as Gas. All the transactions need 21,000 gas as the basic need to run the operation. If a user is interacting with Hyperledger fabric smart contract, it takes 21,000 of gas with additional gas associated with running of that specific smart contract. For contract deployment to interaction with the different contracts, the gas has been compiled for medical smart contracts. More complex the functions/operations involved in the smart contracts consumes more gas resulting in more fee. As from the feasibility point of view, it is clear from the results that the smart contract deployment cost for healthcare management system is very low. In terms of medical system, this cost is very economical and everyone would like to pay this minor fee to gain control over their EHR and maintain their medical data for life time. Figure 12 shows the cost of deployment of smart contracts for each pharmacy as estimated by our system.

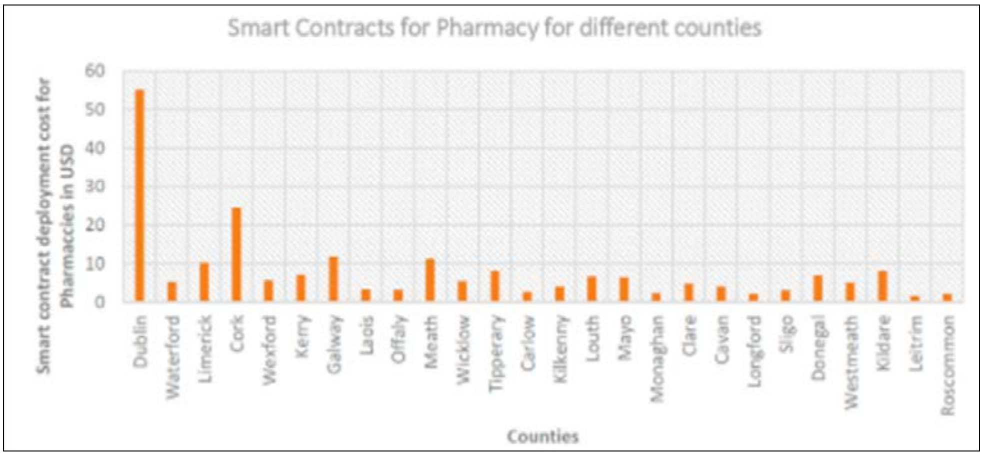

Fig 12(a): Plot showing smart contract deployment cost for countywide pharmacies.

We have estimated the cost for general outpatients, pediatric department patients and surgery patients. The number of transactions for each of these cases and their associated costs as estimated by our system are plotted below.

