Implementating Cross-Enterprise Document Sharing (XDS.b) based on Blockchain Technology

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*Healthcare information sharing and interoperability between healthcare organizations are important factors to healthcare quality and safety since a patient may consult more than one specialist. Many challenges inhibit successful data sharing such as data integrity, security and privacy. Integrating Healthcare Enterprise (IHE) provides Cross-Enterprise Document Sharing (XDS.b) profile that allows the adopted organizations to share health documents between institutions. Security issues were not a focal point at the time of its inception. Healthcare domain has become a major target in emerging cyber-security threats. These threats increase difficulty to maintain secured health information sharing network. These cyberthreats can compromise integrity and availability of data and effect patient’s life. Blockchain technology can be used to solve health information sharing issues. A novel method using Blockchain technology to ensure health information integrity and availability is demonstrated, allowing health document sharing through decentralized network while addressing cyber-security issues through unique characteristics of Blockchain technology.*

Keywords—health information, interoperability, information sharing, information security, blockchain, smart contract, ihe, xds

# Introduction

On the increasing demand for better quality of healthcare services, operation efficiency pays important roles in patient services and economic outcomes. Healthcare information sharing and interoperability between healthcare organizations are one of major solutions to improve healthcare service quality. Patient’s health documents are scattered across different healthcare organizations, due to adoption of specialized healthcare informatics systems deployed by different organizations. Each healthcare organization has their own methods, processes, and workflow to handle healthcare information. This makes it hard for one health information system to interoperate with one another. Sharing health information with not fully trusted party exposing vulnerabilities to patients, business, and organization. The risk-reward ratio from sharing patients’ information with other may not be worthwhile if it were done improperly. This create high friction for one organization to share their information with others. It even more difficult for individual patient to integrate and share their health information between different providers. It revealed that these interoperation problems cause huge decrease in efficiency on healthcare operation and result as lower quality of healthcare service [1]–[8]. Therefore, there are many initiatives that start to standardize healthcare information technology with the goal to allow healthcare organizations to be able to exchange patients’ information with each other. In this work we propose a solution that can solve data integrity and availability issues and reduce the friction of allowing health document sharing between different enterprises. By applying Blockchain technology on the Cross-Enterprise Document Sharing (XDS.b) Profile created by Integrating Healthcare Enterprise (IHE) initiative.

As well as the issue regarding health information sharing between different enterprise, there are also emerging cyber-security threats that threatening healthcare domain. There are many incidents report that hospital hit by ransomware gave medical operation disruption as result in several recent years [9]–[11]. Many cases show that failing on secure integrity and availability of healthcare information cause a major disruptive factor on continuity of medical operation. [12] Assumed that organization policy and employee security awareness about cyber-security were addressed, there are several technics proposed to mitigate the problem. One of major solution being propose is utilization of Blockchain technology on healthcare information or its infrastructure. Cryptographical components and consensus mechanism of Blockchain will give immutable characteristic and secure integrity of the information, while decentralization of published data help secures its availability [13]–[16]. However, due to unique nature of healthcare environment that emphasize on confidentiality of data cause limit in implementation of the technology. Patient data cannot be put directly into Blockchain as it will become persistent by decentralization of Blockchain network as well as it will become more difficult to ensure confidentiality of data when its replica are distributed over the entire network [17]–[19]. So, in this work we propose another approach to make the technology more compatible with implementation on healthcare information. With IHE XDS.b Profile serve its purpose as central hub for health document exchange between different enterprises while not include the document directly into the hub. This make the profile best compatible with Blockchain technology as it will secure availability of health information exchange while increase the survival chance of medical operation continuity when one organization compromised by ransomware as they may have replica of data available on another in the network.

