A Case study for Blockchain in Healthcare service: "RecHealth" Prototype for Dental Clinic based on Hyperledger Fabric platform protocol

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ABSTRACT: *These days all businesses participating in a commercial ecosystem need a ledger to contain a record of transactions. It is vitally important to know that the ledger is identical to the business partners' and free from discrepancies. Blockchain and cryptocurrencies are often discussed in similar contexts, but they are not one and the same. Distributed ledgers do not require a cryptocurrency to work. Many opensource blockchain efforts implement a cryptocurrency as a means to fund mining and participation in consensus. However, the most popular existing blockchains like Bitcoin and Ethereum utilize completely trustless networks and permissionless chains. Most enterprise blockchain applications rely on real world trust relationships wherein the goal is to set up a set of participants in an ecosystem with the needed insurance that the boundaries are flexible enough to bring in more participants in the future. Participants on a permissioned network are known to one another, and therefore have an intrinsic interest in participating in the consensus making process. This community of participants wants to share data with a greater degree of security. Without needing to run proof of work mechanisms, they can resolve more immediate problems than on a public cryptocurrency blockchain. Therefore,financial companies are looking to get involved in business blockchain technologies. A blockchain is made up of many components such as APIs, Smart Contract Layer, Data Store Abstraction, Identity Service, etc. All of these components were designed by Hyperledger Composer so that they can be used in different business contexts and industries. In this paper we will focus on blockchain in healthcare services.*

Keywords: Hyperledger Composer, Blockchain, Healthcare services

I. INTRODUCTION

The healthcare service industry in Thailand represents one of South-East Asia's largest healthcare markets, and one of the largest medical tourism markets worldwide. [1] The number of older persons in Thailand has grown rapidly and will continue to do so in future decades. [2] Healthcare becomes more important and needs more technologies to come and improve the service system in a secure and transparent way. The way in which internet technologies tend to ~~get~~ develop is through ~~a~~ partnerships between organizations, allowing such things as standards, global governance, and implementers.

Interoperability between different providers and hospital systems is a challenge. Sometimes it is a lack of good coordinated data management and exchange. This means health records are fragmented. Different computerized medical systems should be able to share records (historical, radiological, laboratory. etc.) from multiple sources including doctor's offices, hospital computer systems, laboratories and patients' devices or computers. [3]

The Hyperledger platform ~~for~~ implements smart contracts in order to help reduce duplicate efforts, and also prevent gradual detachment between organizations. The adoption of this technology in healthcare services can solve many problems. Hyperledger offers enterprise grade opensource business blockchain technologies, including distributed ledgers, smart contract engines, client libraries, graphical interfaces, utility libraries, and so on. Hyperledger provides the underlying open source software on top of which anyone can set up apps to meet their business needs. Built under technical governance and open collaboration, individual developers, service and solution providers, government associations, corporate members and end users are all invited to participate in the development and promotion of these game-changing technologies.

[4] Hyperledger platforms come in a variety of different frameworks. These meaningfully differentiated approaches to business blockchain frameworks are developed by a growing community. There are have five types of Hyperledger frameworks:

1. Hyperledger Indy
2. Hyperledger Fabric
3. Hyperledger Iroha
4. Hyperledger sawtooth
5. Hyperledger Burrow

Under the umbrella of the Hyperledger approach, many tools are designed specifically for one framework or the other and, through common license and community of communities' approach, are ported to other frameworks. Such as
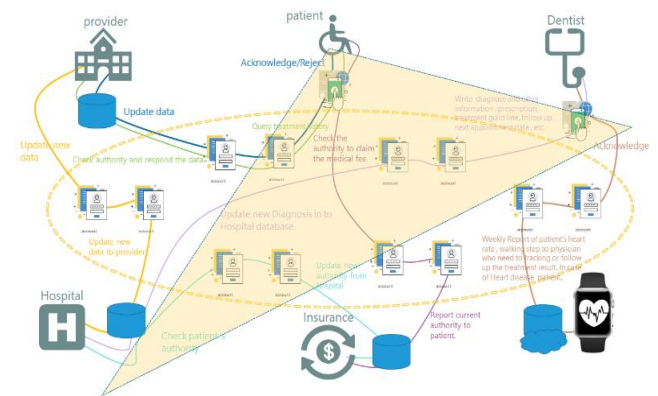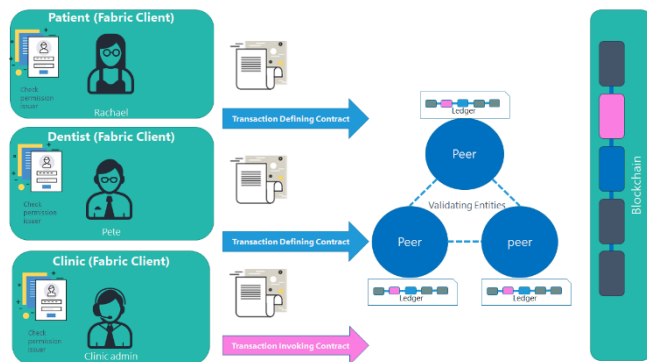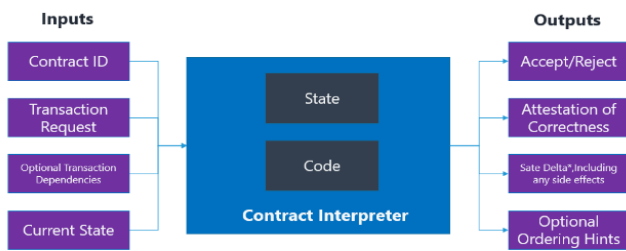
1. Hyperledger Composer
2. Hyperledger Explorer
3. Hyperledger Cello