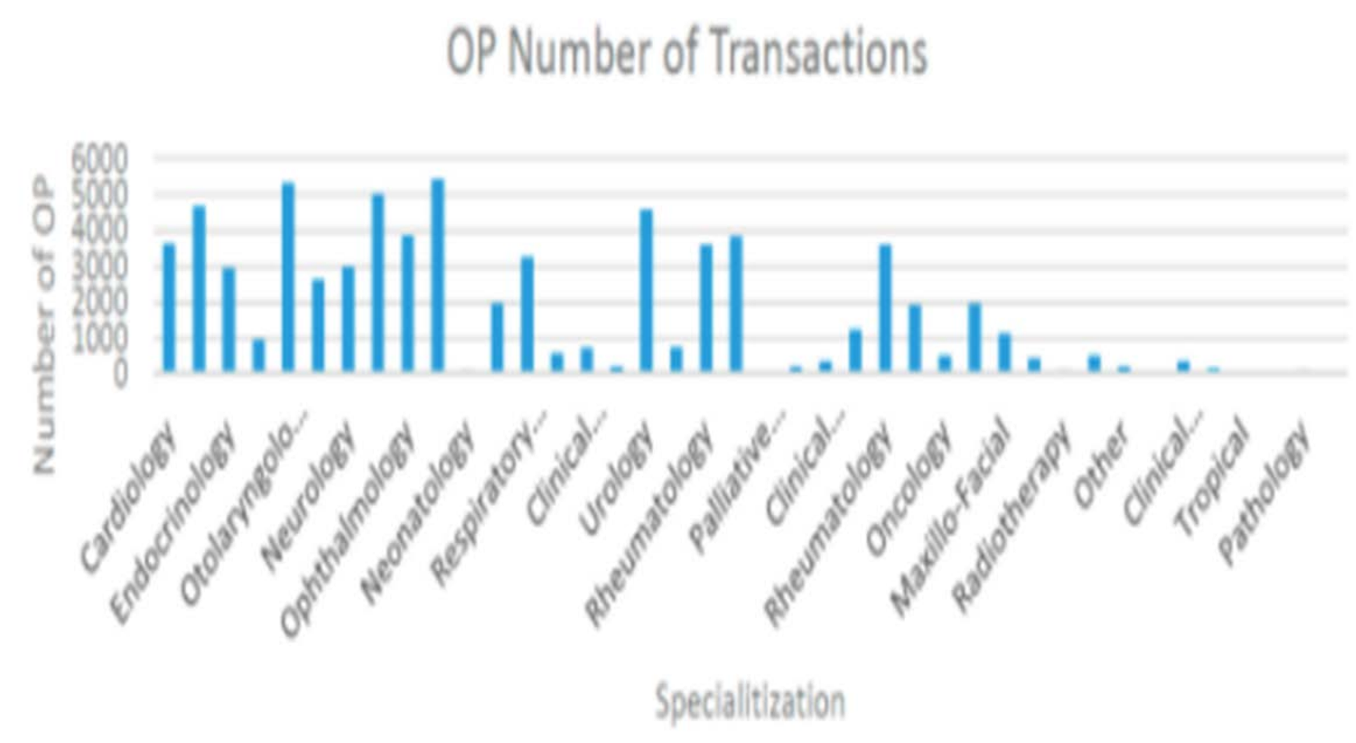

Fig 12(b): Cost comparison among different smart contracts and entities 1.

