Blockchain based Online Pharmacy with Customer Privacy Protection

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Abstract

Corona 19 minimizes face-to-face contact, and online untact platforms are emerging in the medical sector. However, there are potential risks of medicine expiration, medicine misuse, and responsible materials management for secure delivery. In this paper, we investigate three key functional requirements for online pharmacy, and design the blockchain based online pharmacy to meet the requirements. To protect the patient's privacy and to ensure tamper-free traceability, we incorporate the multi-level access authentication scheme for each participant (governments, medical circles, and patients). We show that our system guarantees patient's privacy without further system modification.

1. Introduction

With the development of information and communication technologies and industries, the shopping market is actively becoming online, and hospital reservations and telemedicine becomes online in medical industry [1]. Online pharmacy refers to B2C transactions between pharmacists and medical consumers [2]. In this platform, hospital sends the prescription to pharmacy online, the pharmacy prepares a medicine per prescription, and delivers it to the medical consumer (patients) through delivery [3, 4]. Although online pharmacies have positive effects such as increased access to convenience and medical services, research into drug distribution systems is needed to compensate for risks as they can cause problems such as deterioration of medicines, misuse of medicines, and management of responsible materials for pharmacists and patients.

In this paper, we investigate the functional requirements of online pharmacies and design the full blockchain stack covering medication guidance, logistics management, and personal information protection during entire call flow. We use Hyperledger Fabric as our baseline online pharmacy system with class based authentication and proxy re-encryption scheme modifications. In section 2, we review previous works for online pharmacies and list up three key functional requirements. In section 3, we propose Hyperledger Fabric blockchain based online pharmacy system design, and conclude in section 4.

2. Background

The need for online pharmacy can be summarized in three perspectives. First, the online market is growing rapidly around the world, and consumers are seeking untact consumption due to the outbreak of the coronavirus, which began in the winter of 2019. Consumers have acquired a positive non-face-to-face consumption experience. Based on these experiences, there is a growing demand for quick and easy purchase of medicines at home, which is increasing the need for online purchase and delivery of medicines. Second, medical services are becoming increasingly digital, applying new methods such as telemedicine. Telemedicine means all activities that deliver medical information and medical services over a long distance using interactive information and communication technologies. Currently, patient has to visit the pharmacy to receive prescript drugs after conducting telemedicine at the patient's home or at the place where he/she wants treatment. To solve this contradictory situation, a new method of safely delivering medicine to the patient's location after telemedicine is needed. Third, online pharmacies are needed in that it is the emergence of a new health care system that eliminates the inefficiency of the current health care system. Currently, the pharmaceutical industry in some countries distributes medicines to pharmaceutical companies, wholesalers, hospitals and pharmacies. Due to this structure, pharmaceutical companies' sales and management costs have increased, and many wholesalers have participated in the distribution market, increasing the inefficiency in drug distribution. As these inefficiencies are reflected in drug prices, the end consumer often fails to receive adequate medical services because of high drug prices. By applying blockchain to the overall distribution process of medicines, we can create new market for drug distribution, reducing inefficient wholesale transactions and unnecessary links between hospitals and pharmaceutical companies to increase transparency in drug distribution.

V. Chordiya and M. Garge [5] suggested that online pharmacies have advantages in (1) convenience, (2) time-saving, (3) privacy and confidentiality, and (4) range of drug choices. Shraddha suggested that the advantages of online pharmacies are convenience, cost and time savings, tracking and recording data. There are four major disadvantages of online pharmacies [5]. (1) sale of counterfeit drugs or illegal