Hyperledger focuses on developing a modular architectural framework for enterprise-class distributed ledgers. This includes identifying common and critical components, providing a functional decomposition of an enterprise blockchain stack into component layers and modules, standardizing interfaces between the components, and ensuring interoperability between ledgers.

For some cases, business blockchain requires rapid network consensus systems and short block confirmation times before making additions to the chain. For others, a slower processing time may be acceptable in exchange for lower levels of required trust. Scalability, confidentiality, compliance, workflow complexity, and even security requirements differ drastically. They represent a potentially unique optimization point for the technology. [5]

In our system, we give patients a comprehensive, immutable log and easy access to their medical information across treatment applications. Leveraging unique blockchain properties,Rechealth manages authentication, confidentiality, accountability and data sharing; crucial consideration being

taken when handling sensitive information.

In this paper, we discuss the use of Hyperledger Composer as the base to create smart contracts in our healthcare service prototype.

II. SYSTEM ARCHITECTURE

Figure 1. How smart contracts process requests [4]

Figure 1 illustrates the process for creating smart contracts. The input data includes the contract identifier, the transaction request, optional transaction dependencies, and the current state of the ledger. The input data is taken in by the contract interpreter, which then outputs its acceptance or rejection along with an attestation of correctness, a state delta, and optional ordering hints. Upon acceptance of the smart contract, a call is then made to the consensus service for final commitment into the blockchain.

The smart contract layer validates each request by ensuring that it conforms to policy and the contract specified for the transaction. Invalid requests may be dropped from inclusion within a block, depending on the framework.

Figure 2. Architecture Model of RecHealth system

Figure 2 illustrate when fabric Dentist and Patient clients were checked permission issuer then they are defining the contract in the transaction via application and then send it to the peer. In the same time when Clinic will invoke the contract to see the transaction in the peer. The system will distinct the role of user and validators. Then the invoker will deploy new chaincode and invoke the transaction after that the validator will evaluate the effect of the transaction and reach consensus over the new version of the ledger. The ledger will keep the all total of the transactions include the hash number in each block or transaction.

III. BUSINESS NETWORK CONCEPT

[6] Hyperledger composer is a set of tools that make building blockchain applications easier. It consists of a modelling language called CTO, a user interface called Hyperledger Composer Playground and a Command-Line Interface (CLI).

These tools are designed for rapid configuration, deployment, and testing of a business network integrating a running instance of the Hyperledger Fabric blockchain network.

A business network is a group of entities who accomplish certain goals. In order to achieve these goals, there must be agreement among the members of the business network regarding:

1. Exchange of goods or services.
2. Business rules for an exchange.
3. Which members in the group are allowed to participate, and when they can.

❖ **RecHealth business network concept**

Figure 3. Scope of business network concept in RecHealth

As the figure 3 illustrate the blockchain organization that suppose of single hospital organization that will include Patient, Doctor (In this paper focus on dental clinic so it will describe in to Dentist instead), Hospital, Insurance company, Provider agency company, Device or IOT database health log. In the first intention author attend to create the blockchain organization for hospital and for Electronic Health Record. However, this paper will only focus on the dental clinic that can see the over all picture easier than the big picture. Hence in business network concept will consist in the follow below

1. **Participants**
   1.1. **Dentist:** Person giving the treatment and health consultation to a patient, They have the authority to view the treatment history and create new a plan of treatment.
   1.2. **Patient:** Person receiving treatment services.
   1.3. **Clinic:** Participant responsible for the status of the clinic and helping dentists submit new contracts to the blockchain.
2. **Assets**
   2.1. **Prescription:** Asset containing a dentist's treatment plan and its history.
   2.2. **Contract** Asset containing the price agreed upon between a patient and dentist in the consulting room.
3. **Transactions**
   3.1 **Treatment Interview:** Transactions recording the treatment interview. This is an initial record and can contain treatment history and other relevant information.
   3.2 **Treatment Plan:** Transaction recording the dentist's treatment plan such as a surgery plan, or the processing of treatment. This transaction can be cross-checked after the patient receives treatment.