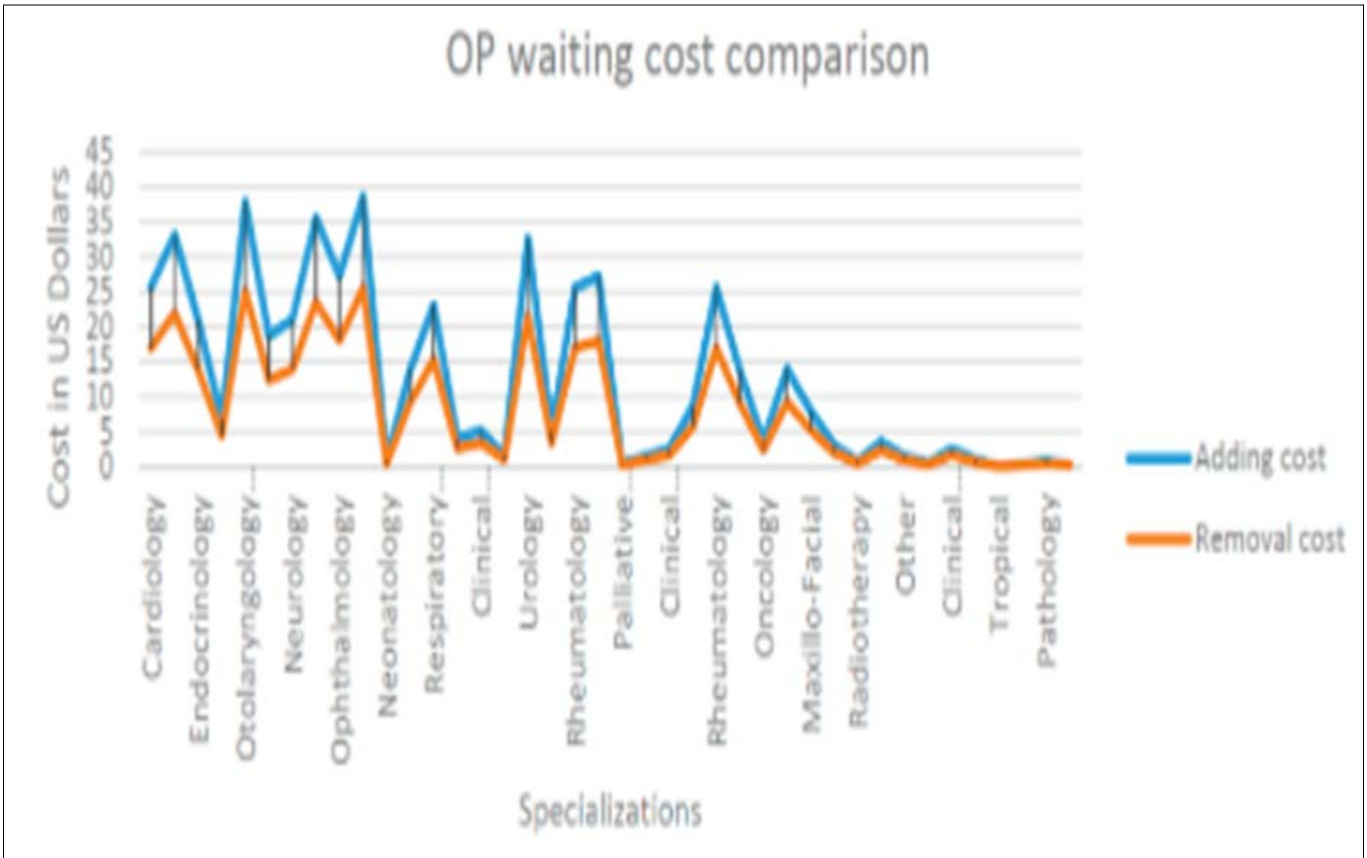

Fig 12(c): Cost comparison among different smart contracts and entities 2.

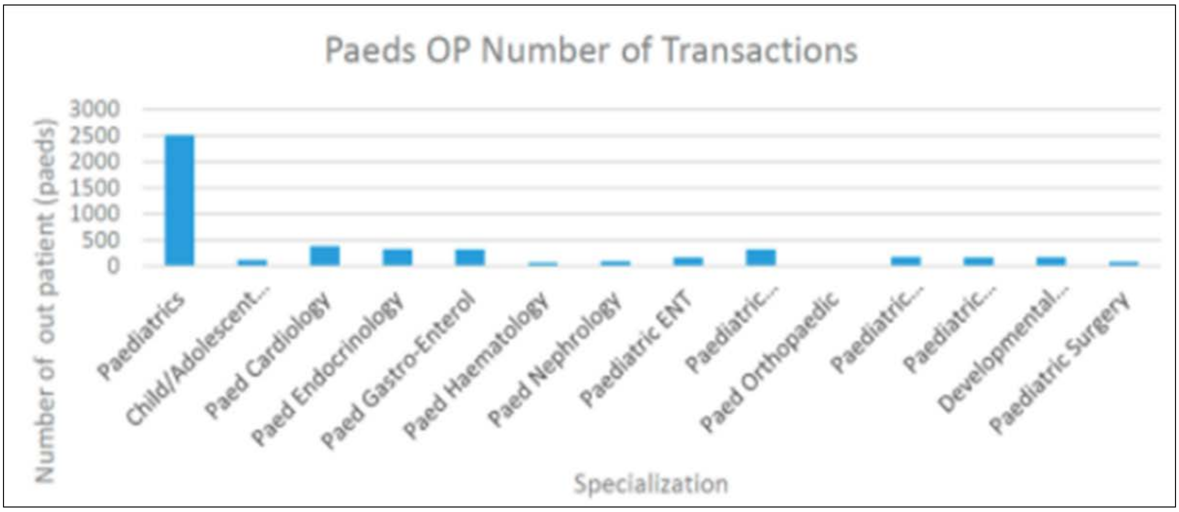

Fig 12(d): Cost comparison among different smart contracts and entities 3.

