MedCode: A blockchain based Patient Referral System

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***Abstract*— In the current healthcare system, it's a common practice to refer patients from one medical practitioner to another to complete his/her treatment procedure. This process is known as a referral. Currently in Sri Lanka due to a lack of a well-organized referral system has led to many shortcomings in the health sector. These include misplacement of referral forms causing repetitions of the same treatment procedures, long queues, and congestion in hospital premises. It has even led to misdiagnosis and incorrect treatment procedures which in some cases has led to the loss of a patient's life. As a result patient's faith in the entire health care system has begun to deteriorate. The primary scope of this research is to promote an electronic health record system(ESR) to provide solutions to the challenges which are met by the current system. In this study, the IBM Hyperledger Fabric framework is used to create a prototype. Then the prototype is tested against common use cases found in the health sector.**

Keywords*— Blockchain, Electronic health records (EHR), Healthcare, Medical referral, Smart contract

I. INTRODUCTION

The healthcare system in Sri Lanka is one of the best in the world. Medication, preventive measures, quality of care, qualified doctors and nurses, surgical procedures have been excellent. But there is a clear technological gap when it comes to the administration and data management that is underpinning the care received by the patients. The ministry of health in Sri Lanka has launched the Health Systems Development Project – Phase II, along with the support provided by the World Bank. The project aims to improve the healthcare system to cater to changing demographics, hence providing more effective service to the public. According to the situation analysis conducted it was concluded that despite the island-wide free of charge, well-structured and accessible health care system, the current system is not patient-centric, lacks longitudinal data, and does not provide reliable patient information.[1] Although most clinics capture longitudinal data using paper-based records they are not shared with other stakeholders involved in the treatment process. Based on the stakeholder consultations carried out by the ministry, many areas were suggested to improve the current system. One of the main areas were a referral system and a patient information system. As an initial step, it was recommended to implement a paper-based system to record the sequence of consultations. Records of patients' consultations and investigations should be in electronic format in long term.

An EHR or EMR (Electronic Medical Record), is a digital document of a patients' medical history. These are maintained by the healthcare provider throughout the treatment of the patient. It contains crucial information, such as demographics, diagnosis, prognosis, lab test results, etc. EHR is a part of a bigger health information system. Therefore, it should not be considered in isolation. The system should be able to share information with other systems. Such systems include public health services, curative services, and institutional/ hospital management in public and private health sectors. There is an absence of governance, digital architecture, and a regulatory mechanism. Undertaking such systems requires continuous devotion to investments in equipment, infrastructure, and competent human resources. Therefore, it is important to study the existing literature. In this study blockchain network is created using the Hyperledger Fabric framework and results are obtained from entering sample patient records.

II. LITERATURE REVIEW

A. Blockchain

In blockchain technology, digital records are divided into blocks and they are secured using encryption mechanisms. [2] It can also be described as a data structure that can be used to store and logically combine data in a peer to peer (P2P) network. It is important to understand why blockchain over traditional databases in research. Key factors are data security, integrity, availability, scalability, and privacy.

B. Public and private blockchains

The current model of the blockchain has two types. They are public/permission-less and private/permissioned blockchain.[2] Bitcoin cryptocurrency operates in a permission-less blockchain where anyone can operate a node and take part through spending a CPU cycle and exhibiting proof of work. The permission-less blockchain uses a public ledger that stores transactions and have no access restrictions to nodes.

Permissioned/Private blockchain model controls the entities who can participate in the protocol and the validation. Furthermore, the nodes usually have established identities and form a consortium. Private blockchains usually keep the write permission to a centralized organization and read permissions to the public or restricted.[2] Hence there is a control over which transactions are valid and enables consensus without proof of work or any additional costs. Trust exists between nodes in private blockchains. Some of the advantages of using private blockchains over public blockchains are high security and privacy, known validators, control over the scalability, less processing power, easiness in fixing and restricting nodes, and freedom to change the rules and revert transactions.

C. Healthcare Frameworks, Prototypes, and Related Work

Blockchain facilitates data in a transactional and localized manner. Therefore, it can be used in healthcare to achieve the balance between privacy and accessibility of EHRs. In the study [3], they have proposed a framework named Ancile which is based on smart contracts in an Ethereum blockchain.