According to [18], Blockchain can be informally defined as a distributed digital ledger of cryptographically signed transactions that are grouped into blocks. Each block is cryptographically linked to the previous one (making it tamper evident) after validation and undergoing a consensus decision. As new blocks are added, older blocks become more difficult to modify (creating tamper resistance). New blocks are replicated across copies of the ledger within the network, and any conflicts are resolved automatically using established rules. This give its characteristics to sustain threat against integrity and availability of information. At the same time, with consensus as vital part of Blockchain, it allows members of Blockchain network to systematically “trusted” each other without the need of mutuality trust or physical agreement. Additionally, as distributed decentralized network, Blockchain require each member to passively share information with each other. By the way, since the introduction of the first Blockchain based cryptocurrency named ‘Bitcoin’, there are many Blockchain platform and service provider entered the industry. One of major platform adopt by many kinds of application is Ethereum. Ethereum was the first major platform that introduce usage of Blockchain in the field of application other than cryptocurrency with its ‘Smartcontract’. Smartcontract allow developer to publish logic model or computational algorithm into Blockchain which enable a while variety of usage for the technology [21], [22]. So, in this work, we also utilize Ethereum’s smartcontract to enable implementation of IHE XDS.b Profile concept with Blockchain.

This paper will explain about our work in 6 main sections. Begin with the explanation about related work that inspire our design, following with background knowledge which our work is based on. Then we move into the detail of design method before dive into implementation technic for concept demonstration. At last, wrap up the concept propose in this work and end with discussion for this work.

# RELATED WORK

## A Blockchain-Based Approach to Health Information Exchange Networks [23]

Kevin Peterson et al. from Mayo Clinic have proposed the concept that using Blockchain as a medium for health information exchange network. The work utilizes Fast Healthcare Interoperability Resources (FHIR) protocol as a gateway which allow members of the network to access health information from each other, while ensure distribution of accessibility within the network by published those gateways to Blockchain. Every activity on the network will be recorded on the Blockchain providing audit trail for the network. They proposed several concept ideas about using computational resource within Blockchain network in the more meaningful way contribute to healthcare environment. Additionally, the work also included several suggestions about Blockchain component that may provide more compatibility of the technology for healthcare information environment. In this work, we adopt the idea of using Blockchain as a medium for health information exchange network and several suggestions provided, that should make Blockchain technology more compatible with healthcare information environment.

## “MedRec” prototype for electronic health records and medical research data [24]

MedRec was proposed as a prototype for electronic health records by utilize Ethereum’s smartcontract to contain metadata about the record ownership, permissions and data integrity represent existing medical records that are stored within individual nodes on the network. The concept will help reduce barriers to effective data sharing addressing interoperability issue caused by economic incentives that encourage “health information blocking”. At the same time, their proposal also benefits as the source of medical research data, by providing anonymized healthcare data for research institution in the form of Blockchain participation reward. Their Blockchain implementation focus on addressing four major issues for health information exchange included: fragmented data which also slow access to medical data, system interoperability, patient agency, and improved data quality and quantity for medical research. Additionally, as MedRec was built on the work of Zyskind et al.[25], they also utilize some cryptographical characteristics of Blockchain to provide accessible “bread crumb trail” which allow data user to trace back medical history to improve operation efficiency. From MedRec, we adopt the concept of using Ethereum’s smartcontract to contain essential information that allow ability to discover data within Blockchain network.

# BACKGROUND KNOWLEDGE

## Cross-Enterprise Document Sharing (XDS.b) Profile from Integrating Healthcare Enterprise initiative (IHE)

Modern medical operation has large amount of healthcare information flow within the system. Throughout the age, many medical provider services and organizations have developed their own health information system and database to increase efficiency of operation in their medical services. As the time past, information of individual patients has scattered amongst different systems. This become new challenge for healthcare enterprise to further enhance their medical service efficiency by sharing health information with other systems within healthcare industry domain

IHE is an initiative by healthcare professionals and industry to improve the way health information systems in healthcare share information. IHE promotes the coordinated use of established standards such as HL7 and DICOM to address specific clinical needs in support of optimal patient care. Systems developed in accordance with IHE communicate with one another better, are easier to implement, and enable care providers to use information more effectively. This helps enable seamless and secure access to health information that is usable whenever and wherever needed. An IHE profile provides use of existing standards, specifications, tools, and services for interoperability. IHE also engages clinicians, health authorities, industries, and users to develop, test, and implement standards-based solutions to vital health information needs. [26] IHE provides convenient and reliable way of specifying a level of compliance to standards enough to successfully reach efficient interoperability.