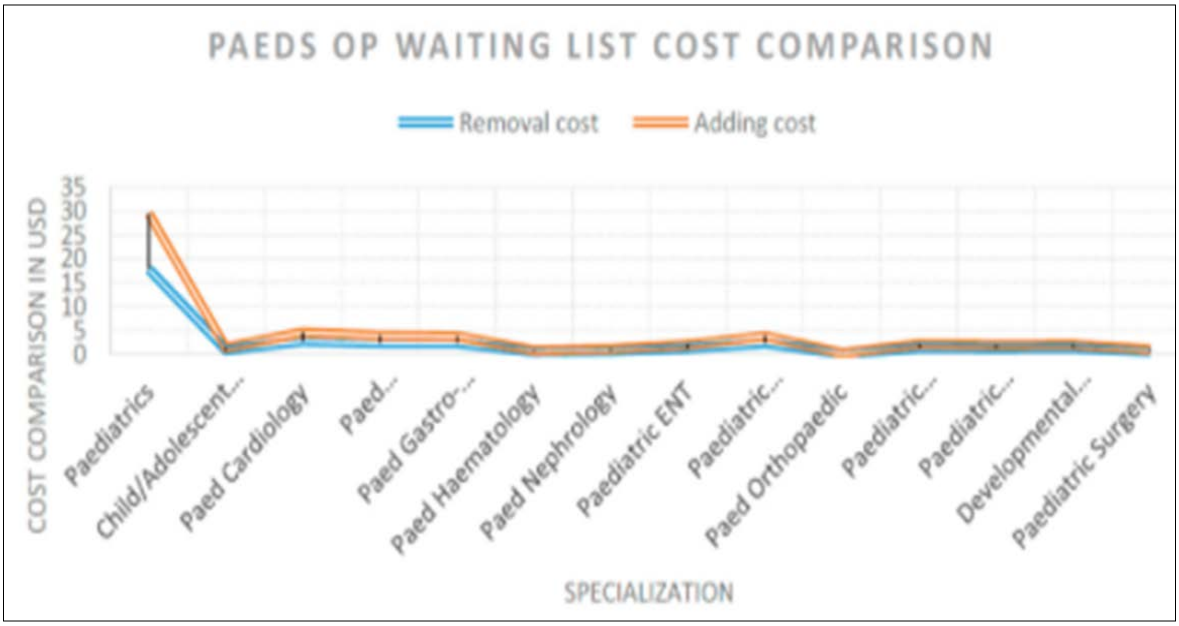

Fig 12(e): Cost comparison among different smart contracts and entities 4.

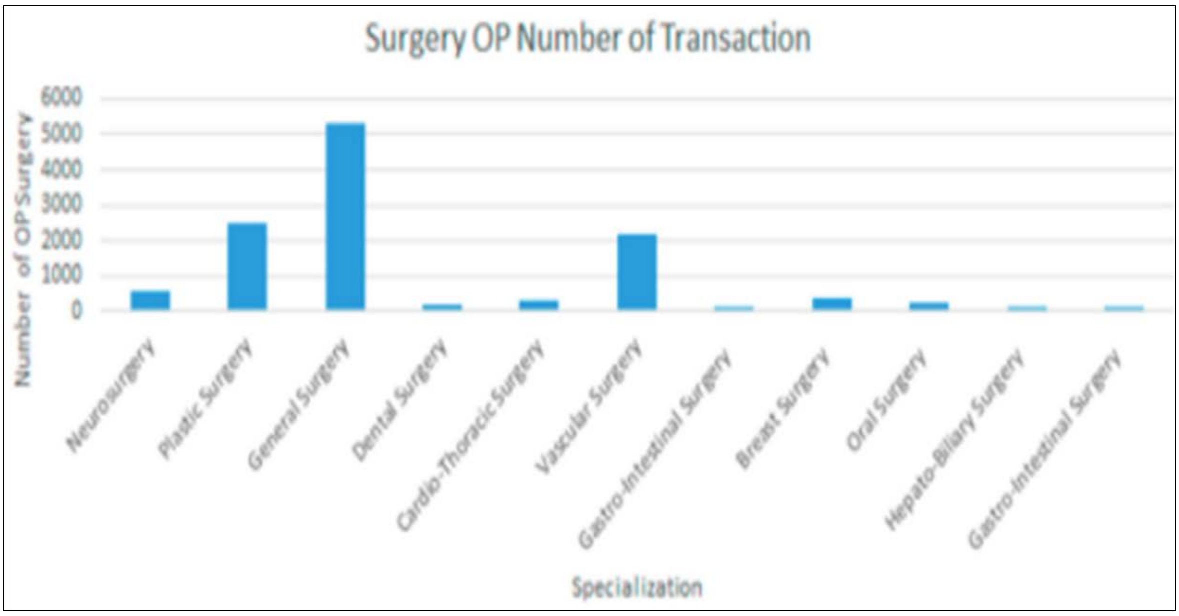

Fig 12(f): Smart contract deployment cost for Inpatients and Day cases (IDPC surgery) across different departments/specialties.