It provides efficient, interoperable, and secure access to medical records while maintaining the privacy of sensitive information. In the same study, advanced cryptographic techniques were used for additional security. Blockchain eliminates an authority or middle management which is required to authorize and validate a transaction based on transparency and trust. It also ensures the privacy and anonymity of the users associated with a transaction are protected. Due to the interoperability of several authorities involved in the healthcare process, the key concern has become the privacy and security of patients' data. [4]

Hospitals and clinics share data within the organization, but there is an inability to share data between systems due to the absence of infrastructure or a reluctance to share data. In [5] a cloud computing network adopting Ethereum blockchain and Amazon Web Services (AWS) is utilized to facilitate semantic level interoperability of EHR systems. It is important to note that communication is achieved without formatting and standardized data forms. The study [2] was conducted to emphasize the use of blockchain technology in managing health records securely across different hospitals. They proposed a prototype called Mblocks that stands for medical blocks. It is a sequence of blocks that have the patient's information. These records can be shared and stored across several stakeholder entities in a protected Hyperledger environment. The system will reduce the time required for a physician to prescribe and take preventive action.

Research conducted in New Zealand was to construct a large-scale EHR system to cater to the needs of the entire health sector. The platform: MedBloc captures a longitudinal interpretation of the patient's health use case and permits patients to give or remove consent for regulating access to their medical records. To protect data, MedBloc adopts an encryption mechanism and imposes a smart contract-based access control technique for regulating access [6]. In the research [7], a decentralized medical data management system called MedRec is introduced. Its modular APIs help to integrate existing EHR systems of different healthcare providers. The network is secured from tampering through the Proof of Work consensus mechanism.

Medical referrals are not simple; an effective referral involves locating a practitioner who is available and has the required specialty. The focus of [8] was to get an idea about the workflow of Canada's referral process in the public healthcare system. Then a health informatics system is proposed to transfer the referral process to an electronic form. The solution consists of a forum-based methodology that provides a shared communication platform for healthcare authorities participating in the referral process. [9] have chosen the Hyperledger fabric framework to develop the solution. Thus, the paper focuses on developing a prototype healthcare service application in the dental clinic sector. Hyperledger composer generates a transaction id number by running a hash mechanism. In this manner, the records of transactions can be kept controlled by the authorities and accessible to the participants.

III. WORKFLOW

In this section, the current referral process of the healthcare sector is discussed. It mainly involves 4 components in a hospital entity.

1) OPD
2) Accident and Emergency
3) Clinic
4) Ward

Following in-hospital and inter-hospital, transactions can take place.

- OPD can *refer* a patient to a Clinic (in the same hospital or a different hospital)
- OPD can *admit* a patient (to a ward in the same hospital)
- Accident and Emergency unit can *admit* a patient (to a ward in the same hospital)
- A clinic can *refer* a patient to another Clinic (in the same hospital or a different hospital)
- A clinic can *admit* a patient (to a ward in the same hospital)
- Ward can *refer* a patient to a Clinic (in the same hospital)

The in-detail process within a single hospital is shown in figure 1.

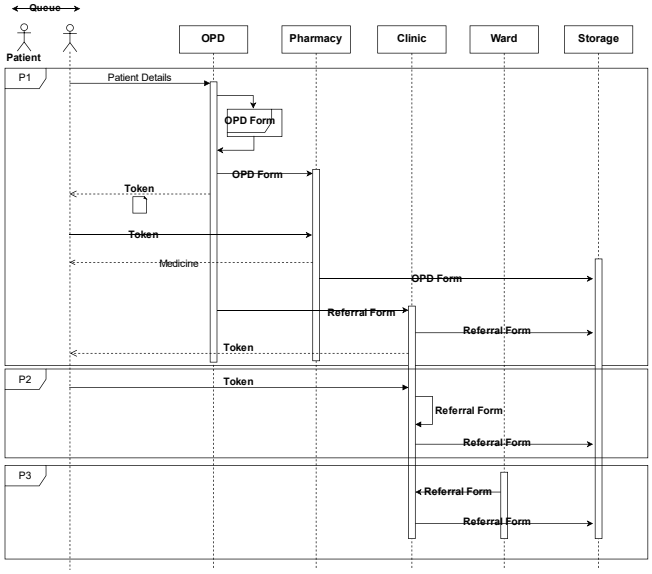

Fig. 1. Referral process

The first scenario is the process P1. P1 begins when the patient visits the OPD and gives his/her details. These details are entered in the OPD Form. OPD Form consists of the following:

1. Medical/Surgical Number – This number gives the patient number for that particular month
2. Daily Count – The daily count gives the patient number for the day
3. Patient Name
4. Sex
5. Age
6. Address (Full)
7. Diagnosis
8. Date

