Droice Labs

# Blockchain Technology
## for Private Health Information Interoperability

## Abstract

Healthcare industry generates terabytes of data every day. Far from state-of-the-art, our health is tracked, diagnosed and treated without utilizing cutting edge technologies we have at our disposal — technologies that are disrupting other industries. Blockchain is one of such technologies that has gained momentum in many other fields by being an extremely secure and scalable solution to address data privacy and shareability concerns. For healthcare, blockchain has the potential to offer significant cost savings and efficiency gains — something the industry has been craving for. From robust interoperable health records to insights into medication adherence, addition of blockchain can substantially create new value and enhance health-related experiences.

This paper talks about how this technology can be leveraged to create a more patient-centric healthcare system facilitating easier, more efficient and more secure interoperability that could reshape our medical experience. Its first chapter gives the necessary background into healthcare industry technology- and data-related challenges providing review of the current trends, legislation pushes and standards in development. The second chapter introduces the concept of blockchain and reviews relevant implementation case studies in healthcare field. The third chapter describes the concept of this proposal — blockchain-based communication protocol for easy, efficient and extra secure private health information transfer that engages healthcare providers, insurance companies and patients and facilitates electronic health record interoperability at an entirely new level. Finally, the paper provides discussion for the proposed methods giving pros, cons and possible limitations of this approach.

## Introduction

Healthcare is one of the industries, which quality, efficiency and sustainability have tremendous impact on economic, social, political and other crucial aspects of the USA well-being and sustainable growth. Healthcare requires progress probably more than any other industry. A lot of attempts are done to facilitate this progress in a safe and reliable manner, since the cost of failure in this industry is extra high.

One of such attempts is seen in the health IT arena with the Medicare Access and CHIP Reauthorization Act of 2015 [6], generally referred as MACRA. One of the core purposes of the act is to facilitate and push healthcare providers and professionals to increase quality of care and efficiency of their services incentivizing use of advanced technology that utilizes electronic health records (EHR) data. These requirements are aggregated in the Merit-based Incentive Payment System, or MIPS, which is an integral part of MACRA and essentially incorporates the Meaningful Use (MU) Stage 3 requirements into MACRA itself.

MU Stage 3 Incentive programs are grouped into *8 main objectives* [17] for eligible professionals (EPs) and eligible hospitals (EHs), which include protecting patient health information, providing patients electronic access to their health information, coordinating care through patient engagement, enhancing health information exchange and number of other patient-centric goals. Needless to say, more than 60 percent of the proposed measures require interoperability [7], and numerous attempts are made to bring improvements to existing healthcare resource interoperability setup.

Further we provide an outline of the MU Stage 3 requirements that are targeted and sought to be enhanced with the blockchain-based proposal within this paper.

**Patient-facing EHR functions:**

- Patient access to information. There are 2 measures [12] [6]:
    1. 80% of patients must be able to access their records either through View/Download/Transmit function or through an ONC-certified API;
    2. 35% of patients must be given access to patient specific educational resources. This objective requires that access is provided to patients.
- Active Patient Engagement. There are 3 measures [12] [6]:
    1. 25% of patients must access their records either through View/Download/Transmit protocols or through an ONC-certified API that can be used by third-party applications to provide patients access with 24 hours of its availability to the provider;
    2. 35% of patients must be able to receive clinically relevant secure messages;

3. provider must incorporate information from patients / non-clinical settings for 15% of patients. These measures do require patient's action, and the most challenging measure will be the last one, which requires patient-generated data.

The MU Stage 3 rule give patients a high priority by making patients better custodians of their own care [17], the MU and certification give a large boost to those efforts. It can specifically be explained by Objective 5, which emphasizes on the following [6]:

i) Timely access of patients to their full health record and engage in patient-centered communication for care planning and coordination.

ii) Specifically, an additional functionality known as Application Programming Interfaces (API), which would allow providers to enable new functionalities to support data access and patient exchange.

iii) APIs may be enabled by a provider or provider organization to provide the patient with access to their health information through a third-party application with more flexibility than is often found in many current "patient portals. Patients could collect their health information from multiple providers and potentially incorporate all of their health information into a single portal, application, program, or other software.