3.3 Treatment Fee: Transaction submitted by the patient confirming that the clinic acknowledges the treatment. This causes the status to go from unpaid to paid.

3.4 Treatment Received: Transaction submitted by the clinic showing the price agreed upon by the dentist and patient.

Blockchain provide a unique opportunity to support healthcare. In this section, we purpose four scenarios: Transfer patient cases, Treatment history tracking, Sharing Dentist between clinic, Dental laboratory sharing.

Scenario1: Transfer patient cases. Some case in reality or some clinic the dentist has variety of ability to treat their patient. However, in case that very hard and need professional we can transfer to other dentist in other clinic, While the all data still sync together, and no one can delete it.

- A patient often visits multiple disconnected clinic or hospitals. Patient has to keep all data update all the time. Sometimes we can't find the data because the hospital disconnected in the system.
- Due to disconnect the system in the other hospitals or clinic, the data will unavailable on time in need, so patient have to test the result of laboratory again such as X-ray and it will add more cost in the end.

Scenario2: Treatment History Tracking. It is available to traceable patient's history that had been treat at the old clinic before

-The traceable information will include timestamp, hash number and all transaction that had been submit that involve with the unique id of patient.

-When the data can be traceable, and it can read by the participant that have authority.

Scenario3: Sharing Dentist between clinics. When we can sharing the ledger among entities such as patient dentist clinic will facilitate medication and cost management for a patient, providing and update about the prescriptions data that will improve that dentist use a proper treatment to the patient or not, from monitoring if a patient follow the transactions that dentist submit correctly it will be easier to communication between dentist and patient .Moreover in this scenario dentist can use this benefit to have a freedom to work the other clinic that has assign in the same organization.

Scenario4: Dental laboratory sharing. AS we know the dentist tools are so expensive such as X-ray machines or something for lab tools that have a high cost. So, if we can use it together it can be cut the cost that too high out and patient can discount the service charge.

IV. ACCESS CONTROL

❖ **RecHealth access control**
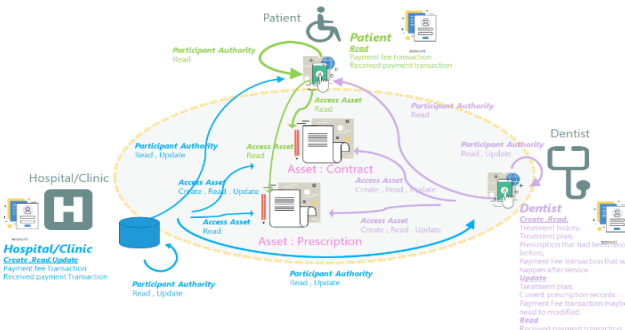
Figure 4. The Access control business network concept in RecHealth

In business network, not every participant has access to everything. In figure 4 illustrate the access control of the system as we can see at the table 1. Participant dentist can't create some transaction by them self. Access control is used to limit who had access to what and under what conditions. Under the agreement condition in the blockchain each participant will be approve each transaction that has allowed them to access or can't access the activities, which it is an immutability transaction that can tracked all of approval via the hash number in each blockchain.

Participant	Participants accessed	Assets accessed	Transaction accessed
Dentist	Dentist (RU) Patient (R)	Prescription (CRU) Contract (CRU)	Treatment Interview (CRU) Treatment Plan (CRU) Treatment Fee (RU) Treatment Received (R)
Patient	Patient (R)	Prescription(R) Contract(R)	Treatment Fee (R) Treatment Received (R)
Clinic	Patient (RU) Dentist (RU) Clinic (RU)	Prescription(R) Contract (CRU)	Treatment Fee (CRU) Treatment Received (CRU)

Table 1 Access control and limitation in each participant.

V. CASE STUDY

This section provides a case study to demonstrate the system of the proposed framework for distributed access control in the system. First, introduce the hardware and software used in the study it is very easy in to install docker and fabric in our local computer [8] and then present how the access control is implements based on the framework.

1. **Hardware**
- Lenovo Ideal pad processor Intel® Core (TM) i7-6700HQ CPU @ 2.60 GHz 2.59 GHz
- RAM 16.0 GB (15.8 GB usable)
- Ubuntu 16.04.3 LTS
2. **Software**
- Hyperledger Fabric v.1.2 [9]
- Docker version 18.06.0-ce, build 0ffa825
- Composer-playground v0.20.0
- git version 2.18.0
- node version 8.11.3
- npm version 6.3.0
- nvm version 0.33.2
- Mozilla Firefox 60.0.1
- Visual Studio code version: 1.26.0

❖ **Prototype Evaluation**

RecHealth create blockchain that manage permission to any participants. It will log every activity that happen on the system. The immutable log of medical history, which is not only comprehensive, but also accessible and credible. As we know the blockchain ledgers keeps an auditable history of medical interactions and payment between patients, dentist and clinic. Below we consider the prototype result. Below will demonstrate the traceable result of payment between patient and clinic. work flow to receive the treatment and payment.