9. Notes
10. Treatment

Sample OPD Form is shown in figure 2. Medical/Surgical Number + Date (Stamp Seal) acts as a unique identifier of a patient. The Medical/Surgical Number gives the total number of patients that visited the OPD up to the current patient within that month. For example, in figure 2, No. is 6043 which means this form belongs to the 6043rd patient of October 2020(date stamp). In the top left-hand corner, there is another number which is the daily count. In the given form that number is 113 meaning that the current patient is the 113th patient on the current day (which is 15th October 2020). After patient details; Name, Sex, Age, Address (Full) are entered into the form, the patient is directed to a doctor in the OPD. Here the doctor fills the Diagnosis, Notes, and Treatment section of the OPD form.

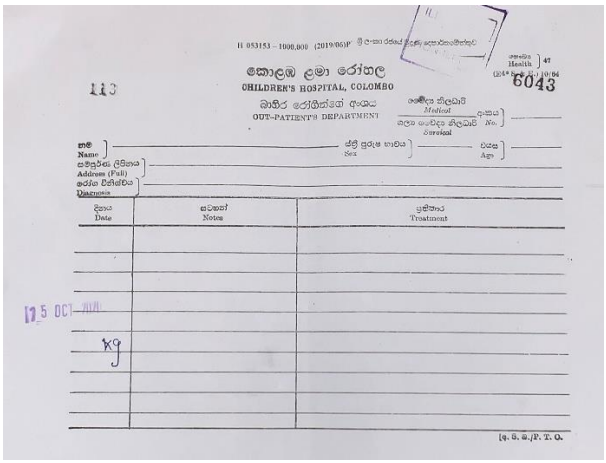

Fig. 2. OPD Form

Based on the doctor's diagnosis P1 can be divided into two distinct sub-processes; SP1 and SP2(shown but not named in figure 1 to maintain clarity). The first one is if the doctor identified the illness and prescribes medicine, the OPD form is sent to the pharmacy and the patient is given a token. This token consists of the medical/surgical number of the OPD form and the date. Then the patient is directed to the pharmacy where he/she uses the token to get the medicine. Pharmacy cross-checks the token with the previously received OPD form and issues the corresponding medical drugs. After the process, the OPD form is stored for a month and the patient leaves with the medication and the token. (This token is valid for one month as the OPD form is stored for a month).

The second sub-process is where the doctor refers the patient to another physician. Sample Referral Form is shown in figure 3. It consists of the details shown below.

1. Date
2. OPD No – This is the same as the medical/surgical number in the OPD Form
3. Patient Name
4. Sex
5. Age
6. Consultant Name
7. Clinic Name
8. History
9. Probable Diagnosis
10. Name of the MO(OPD)
11. Signature
12. Clinic Table – Clinic, Clinic Time, Days of the week

All the details in the referral form are filled by the OPD doctor referring the patient to a clinic. Then the patient is directed to the clinic where the referral form gets stored and a clinic book gets open with the Date and the OPD No. (This number is the same as the unique identifier: Medical/Surgical Number + Date). In the end, the patient gets a token from the clinic containing this unique identifier.

The second scenario in figure 1 is the process P2. This shows the patient attending clinic with the token and gets referred to another clinic by the doctor (A clinic can refer a patient to another clinic).

The third scenario is a patient who is admitted gets discharged from a ward and get referred to a clinic by a doctor in the ward.

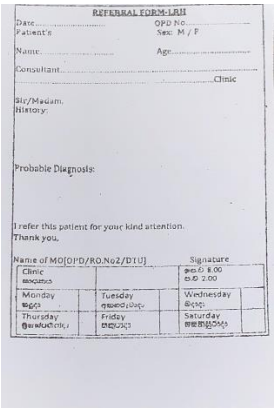

Fig. 3. Referral Form

IV. METHODOLOGY

A. IBM Hyperledger Fabric

According to [10], Hyperledger is an open-source global collaboration that works towards advancing cross-industry blockchain technologies. Hyperledger Fabric is one of the projects under Hyperledger where it intends to develop blockchain technology that accomplice the cross-industry open standard platform for distributed ledgers. It provides solutions to a broad range of industries through distributed ledgers on permissioned networks. Hyperledger Fabric is a permissioned blockchain technology where members of the network are known, and it is best suited for applications that require privacy. Members of a Fabric network are enrolled through a trusted MSP (Membership Service Provider). Its modular architecture increases the confidentiality, flexibility, and resilience of blockchain solutions. It is a system where individuals manage transactions, and it uses smart contracts similar to other blockchain technologies.