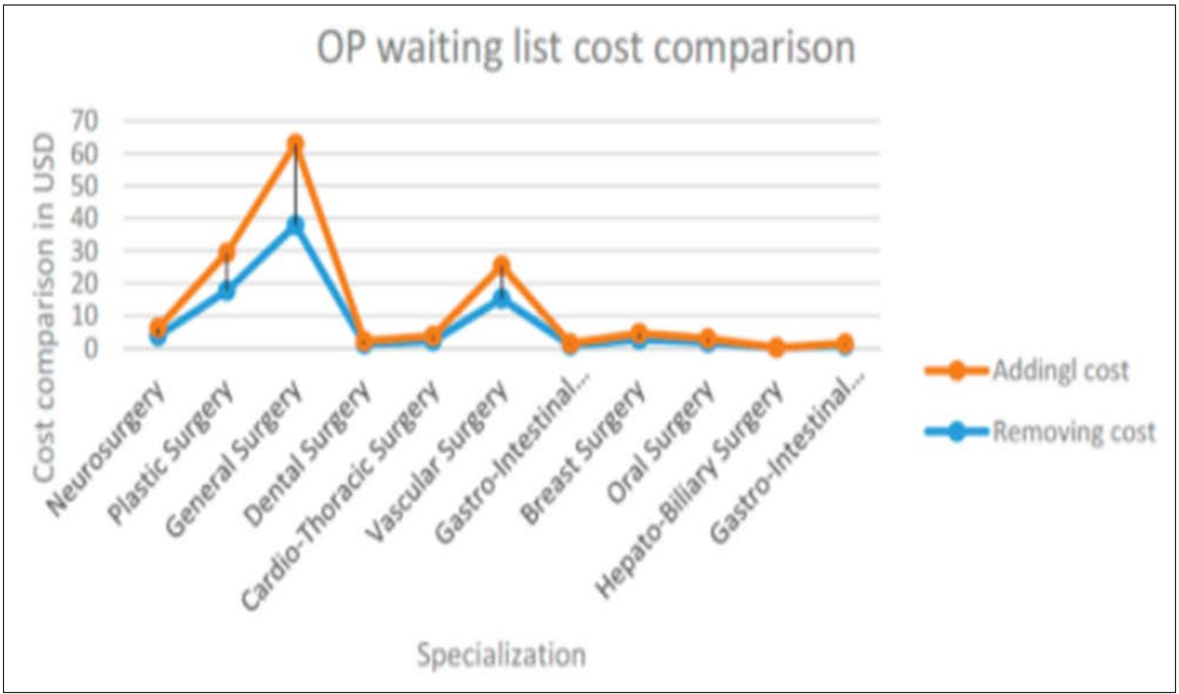

Fig 12(g): Smart contract deployment cost for Inpatients and Day cases (surgery) across different departments/specialty

6. Conclusion

Using blockchain technology, our smart contract-based healthcare management system has shown how decentralization principles can be applied in medical ecosystem for large-scale data management and to streamline complex medical procedures. We demonstrate an innovative approach to medical record handling, providing auditability, interoperability and accessibility using smart contracts. Designed to record flexibility and granularity, this system enables the sharing of patient data and incentives to support the system for medical researchers. (Engelhardt) [38].