1. Patient walk in to the clinic and she ask dentist to check up her teeth.

2. Dentist checkup her teeth and interview treatment history from the patient. The dentist will submit the transaction of *'Treatment interview'*. Patient can use the system to read this history interview log in anytime.
3. Patient and Dentist make a '*Contract*' together and then send this contract to clinic admin to key the contract asset in the system.
4. Dentist will submit the transaction *'Treatmentplan'* and records the plan of treatment in this transaction. Then dentist start to service and give a treatment to the patient. This working plan is including the dental laboratory (x-ray) and all services.
5. After patient receive the treatment from dentist patient will confirm by submit *'Transaction fee'* to confirm that she/he get the treatment from this dentist already.
6. Dentist will give the information to patient about the treatment and write the *'prescription'* in the prescription asset
7. After patient receive the service from dentist the clinic will calculate all the payment to the patient by submit the transaction *'Treatmentrecieved',* the money in account balance will transfer from patient to clinic directly.

As we will evaluate in this prototype we can see that the working flow will pass by the submission of transaction in every process will get the agreement with each participant, In the same time when participant submit the transaction the system will allow to create time stamp and Hash number in each activity or transaction that occur in the chain. We can see that to use blockchain it is appropriate for security and interoperability are need in healthcare services.

Figure 5. Account Balance in clinic before submitting, the transaction has 1,000,000 units.

Figure 6. Account Balance in clinic after submitting, the transaction has 1,042,300 units.

Figure 7. Account Balance in Patient before submitting, the transaction has 66,000,000,000 units.

Figure 8. Account Balance in Patient after submitting, the transaction has 65,999,957,700 units.

Figure 9. Asset Contract has created by agreement between patient and dentist in this picture total of the price is 42,200 units

Figure 10. Submit transaction process by clinic admin they will add the external services price here in this transaction has been add more 100 units

Figure 11. Historian record with the hash number and timestamp

Figure 12. The example of blockchain in the system it will chain from the previous block with timestamp.

As the figure 5-12 will explain in the following, in figure 5-6 demonstrate before and after of participant *clinic* submit the transaction, when the transaction has invoked it will check the condition that involve in itself and then it will send the service to ask other peer to submit if it need, then it will end the service to ordering service to distributed the validated blockchain to each peer. In this case the peer who participate in the condition that have patient and clinic we can see the figure 7-8 of participant *patient* has been discount the balance on her account balance. Figure 9 is the smart contract that we set it as an asset to be a condition for calculate and execute by figure 10. Figure 10 will include the external service prices (Dental laboratory from another clinics) after patient use the shared ecosystem from another clinics or hospitals. Figure 11 Hash number and timestamp was created after ordering service send all the validated blockchain to each peer, so we can see the Hash number in each peer that been occur the activities. Figure 12 demonstrate the other blockchain that has been occur before these activities such as the dentist submit the transaction of *Treatment Interview* and *Treatment plan* in each transaction has combined with Hash number also.

VI.   CONCLUSIONS

In this initial paper, Introduced a modular framework of Hyperledger for enterprise class. Author has selected the Hyperledger Fabric to use and develop in this prototype. The across data in healthcare service still the important thing that have to use the blockchain infrastructure helping to construct the data smartly. To realize the interest of ageing society that will happen in decades we require collaboration and standardization among entities. Not only the dentist care service but all of healthcare service that we have to consider about insecurity and data redundancy or risk from the dishonest agency provider.

Blockchain make more trust and security with the architecture is tamper-proof and resilient when compared to centralized solutions, allowing for an immutable secure and shared library of health data. As we can see in this prototype we can notice it has been show in every activity that has submit transaction will have Hash number in each transaction, so it is easy to traceable of the data and know who has been change the data before. We look forward to continued work on RecHealth project infrastructure, following the standard policy and technical components of an interoperation health IT stack. We remain committed to the principles of open source software and will release our research framework on GitHub as a platform for the further development.

VII.   FUTURE WORKS

As this prototype develop on Hyperledger composer architecture it allowed pluggable and easy to be integrating with existing systems, prioritizing open APIs [7] and network structure transparency. We are currently in the process of gathering functionality requirements and addition use-case scenarios from the other standard EHR (such as HL7 HER system) [10] for healthcare service organization, we hope to complete additional rounds of security testing include other penetration testing and a bug bounty program.

Finally, although in this prototype it designs for dental clinic at first but it also design and develop to larger project for healthcare service in the future.

VIII.   ACKNOWLEDGMENT

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