Amongst many profiles created by IHE, there is one major profile that serve to improve efficiency of health information sharing between different enterprises called “Cross-Enterprise Document Sharing Profile (XDS.b)” [27]. The main goal of XDS.b profile is to allow enterprises that being a member of health document sharing network (called “XDS Affinity Domain”) to discover shared health document stored in the system of other enterprise via central registry (named “XDS Document Registry”). The XDS Document Registry register set of META-data attributes belong to each health documents to allow health information system to discover existing health document that stored within other organizations and able to systematically access the document using the information provided by META-data attributes. By specified format of transactions and method for each system to communicate with each other, XDS.b make sure that all the systems within the network can communicate with each other in the same way. This allow document consumer and user in the network to share health document with each other and put it to use as needed efficiently.

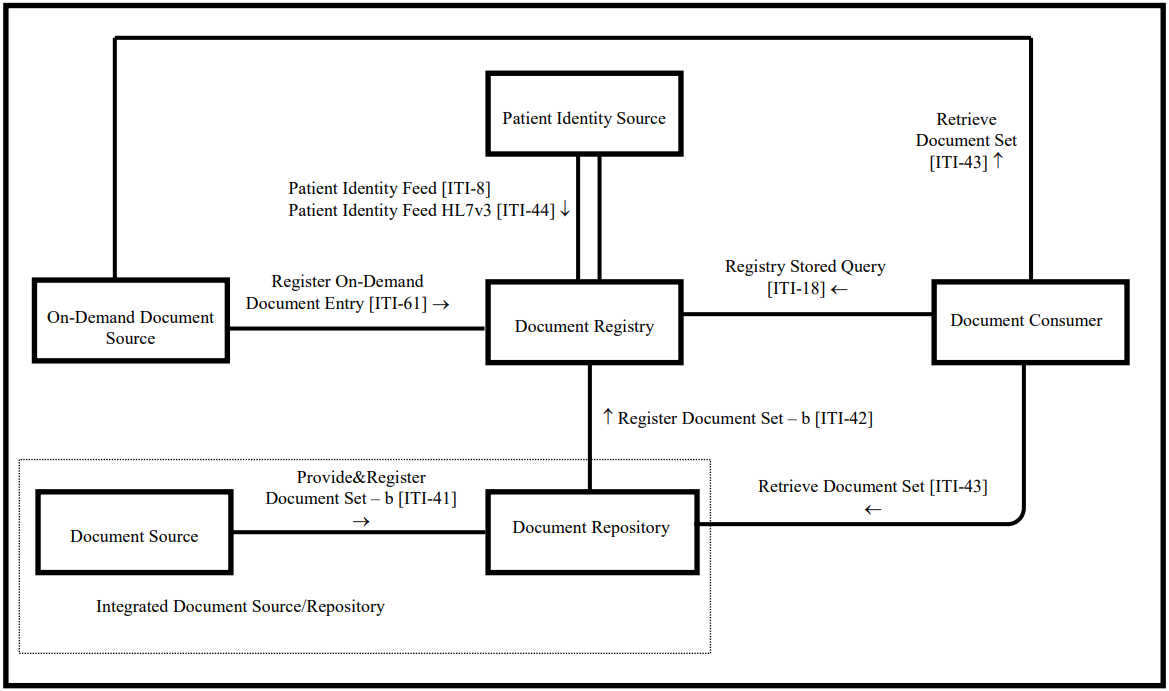


Figure 1 Cross-Enterprise Document Sharing – b (XDS.b) [27]