B. Proposed Solution

The decentralized nature of the blockchain allows easier modeling of the medical data sharing between real-world hospitals. Patients can be uniquely identified by the NIC (National Identity Card) number. Initially, the patients are registered on the system using the NIC at the nearest hospital to their residence. After the staff enters the details, the patient

can meet the doctor/physician. Then the physician can record the patient information after logging in to the blockchain system. The system is decentralized meaning that all the participating hospitals can transfer and share patient medical data through a highly secure and widely available private blockchain network. This network is named MedCode. Personal health data of patients; medical history, referrals, prescriptions, next visit, etc. can be viewed through a web interface after logging into the system. There is an admin for each hospital and a super-admin for the entire blockchain system. The super-admin has complete control over the addition of participants, managing them, and granting access levels. To add a new transaction/block to the network all the collaborators in the system; patient, doctor, hospital admin, super-admin should have the consensus and approval. Since the patient records are generated separately by different healthcare providers/hospitals each provider is required to maintain the blockchain which comprises the creation, appending, and verification of blocks. Figure 4 illustrates this process.

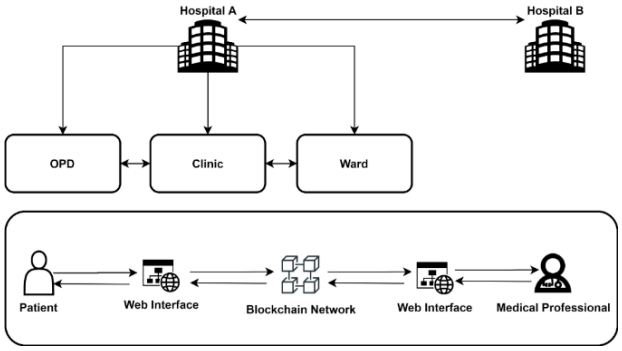

Fig. 4. Overview of the MedCode System

Figure 5 shows the detailed view of a network node in a hospital. Involved parties have a specific interface to interact with the system and their actions are shown. Every action of the participant gets recorded. These actions result in transactions. In order to add a new block, all the participants; admins, NIC authority, doctor, and the patient should approve the transaction and have consensus.

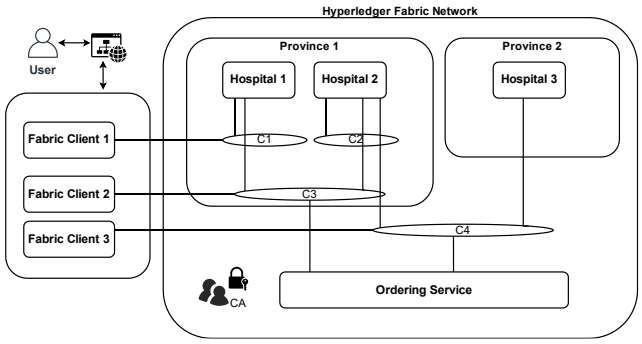

Fig. 5. Detailed network diagram of MedCode

a) Ordering Service: Also called orderer is a well-defined set of nodes that orders transactions into a block and then distributes blocks to associated peers for endorsement and commit. The ordering service is independent of the peer processes. It orders transactions on a first-come-first-serve basis for all the channels on the business network. It is a common binding for the entire network; it holds the cryptographic identity material tied to each Member.

b) Organization (Hospital 1, Hospital 2, Hospital 3): Stated as "members" of the network, organizations are invited to connect to the blockchain by a blockchain network provider. Adding the organization's Membership Service Provider to the network allows the organization to join the blockchain network. The MSP also elaborate how other members of the network could verify signatures (such as those over transactions) that are generated by a valid identity, issued by that organization. The access rights of identities inside an MSP are administered by policies which are also agreed upon when the organization is joined to the network. An organization can be as big as a multi-national company or as small as a single individual. The transaction endpoint of an organization is a Peer. A collection of organizations forms a Consortium. While all the organizations on a blockchain network are members, not every single organization will be part of a consortium.

c) Certificate Authority (CA): Hyperledger Fabric CA is the default Certificate Authority component, which issues PKI-based certificates to network member organizations and their participants. The CA issues one enrollment certificate (ECert) to each authorized user and one root certificate (rootCert) to each member.

d) Channels (C1, C2, C3, C4): A channel is a private blockchain overlay that supports confidentiality and data isolation. A channel-specific ledger is shared across the peers in the channel. Transacting parties must be authenticated to a channel in order to interact with it. Channels are defined by a Configuration-Block.

e) Fabric Client (1, 2, 3): Fabric Client is an end-user application that allows users to interact with the network. In the diagram above patient, doctor, and hospital admin uses client 1, Provincial admin uses client 2, and MedCode admin, NIC authority uses client 3.