**Interoperability:** It majorly talks about health information exchange and pubic health and clinical data registry reporting. Measures include [6] facilitating data exchange between laboratories and hospitals, multiple healthcare provider units and between healthcare providers and health insurance companies [12]. Hospitals are responsible for delivering improvements in interoperability and they are seeking for convenient, cost-efficient solutions that address these goals.

## Healthcare trends

We are at a critical point of convergence of technology, policy and demand to change the way we access and share health information. To achieve improvement, it is crucial to make health information available when and where it matters most to patients. Now that the EHR infrastructure is in place, the industry is getting ready for the next phase of information sharing, improving patient outcomes and collecting digital dividend.

Upcoming years are set to see a rise in patient engagement where they are able to easily deliver records to appropriate parties; thus, enabling them to take control of their health and care delivery. Provider willingness [5] to permit patient engagement is also set to increase across the country. In addition, electronic access is also estimated to propel an increase of patient-facing applications. Standards such as FHIR (Fast Healthcare Interoperability Resources) [11] for exchanging healthcare information electronically are intended to address most common interoperability needs of implementers [20] and provide solutions for many real world problems.

Another step towards higher patient engagement is telemedicine [3], a bidirectional communication via a virtual platform between a patient and a healthcare provider. The usage of telemedicine is up to 50% since 2013 with nearly 15 million people using such services in 2015. The facts [2] show the following:

- *Legislation*: To date, 29 states are legislating that commercial insurers cover telemedicine and 8 more laws are proposed in 2016.
- *Technology advancements*: 32% of consumers have at least 1 health app on their phone (from 16% in 2013).
- *Medicaid Coverage*: 86% of states cover telemedicine services state wise.
- *Employer Adoption*: 35% of employer onsite health centers offer telemedicine and 12% plan to offer in the next 2 years.
- *Older Adults*: 53% of the 59% of adults 65+ who use the Internet say health information is their top motivation for getting online.

All these facts provide evidence that citizens are becoming familiar with the very concept of taking ownership over their private health information and EHRs, and both technological advancements and governmental regulations facilitate this progress.

## Blockchain Technology and Its Applications

Blockchain is a technology that was developed as one of the main components of Bitcoin cryptocurrency [21] and served the main purpose of maintaining public, though immutable and secure ledger [19] of all the bitcoin transactions that ever existed.

Blockchain is a distributed, tamper-proof data structure acting as a public ledger of time-stamped transactions. It provides a method [3] for establishing the existence of a transaction at a particular time that can be independently verified by any interested party. When someone wishes to add to it, participants in the network – all of whom have copies of the existing blockchain – run algorithms to evaluate and verify the proposed action. Once the majority of "nodes" confirm that a transaction is valid, i.e. matches the blockchain history, the new transaction is approved and added to the chain. Once a block of data is recorded on a blockchain ledger it is extremely difficult to change or remove it, as doing so would require changing the record on many thousands of machines worldwide. This prevents tampering or future revision of a submitted time-stamped record.

In a blockchain-based network, any user can read and write data. It is not controlled by a single entity and it is accessible by every user. A general blockchain features a decentralized database, cryptographic signatures and trusted time-stamping. Regarding the current needs of healthcare IT provision described above, these core features make blockchain a very attractive concept to address issues of interoperability and patient engagement in the current setup.

With the percentage of US hospitals using digital records [5] increasing from 9.4% to 75.5% between 2008 and 2014, the benefits of electronic medical health records are broadly accepted to add value to patient care. Centralization of healthcare data makes it more vulnerable to security breaches as a single breach event can compromise millions of patients' data privacy. On the other hand, by tightening the security [9] around this central server, it becomes almost impossible for patients to get access to their data in a realistic manner.