drugs (expired medicine), (2) improper self-treatment, (3) misuse of medicines because of the lack of proper safety guides information given for the patients, (4) lack of personal and financial information protection. In response, state and federal regulations through certification systems such as AMA (American Medical Association) and NABP (National Pharmaceutical and Social Commission)'s VIPPS (Internet Pharmacy Working Site Validation) were presented and advice was given to consumers using online pharmacies. There are a total of 11 certification conditions for VIPPS, and certification marks are given to online pharmacies that meet the conditions to ensure the safety of drug distribution. Pillpack and Capsule are online B2C pharmacies that connect pharmacies to consumers under the VIPPS certification system. They share the common point of sending prescriptions through mobile applications, receiving online pharmacy prescriptions, preparing drugs, and delivering medicines to places that patients want. Pillpack is a regular delivery of medicines to patients with chronic diseases. They offer delivery services that allow customers to take medication on time. In addition, if the customer needs to reissue the prescription by providing a refill service, Pillpack can contact the hospital directly and receive the prescription instead, and negotiate a price with the insurance company to provide medicine at a low price to the consumer. For similar online pharmacy capsules, patients submit a prescription to the pharmacy via the mobile app and provide a service that delivers the prescription to the patient's home or office within an hour. This aims to increase the convenience of patients by reducing the amount of time patients spend visiting or waiting for prescription drugs.

Blockchain is a decentralized method that has strengths in data sharing and integrity, and Radanović, Igor and Likicé and Robert emphasized that blockchain technology is a decentralized database, suggesting that it can be used to develop personalized medicines, streamline medical and health insurance, and improve public health policies. Blockchain technology is heavily used for data management, especially to increase the security of medical records, medical information, and electronic medical records and patient data sharing are becoming a central issue in the healthcare industry. Blockchain technology can ensure data confidentiality and illegal modifications protection thereby established a secure channel between patients and physicians by using anti-modulation and distributed storage of transactions and password-based key arrangement. Casado-Vara et al. proposed a medical history data sharing system with blockchain technology, which allows authorized medical staff to access blockchain to view and share patient records with smart devices, smart contracts, and security technologies. Tanwar et al. focus on the importance of data security in Healthcare and used blockchain for integrated and secure data. They use permission-based EHR (electronic healthcare record) sharing system utilizing the concepts of symmetric key cryptographic sharing with distributed ledger and chain code.

3. Functional Requirements of Online Pharmacy

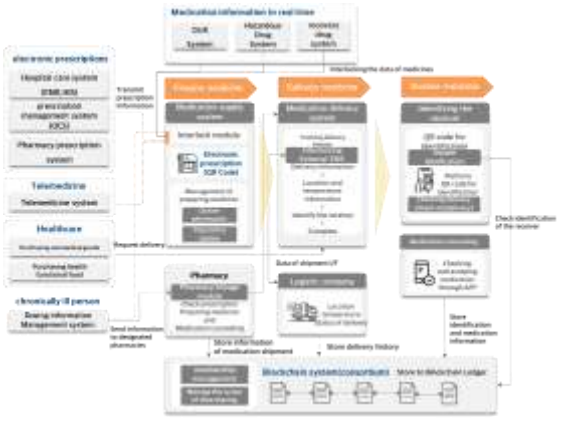
The most worrisome thing about running an online pharmacy is that drugs can be distributed on illegal online pharmacy. US VIPPS certification schemes require compliance for online pharmacies, and the UK also provides compliance with drug sales and delivery on internet. However, there is a risk of illegally operating online pharmacies without going through these certification systems or selling drugs at online pharmacies without knowing the authenticity of the drug. Because drugs are directly linked to life, many countries are increasing the stability of drug distribution with online pharmacy certification systems, but there is still a lack of ways to manage the risks that may arise from the delivery process. For secure online pharmacy, we identified three key requirements as follows. (1) **Proper medication instruction to prevent drug misuse**. It is common for pharmacists to give medication guidance verbally to patients when they purchase drugs. This is because the pharmacist communicates the dose method and precautions verbally in the face of the patient, resulting in the patient taking the medication properly. Online pharmacy Pillpack pack medicines individually and fill out medication guidance, helping patients accurately take medication and, if necessary, always talking to a counselor for 24 hours. (2) **Accountability management on each stage of logistics.** Degradation of medicines at distribution stages can cause serious side effects on patients. Because it is life-threatening and we should enforce accountability at each stage of distribution. In general, the transparency of drug distribution is enhanced by real time tracking the history of the entire distribution process until the drug is taken to the end consumer through bar codes or serial numbers. and the entities supplying to the end customers such as nursing institutions, hospitals, clinics and pharmacies do not participate, causing limitations on monitoring all stages of distribution. (3) **Personal information (privacy protection)**. Medical records are now digitized and stored as electronic records, as such, the medical industry is transforming into an IT and data-driven industry. However, it is common for a patient to receive a paper prescription after receiving medical treatment at a hospital and then submit it to a pharmacist to receive prescription drugs. In this process, there is a possible leakage of patients' personal information if the prescription is lost or exposed to others. If a patient's medical information is leaked, it can cause as much damage as a financial information leakage, so access to medical and prescription information should not be available to third parties. Therefore, medical information related to prescriptions should be shared only with direct stakeholders such as