## Blockchain Technology

Blockchain technology is a method that applied cryptographical technics to locally ensure integrity of data while rely on decentralization and consensus mechanism to ensure integrity and availability of all data existing in the network. These cryptographical technic included the one that form ‘Block’ and another one that form ‘Chain’. In Blockchain, those data being published are small fragment of information that represent proof of action in its own application. Therefore, it was called ‘transaction’. A set of transactions approach Blockchain network at the same period will be hashed together imagine like put these transactions into the same box and named each of it with its hash value, formed a ‘Block’. Additionally, the hash value of each block also includes hash value of previously generated block cause formation of a ‘Chain’. Any attempt to modify content of published block will cause change in hash value of entire chain trigger rejection from the network. These two technics form together to become ‘Blockchain’ which prevent modification of published content and ensure integrity of data. The technology also relies on ‘decentralization’ of data where copy of entire chain was kept by many participants of the network called ‘node’. Combined with consensus mechanism, the mechanism that invented to ensure that no one in the network can freely attempt to modify content published inside Blockchain while select a trustable node who will verify certain Block being publish to the Chain. Some consensus like Proof of Work (PoW), require participant nodes (called ‘miner’) who want to verify a Block to compete to solve mathematic puzzle. The winner will be able to verify Block and get reward based on each network. As the puzzle require each node to spend huge amount of computational resource, give randomness which make it nearly impossible for miner node to verify prefer Block. On the other hand, some consensus mechanism like Practical-Byzantine False Tolerance (PBFT), invented to allow Blockchain network with limited computational resource to select trustable validator. Instead of relying on computational resource, this kind of consensus use voting mechanism which sacrifice ability to welcome anonymous node into the network while rely on the environment that most of the nodes are not corrupted. This enable the mechanism to create a passive ‘trust’ amongst the network as no one in the network have absolute right to rules and manipulate the network and its content at their own will, while they can entrust their transaction into the chain. [20]

## Ethereum and smartcontract

Ethereum are one of well-known open source Blockchain platform. The platform initially invented by a developer named Vitalik Buterin and further developed by Ethereum community. Main approach of Ethereum Blockchain is about using Blockchain technology for applications other than cryptocurrency. The platform proposed concept about ‘smart contract’. [21], [22] Smartcontract allow developer to integrate their small size of computation algorithm or snippet of logic into Blockchain. This give Blockchain characteristics [*Ref.*] to those code. Enable wide variety of applications to work with Blockchain. The concept of smartcontract later adopted by other Blockchain platform, created infinite possibilities of Blockchain application suitable with variety of computational environment and usage. While each Blockchain platforms have their own technical method for implementation, Ethereum’s smartcontract rely on Javascript-like language called ‘Solidity’. The language invented to allow codification of human-understandable logic into programming language format understandable by ‘Ethereum Virtual Machine (EVM)’ named ‘JSON-RPC’. EVM represent a computational resource that shared amongst Ethereum network which allow machines with different environment to interact with Ethereum Blockchain without the need for specific computational environment or hardware. This allow Ethereum network to formed by wide variety of machines with different operation system and internal environment. At the same time, Ethereum Blockchain can adopt variety of consensus mechanism. The main Ethereum Blockchain initially adopted PoW. Due to limitation as it requires huge amount of computational resource to stay active, Ethereum network later forked the Blockchain line into several chain lines with different consensus. i.e. Proof of Stake and PBFT which adopt voting-like mechanism to allow reduction of computational resources consumption. As time passed, with Ethereum community keep growing, now there are wide variety of consensus mechanism proposed to suit with different application and network environment.

# METHOD

This section describes a method of how the Blockchain was designed to operate under IHE XDS.b profile process flow. The first part introduces about architecture design and roughly defines how we integrate Blockchain components into IHE XDS.b profile process flow. The second part explains the first part further into the aspect of Blockchain components. This part focuses more on how we adopt and setup existing Blockchain platform to match our requirement for usage in our scenario. The last part further explains the first part in term of integrating IHE XDS.b profile with Blockchain. This part focuses on how we create and adapt each component in our work to meet the requirement specified by IHE XDS.b profile.

## Design Scenario (A Use Case?)

User at Hospital (A) need to start with specifying value corresponding to XDS META-data attributes (Patient name, ID, etc.) that unique to Mr.Bob and use it to search for associated registry using Document Registry Searcher program. Document Registry Searcher uses specified values to find for registered META-data attributes set in smartcontract. When matched, Document Registry Searcher returns the whole META-data attributes set of those matched one to the user at Hospital (A). In this case, it may return more than one registry set that associated with Mr.Bob. User at Hospital (A) may need to seek for the one with latest timestamp or the one they needed to use. When the registry set was picked, they may need to use repository URI included in META-data attributes set to request for actual document in Hospital (B). After that, Hospital (B) will response by allow Hospital (A) to access content of the document.