Blockchain technology [16] has the potential to address the concerns regarding access, security, scalability and privacy of such electronic medical records. The technology being more tamper-proof and time-stamped can create a platform for all the different stakeholders in the healthcare system to collaborate in creating a patient-centric model that secures clinical data in order to use the verified data to the fullest for the benefit of the stakeholders. This concept is the underlying element of the proposal presented in this paper, however before moving to its detailed description we review the most notable concepts of blockchain implementation in the healthcare industry. The following case studies provide relevant insight in how blockchain can address and improve problems and needs in healthcare described in the first part of the paper.

## Interoperability & Transparency

Blockchains applied to healthcare can solve the global interoperability challenge [20] of electronic medical records and improve data flow between disparate systems. A tool that is built for interoperability by design, blockchains are essentially a protocol layer [23], like TCP/IP for the internet. It can thus be a completely open source, like a language that all of the companies that are participating, agree to speak in order to be able to interoperate with each other. The transparency and trust among the participants is increased while creating a more patient-centric healthcare system.

**Study:** Following is a real world instance of usage of blockchain network for developing applications and shared infrastructure.

A network of developing applications and shared infrastructure for healthcare powered by ethereum blockchain has been launched by Gem [9], a provider of enterprise blockchain solutions, launched ***Gem Health***. The company [13] intends to leverage blockchain technology to address the trade-off between patient centric care and operational efficiency by creating a healthcare ecosystem connected to universal data infrastructure. They use this shared infrastructure to create global data standards without compromising privacy and security.

The Gem Health blockchain network includes identity schemas, data storage, and smart contract applications that are executed on a shared data infrastructure. Using the Gem Health network, different healthcare operators can access the same information, which will permit the development of a new class of blockchain-based applications that will unlock wasted resources and solve important operational problems in healthcare.

The firm [24] uses blockchain-enabled data sharing with guaranteed data integrity, to build a global repository of data within the healthcare and other industries, which each party can trust reliably. Moving away from a concentrated medium, the firm uses blockchain technology to focus on sharing the same data transparently. In particular, they believe that blockchains will permit creating a robust and resilient healthcare ecosystem with industry-wide workflows involving data moving around among multiple parties. The firm has received early support from a major operator Philips Healthcare, for its implementation of blockchain technology. This serves as a strong evidence that the industry sees potential in the blockchain technology and its key players are exploring ways to bring it to the market.

### Patient-Centricity & Security

A lot of sensitive information is associated with health: identity, diseases, treatments, payment, etc. Individual health condition is one of the most private things a person can have, yet again and again, data breaches release considerable amounts of this extremely sensitive information on the web.

Here are two examples of large-scale breaches:

- *Anthem:* 80 million patient and employee records leaked
- *UCLA Health:* 4.5 million patients leaked

In each of these cases [9], a single point of failure enabled data breach. Blockchains, designed as a new type of security model for critical data can help prevent this with multiple checkpoints, multisignatures and cryptography. The data is hashed onto the blockchain and then, using multisignatures, people can gain access only if there is approval from the appropriate number of people. Using this technology, there could be a rule that for patient records to be accessed, the doctor, nurse and patient must all approve; or, for example, 2 out of 3 people/involved parties have to approve the access request.

A blockchain can then be used to permanently record network activity, which users can index or append based on access rights defined by the identity framework. ***Factom*** and ***Health Nautica*** are looking to secure medical records and audit trails by encrypting the data with a timestamp to verify its accuracy [10]. As a foundation of Bitcoin, blockchain has already been put through its paces as a secure method of conducting very private transactions.

**Study:** Following is a conceptual example of an attempt to use blockchains to create a forward-thinking EHR solution, providing tools for patient-centered, patient-managed care by maintaining the privacy and ensuring security of the patient data.

***My Health in Real Life (myHealthIRL.com, myHIRL***) [13] is a decentralized application, where individuals can maintain and control their own health records and then share them with healthcare providers or any other collaborators they choose. The myHealthIRL tools facilitate this form of collaboration. Patients can find their collaborators anywhere in the world and have an online consultation. The collaborators may include: nurses, doctors, nutritionists, chiropractors, friends or any other individual with similar issues/goals. From these collaborations, an individual can gain insights about which therapies have the most effective outcomes and create a global set of health data for the use by researchers and individuals.