patients, doctors and pharmacists so that it cannot be leaked to third parties. Government agencies that manage drug information and information collection agencies that are legally permitted to share insurance claims also need to increase security in personal information protection by limiting the information that can be shared and utilized according to their respective business characteristics. Therefore, each stakeholder can selectively share a patient's medical and prescription information to prevent leakage and infringement of personal information.

4. Blockchain based Privacy Protected Online Pharmacy

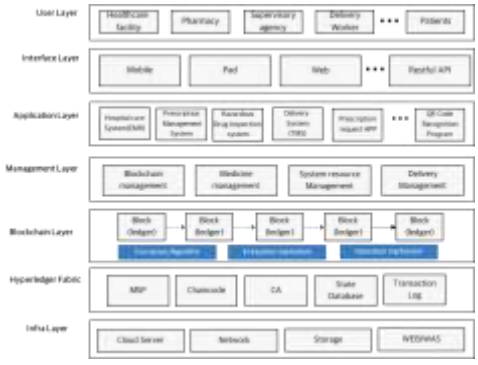
Blockchain is a technology that ensures data stability, reliability, integrity, and transparency because added transactions cannot be deleted or changed, and are reliable, auditable and immutable. Because drug distribution/medical and health information is highly sensitive personal information, it is required to a significant level of reliability and security [10]. Therefore, the application of blockchain technology is necessary to protect data. In this paper, we propose Hyperledger Fabric based online pharmacy system with privacy protection for the online patients who wants medicines for their medical prescriptions. Hyperledger fabric is not public blockchain. In public blockchain, anyone can participate because they do not require identification, but in private blockchain, only authorized participants can join the blockchain, so that private (permissioned) blockchain provides privacy and confidentiality function. Hyperledger fabric includes a set of nodes in a network, and each node should have identity to participate in the network. Thus, only certified participants can participate in the blockchain, and in online pharmaceutical systems, confidentiality of privacy can be increased by setting the scope of disclosure differently for each participant. Furthermore, efficiency and scalability can be achieved in platform operations due to faster processing speed and greater amount of data that can be processed than in public blockchain.

Fig. 1 shows the three stage of online pharmacy system: (1) medicine preparation, (2) medicine delivery, (3) medicine receipt. First, an electronic prescription is sent to the interlocking module of the medication supply system through the hospital care system, prescription management system, and pharmacy system before preparing the medication. Prescription information is also sent to the medication supply system when the patient receives telemedicine. In conjunction with the DUR system, the hazardous drug system and the recovery drug system, the system automatically checks the safety of the medication in order to verify safe medicines information in the prescription received. Afterwards, pharmacists at online pharmacies prepare medicines based on identified information, then perform medicine delivery. Second, the shipping company manages the delivery data in the blockchain during medicine delivery phase. Blockchain records the delivery history, real-time location and temperature information generated during the delivery process are stored in conjunction with external TMS, and when the medicine is delivered to the recipient, the delivery process is completed by a professional shipper checking the recipient's identity. Third, identification of patients who have applied for the purchase of the medication is carried out through an identification QR code during medicine receipt stage. The patient provides a QR code that is generated based on his or her personal information to his or her mobile device and receives the medication after identity verification.



(Figure 1) Hyperledger Fabric based online pharmacy: call flow.

As soon as it is delivered, the pharmacist delivers the medication guidance to the patient's mobile device through the server. Afterwards, when the patient confirms it, the delivery of the medication to the patient is completed. Data and transactions occurring in all of these processes are stored in the blockchain ledger in real time and are shared to participants in the blockchain to enhance transparency and traceability for all processes where medicines are delivered.