C. Algorithm

1. Super admin (MedCode admin) registers provincial admin
2. Provincial admin registers the hospital admins and allocates them to the corresponding hospitals in the province
3. Hospital admin registers patient using NIC
4. Patient visits the hospital, present their NIC to the hospital admin
5. Hospital admin uses the NIC to get the patient details
6. The patient is directed to the relevant doctor
7. Doctor logs into the MedCode and checks the patient health records, medical history, hospital visits, prescriptions
8. The doctor updates the patient record with the identified diagnosis
9. A new block is added updating the healthcare data. The data gets accessible to all authorized stakeholders

D. Participants

Participants are the users that interact with each other and have specific roles in the blockchain network. Participants can propose, verify, and participate in transactions in the business

network. The identification of participants is done by analyzing use cases and figuring out the roles of each candidate. Types of information that each participant can see and transactions they can propose should be clearly defined. These typically depend on each participant's role. Contractual agreements between the involved parties should be stated.

TABLE I. NETWORK PARTICIPANTS

Participant	**Role**
MedCode Admin	Owner
Provincial Admin	Maintainer
Hospital Admin	Maintainer
NIC Authority	Maintainer
Doctor	End-user
Patient	End-user

E. Assets

Assets are tangible or intangible collection of things that provide value to the network participants. Assets can be either physical; cars, houses, or virtual; patient data, documents. Assets are identified by analyzing business use cases. Each asset has characteristics and attributes. State changes of these assets result in adding transaction records to the ledger. Assets can be updated, modified, exchanged, or change in ownership. Medcode platform comprises of following assets:

- NIC – Unique patient identifier
- Personal data of patients
- Medical history of patients
- Prescription data

F. Transactions and Functions

A transaction is a single unit of work initiated by participants and registered in the blockchain ledger. The transaction may involve one or more assets. It is important to note that transactions are immutable after they are recorded in the ledger. Transactions are identified through the following:

- Identifying example transactions in the system
- Describing the network component where transactions are recorded
- Identifying the processes where participants approve transactions

TABLE II. NETWORK TRANSACTIONS

Participant	**Transactions**
MedCode Admin	Defining access levels Maintaining the network Creating smart contracts
Provincial Admin	Add hospital admins Assign hospitals to hospital admins Make sure the patient receive their best care within the province
Hospital Admin	Add patients, doctors Enter the patient's personal data Assign doctors to departments Validate the patient's visit to the hospital
NIC Authority	Verify a patient's NIC Allow access to patient's data through NIC
Doctor	View the patient's medical history Exchange the patient's medical history View prescription data Add new prescriptions Add new medical history records
Patient	View personal data View medical history View prescription data

G. Implementation in Hyperledger Fabric

Figure 6 illustrates the use of Hyperledger Composer to come with the Business network archive file (.bna). It is composed by packing up Model file (.cto), Script or Logic file (.js), Access control file (.acl), and Query file (.qry). .bna file can then be deployed to a local computer or cloud.

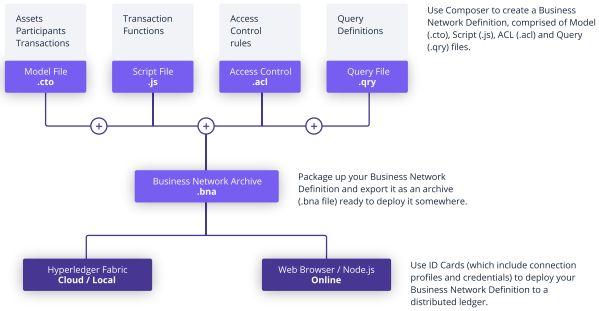

Fig. 6. Business network Archive file structure[11]

Hyperledger composer playground was used to create and test the business network.

V. RESULTS AND DISCUSSION

The MedCode network has been created successfully with the necessary files for testing. Hyperledger fabric consists of options to test the business network for its functionality. MedCode Admin has full authority over the asset creation, participant creation, and granting access to different stakeholders in the network. Figure 7 illustrates all the transactions available in the MedCode system from the view of MedCode Admin.