The myHealthIRL wallet can bring control back to the individual and facilitate a more proactive approach to health by:

- Allowing health data of any type to be stored by the individual.
- Collecting data from social tools and smart divides and automatically adding this data to the wallet.
- Providing functionality for an individual to find a healthcare provider and pay for services such as online consultation.
- Enabling the sharing of health records.
- Allowing keeping track of medication and therapies, displaying tests and scans, requesting support and service and creating an overall picture of patients’ health.

**Other applications**

Even though the benefits of creating and maintaining electronic medical records of patients has been established, the exorbitant cost of managing and maintaining the system has put many hospitals off from implementing it. Blockchains [7], used to maintain medical records and patient generated data can address this issue. The technology also has its implications on population health management as well where it could help payers create risk adjustment strategies that are tailored to a patient’s unique health status. If the blockchain could help payers address the privacy and security concerns of developing an individualized take on the financial side of population health management, it could help to alleviate some of the major criticisms [10] leveled at the Affordable Care Act and its subsidy framework.

## Methods for Blockchain-based Interoperability Concept

As demonstrated above, blockchain provides very compelling answers to primary healthcare issues such as interoperability, private health information security and interoperability of private data.

The concept that we propose is ***a centralized platform that decentralizes health data** [18]* ***(medical records) increasing security of sensitive information.*** Patients can now use their own signature, combined with that of a hospital signature to unlock data to provide more secure access to medical information for use in treatment. The patient by using their profile has ***full control of their medical information*** and ***can select the information shared and viewed by providers or doctors***. This model lifts the costly burden of maintaining of patient's medical histories away from the hospitals: eventually cost savings will make it full cycle back to the patient receiving care.

The following sections talk about the implementation of blockchain features towards utilizing the potential areas of improvement in the healthcare industry that were emphasized above: patient access to the private health information, active patient engagement in healthcare process, easy interoperability of the private health information and robust and reliable security of such data sharing and communicating through the network.

**Asymmetric Key Encryption**

Every individual node on the blockchain [1] is uniquely identifiable by a public key which is part of a public/private Key pair that is generated when the node is added to the blockchain. This public key acts as the address to which information is sent after encryption. This information can be viewed only with the private key of the owner. If data is to be shared between two entities over the blockchain the data is encrypted by the sender's private key and the receiver's public key. This would actually provide confidentiality and integrity of the data while making it invulnerable during transmission. This ensures that data is never in decrypted form except when at the endpoint where the private key is stored. Private keys are never shared over the network. In case a private key is ever compromised we could use a *MultiSignature* (*multisig) wallet* to provide a backup for this scenario.

**MultiSignature**

MultiSignature *(multisig)* refers to requiring more than one key to authorize a transaction. Standard transactions on the blockchain could be called "single-signature transactions," because transfers require only one signature — from the owner of the private key associated with the Blockchain address [15]. However, the blockchain network supports much more complicated transactions that require the signatures of multiple people before the funds can be transferred. These are often referred to as M-of-N transactions. The idea is that the information becomes "encumbered" by providing addresses of multiple parties, thus requiring cooperation of those parties in order to do anything with them. Here are some examples:

- ***1-of-2:*** Doctor visits patient and information is added or changed in the wallet.
- ***2-of-2:*** 2 Different doctors collaborating on a patient's information. Data can only be changed once both of them have reached a consensus.
- ***2-of-3:*** Doctor, Patient and Hospital. Once doctor and patient agree on treatment they can move forward. Patient can contact hospital and switch doctors. Doctor has to get authorization from either the patient or the hospital to make changes to health information. Doctor and hospital can provide a backup to patient's data if the patient loses access to his private key.
- ***2-of-3:*** Patient, Hospital and Provider. Patient and Provider decide to switch hospitals. Hospital and Patient agree to change treatment. Hospital and provider make changes in patient's status.
- ***3-of-4:*** Doctor, Patient, Hospital and Relative: Doctor, Hospital and Relative can override the patient's wishes in an appropriate case. Patient and Relative can override the doctor's wishes if it is appropriate only after authorization from the hospital.