## Architecture Design

A requirement that needs to be setup to meet our scenario included type of Blockchain network, who is Blockchain participant node, and consensus which allow trustless publishing of block into the Blockchain ledger. In our scenario, we declare that participant node is machine hosted by members of XDS Affinity Domain which assume to be each hospital. Each Blockchain participant node will take the main role as XDS Document Registry actor which will maintain Blockchain ledger where document registry entry is kept. As the Blockchain allows only XDS Affinity Domain members to participate as node, this make the Blockchain type classified as permissioned chain. For consensus, it may need to be the consensus that can process large amount of Blockchain transaction at certain time due to continuous nature of medical operation. Smartcontract will be the main component that takes the role to keep all set of META-data attributes separated by each document, within Blockchain ledger. When Document Registry Searcher program was triggered by document user, the Searcher will perform iteration search on all META-data attributes set existing on the chain. All matched set will return to document user as list for the user to pick the one they needed. After the user picked the set they needed, user-side program will trigger smartcontract to return the whole set of META-data attributes of the selected set. Eventually, user-side program will use retrieved META-data attributes and repository URI to access actual document in its repository in hosting hospital.

# IMPLEMENTATION

This section will focus on technical explanation on concept implementation. The first part introduces about XDS Toolkit which is the source of XDS transaction sample for our implementation and act as validation tool to verify if our implementation complies to XDS.b profile. The second part will explain about technical setup of Blockchain platform for our implementation. The third part describes implementation of software that acts as component to integrate Blockchain to XDS.b process flow. This software behaves as the middle between function of XDS Document Registry actor and function as Ethereum Blockchain node. The last part will explain behavior of smart contract that we designed in technical aspect.

## XDS Toolkit

XDS Toolkit was provided by United States National Institute of Standards and Technology (NIST) [40]. The toolkit was developed to allow developers to test their software if it complies with IHE XDS.b profile and can communicate with other system. XDS Toolkit provide many tools that can send sample XDS transactions to specific location and wait for proper respond defined in XDS.b profile. These tools came in variant depend on what type of XDS actor that the testing software is.

## Blockchain Setup for Implementation

To directly command behavior of each Blockchain node, we require Geth client which allows user to issue command to the node like start-stop mining and start sync Blockchain data with other node. For programming smart contract, Ethereum providing IDE for Solidity language that can compile and deploy smart contract to local Ethereum node. To interface our program to Ethereum smart contract, we can use Ethereum API tools like Web3js [38] as a middle. Web3js allows smart contract control through Javascript language and transition variable from Javascript to Solidity. Then, Blockchain platform is ready for smart contract design and implementation of XDS.b profile.

## XDS Document Registry Actor

In the implementation of this work, XDS Document Registry actor will be the main actor that will be converted from using common database to use Blockchain ledger to keep associated data. The software program must be able to communicate with XDS Document Repository actor and XDS Document Consumer actor. At the same time, the software will need to act as the middle between XDS system and Blockchain. Then, Blockchain platform is ready for smart contract design and implementation of XDS.b profile.

## Document Registry Smart Contract

Smartcontract was developed to store any kind of programming algorithm. So, we design smart contract which when executed, it will spawn smart contract that store given document META-data attributes value within number labeled smartcontract instances which encoded in Blockchain transaction. When these instances were called, it will return the stored metadata attributes value back. Allow the search program to identify the set. At the same time, this allow document registry to store within Ethereum Blockchain. These composed to function as Document Registry Smart Contract.

# Conclusion

# discussion

This work proposed the idea about implementing IHE XDS.b profile based on Blockchain technology in the goal to allow health document sharing between enterprises while reduce the friction that prevents the scenario to make it to reality by addressing “trust” issue with Blockchain. And with Blockchain implemented, it also helps increase sustainability of health information network against cyber-attacks. For example, in the case that some hospital may be hit by ransomware and lose access to health documents, this proposed Blockchain concept may assist in retrieving lost documents from other network members who share the documents. However, there still several challenges about privacy of patient information that may need to be addressed depend on the organization adopting this concept.

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