There is an option to view record history (through historian records) in the Hyperledger Fabric platform. It shows every transaction that took place with transaction id (Hash key) and timestamp. Figure 8 shows the screenshot of a transaction where a doctor diagnoses a patient and update the patient record. (Hash is highlighted).

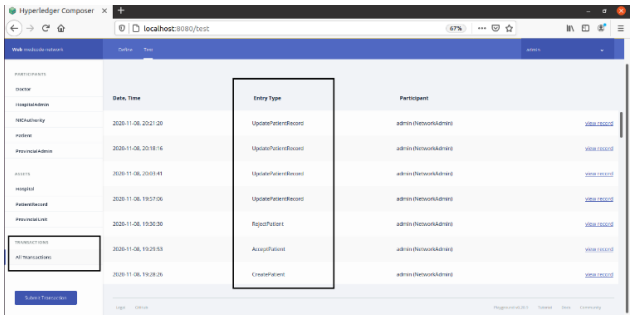

Fig. 7. Transaction Blocks in MedCode

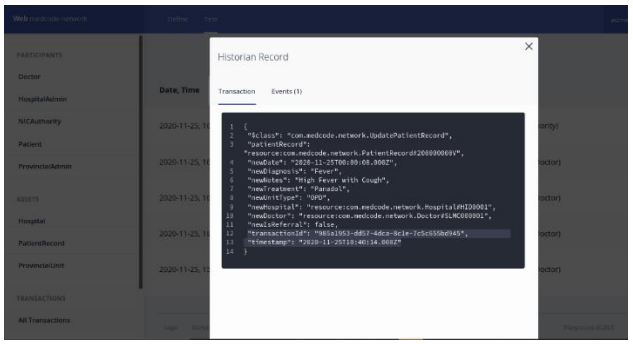

Fig. 8. Update patient record transaction with key and timestamp

In figure 9 a doctor (SLMC000001) referring a patient(200000000v) to another physician (SLMC000002) at a different hospital (HID0002) is shown.

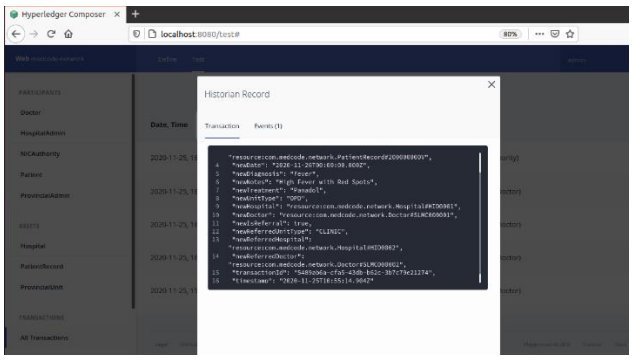

Fig. 9. Update patient record transaction with key and timestamp

MedCode Admin has authorized NIC authority to manage patient details and verify patient information. Patient verification/acceptance transaction has been successfully added to the MedCode network. Following Figure 10 shows the transaction details, the entity who carried out the transaction, and the time-stamp.

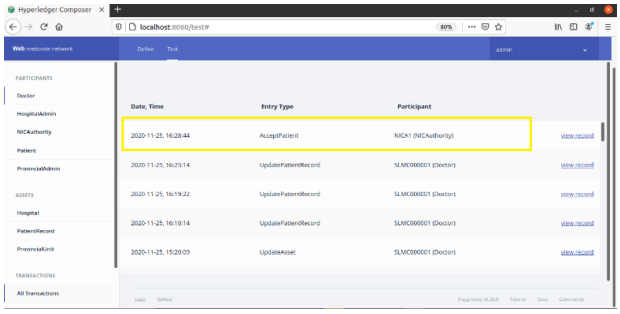

Fig. 10. Added transactions in MedCode

VI. Conclusion

The MedCode blockchain system has been implemented and tested successfully using IBM Hyperledger Fabric. The strong set of security settings provided by Hyperledger fabric allowed us to achieve data privacy, security, and integrity. Every transaction is validated against the consensus protocol which all the authorized participants agree to. Since the shared, immutable, and permissioned ledger is the single source of truth, it provides more confidence to handle sensitive data. The primary goal of this research is to propose a prototype to facilitate the storage and sharing of patient records securely while preserving privacy, anonymity. The referral process is facilitated by giving access to the practitioners and other relevant authorities based on the consent provided by the patient. IBM Hyperledger Fabric allowed us to achieve this objective with ease and provided tools to test the blockchain system after deployment. Network participants can carry out transactions by logging into the system. This methodology can be further modified to integrate the existing health record systems to the blockchain network in the future.

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