(Figure 2) Blockchain-based pharmaceutical management framework.

Fig. 2 describes the seven-layer system framework of a blockchain-based medication management system. Medical institutions, pharmacies, regulators, shippers, and patients are identified in User Layer. Infrastructure layer (hardware and operation software) includes cloud servers, networks, storage, and WEB/WAS. Hyperledger (consortium) layer includes MSP, chain code, CA, state database, and transaction logs. This layer guarantees that only authorized participants participate in the network. Blockchain layer performs

fundamental blockchain operations such as data block generation for real time pharmacy transactions with consensus algorithm to ensure persistence. Management layer manages blockchain networks and system resources (mainly third-party systems linked to system support management). Application layer includes medical system, medication prescription system, hazardous drug testing system, drug delivery system, and QR code application that checks the receipt of the medication. Interface layer connects devices and devices compatible with mobile devices, pads, websites, etc.

In the hyperledger fabric layer, information access can be set differently for each participant. As shown in Table 1, information on the platform can be divided into personal information, identity information, prescription information, medication order information, delivery information, and purchase history. Users and platform participants have different rights to access information, so they only have access to the information they need. Users of the platform have access to all information, but pharmacies and hospitals should have access to the information needed for prescription, identification and prescription information, and government departments and insurers have limited access to information that does not require shipping and purchasing information. As for the delivery company, only the recipient's personal information and delivery history is accessible, and for the platform operator, sensitive personal information such as identity and prescription information are restricted, and only the information necessary for platform operation is accessible. By applying Hyperledger Fabric to the online platform, each participant can only access necessary information, thus protecting users' personal information and enhancing security.

<Table 1> Information access rights matrix.

	Personal	Identity	Prescription	drugs order	Delivery	Purchasing
Patient	Accessible	Accessible	Accessible	Accessible	Accessible	Accessible
Platform operator	Accessible	Inaccessible	Inaccessible	Accessible	Accessible	Accessible
Pharm-acy	Accessible	Accessible	Accessible	Inaccessible	Accessible	Inaccessible
Hospital	Accessible	Accessible	Accessible	Inaccessible	Inaccessible	Inaccessible
Government	Inaccessible	Accessible	Accessible	Inaccessible	Inaccessible	Inaccessible
Insura-nce company	Inaccessible	Accessible	Accessible	Inaccessible	Inaccessible	Inaccessible
Logistic	Accessible	Inaccessible	Inaccessible	Inaccessible	Accessible	Inaccessible

Blockchain has been emerging as a way to protect data sovereignty. With blockchain, data is decentralized and shared with the blockchain participants through a consensus algorithm to ensure stability and interoperability. Since online drug distribution handles the most important data of individuals, information protection needs to be ensured using the distributed ledger technology of blockchain. Data sovereignty can be guaranteed by enabling an individual to directly manage one's own medical information as the data owner through the online pharmacy platform. Identity authentication server uses the user identification information stored in the blockchain repository to allow that user access to the system. In addition, patient-specific authentication codes are generated for confirmation of drug receipt and stored distributed in the blockchain repository as user identification. The authentication code is then received from the shipper's terminal and the authentication process for that authentication code is carried out. Medication guidance server provides medication guidance to patients when they receive medication from patients who have ordered the medication. That is, when the certification of the medication recipient by the identity authentication server is completed, medication guidance is carried out for that recipient.

5. Conclusion

As medical services digitized (e.g. telemedicine and health care through wearable devices), there are more demand on online medical supply chain. However, online pharmacy has the risk of illegal drug distribution and incorrect delivery. Nationwide certification systems are also required for online pharmacy operation, and we propose blockchain based online pharmacy to meet the requirement, increasing the accessibility and convenience. In this paper, we proposed online pharmacy system with privacy protection using different access right assignment for each participating entity. We implemented online pharmacy system using Hyperledger Fabric (permissioned private blockchain) to support privacy preserving for patients who wants secure delivery of their prescription medicine. In addition, each transaction generated during the drug distribution process was encrypted in the blockchain and stored at time stamp, making it impossible to tamper with the data, thus providing a system for ensuring traceability and transparency of transactions.

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