We have proposed potential applications of blockchain technology in the management of health data. We implemented a system for data management and sharing based on the requirements from a medical perspective. Using blockchain technology, privacy, security, availability and fine-grained control of access to EHR data can be ensured. The ultimate goal of using blockchain the way outlined in this paper is to improve healthcare processes and thus patient outcomes. Blockchain can help in many ways; reducing transaction costs by using smart contracts which are embedded general purpose protocols to simplify procedures, reduce administrative burdens and remove intermediaries. Other blockchain efforts are aimed at improving the collection, use and sharing of health data from patients, researchers and sub-processors of data. (40. Zyskind & Nathan, 2015) [40]. Our proposed system uses blockchain technology to create a healthcare ecosystem that is iterative, scalable, secure, accessible and decentralized. This would allow patients to exchange their medical records freely and safely with doctors, hospitals, research organizations and other stakeholders-all while maintaining full control over the privacy of their medical data. This will solve many of the current healthcare system's issues, including data soloing, legacy network incongruity, unstructured data collection difficulties, prohibitively high administrative costs, lack of data security, and unaddressed privacy concerns.

6.1 Limitations of blockchain Hyperledger fabric in health care management system

- **Network fault tolerance**
  Fault tolerance refers to the ability of a system (computer, network, cloud cluster, etc.) to continue operating without interruption when one or more of its components fail.
  The objective of creating a fault-tolerant system is to prevent disruptions arising from a single point of failure, ensuring the high availability and business continuity of mission-critical applications or systems.
  Fault-tolerant systems use backup components that automatically take the place of failed components, ensuring no loss of service. These include:
- **Hardware systems:** That are backed up by identical or equivalent systems. For example, a server can be made fault tolerant by using an identical server running in parallel, with all operations mirrored to the backup server.
- **Software systems:** That are backed up by other software instances. For example, a database with customer information can be continuously replicated to another machine. If the primary database goes down, operations can be automatically redirected to the second database.
- **Power sources:** That are made fault tolerant using alternative sources. For example, many organizations have power generators that can take over in case main line electricity fails.
- **Minimum SDKs and APIs**
  The min sdk version is the minimum version of the Android operating system required to run our application. The target sdk version is the version of Android that our app was created to run on.
  As we develop our application on Android, it's useful to understand the platform's general approach to API change management. It's also important to understand the API Level identifier and the role it plays in ensuring

our application's compatibility with devices on which it may be installed.

The sections below provide information about API Level and how it affects our applications. (Nakamoto) [41].

- **Complex Architecture**

  Hyperledger Fabric is a permissioned blockchain framework, with a modular architecture (plug-and-play). It leverages container technology to host smart contract (Chain code) which contains application logic. Before going to each component in detail let us see a high-level transaction flow and basic components involved. (Curran, 2018) [42].

  The Hyperledger Fabric architecture delivers the following advantages:
- **Chain code trust flexibility:** The architecture separates trust assumptions for chain codes (blockchain applications) from trust assumptions for ordering. In other words, the ordering service may be provided by one set of nodes (orders) and tolerate some of them to fail or misbehave, and the endorsers may be different for each chain code.
- **Scalability:** As the endorser nodes responsible for particular chain code are orthogonal to the orders, the system may scale better than if these functions were done by the same nodes. In particular, this result when different chain codes specify disjoint endorsers, which introduces a partitioning of chain codes between endorsers and allows parallel chain code execution (endorsement). Besides, chain code execution, which can potentially be costly, is removed from the critical path of the ordering service.
- **Confidentiality:** The architecture facilitates deployment of chain codes that have confidentiality requirements with respect to the content and state updates of its transactions.
- **Consensus modularity:** The architecture is modular and allows pluggable consensus implementations. (Khatoon, Verma, Southernwood, Massey, &) [43]
- **Inadequately skilled programmers**

  Programmers cannot write good code unless they understand what they are typing. At the most basic level, this means they need to understand the rules of their programming language well. It is obvious when a programmer doesn't because they solve problems in indirect ways and litter the code with unnecessary statements that they are clueless as to what they actually do. Their mental model of the program does not match with the actual behavior of the code

6.3 Future work

While we are making this project, we have thought about various aspects, which will be very helpful for the people who will be using it. Such as, this software will be available for a little amount of money so that everyone can use it. It won't cast them any extra charge. The people who live in rural areas will also be able to use it. The renowned doctors will also be reachable through our platform in 24/7.

7. References

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