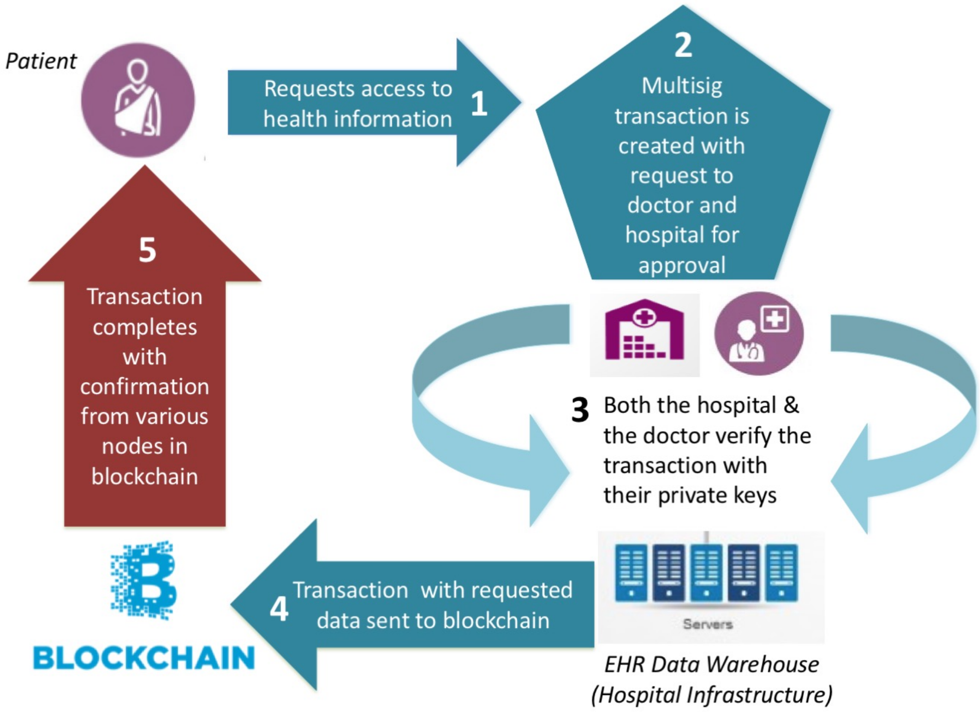
Patient
Requests access to health information
1
2
Multisig transaction is created with request to doctor and hospital for approval
3
Both the hospital & the doctor verify the transaction with their private keys
Servers
EHR Data Warehouse
(Hospital Infrastructure)
4
Transaction with requested data sent to blockchain
BLOCKCHAIN
5
Transaction completes with confirmation from various nodes in blockchain

*Figure 1. MultiSignature concept workflow in the hospital environment*

### Trustless Shared Ledger

A blockchain transaction is not based on any form of trust between the participants. All transactions are cryptographically confirmed by member nodes to be mathematically true.

For example a Bitcoin transaction needs to be confirmed by at least 3 nodes of the distributed system [18] to be considered complete. In our case this feature can be instrumental in providing interoperability between entities that do not necessarily trust each other. In newer blockchains such as Ethereum, smart contracts [8] form another layer of rules, which will be followed by every node, regardless of trust or owner of the node. Smart contracts allow us to translate real life situations or transactions into a transaction on the blockchain. Legally binding contracts could be forged in the form of smart contracts and would be enforced without trust or bias. This allows us to take trustlessness to a higher level and in the healthcare industry, allows us to extend contractual coverage to entities on the blockchain, such as between the patient and insurers, or between the hospital and the provider. The following flowchart gives an overview of the blockchain concept.

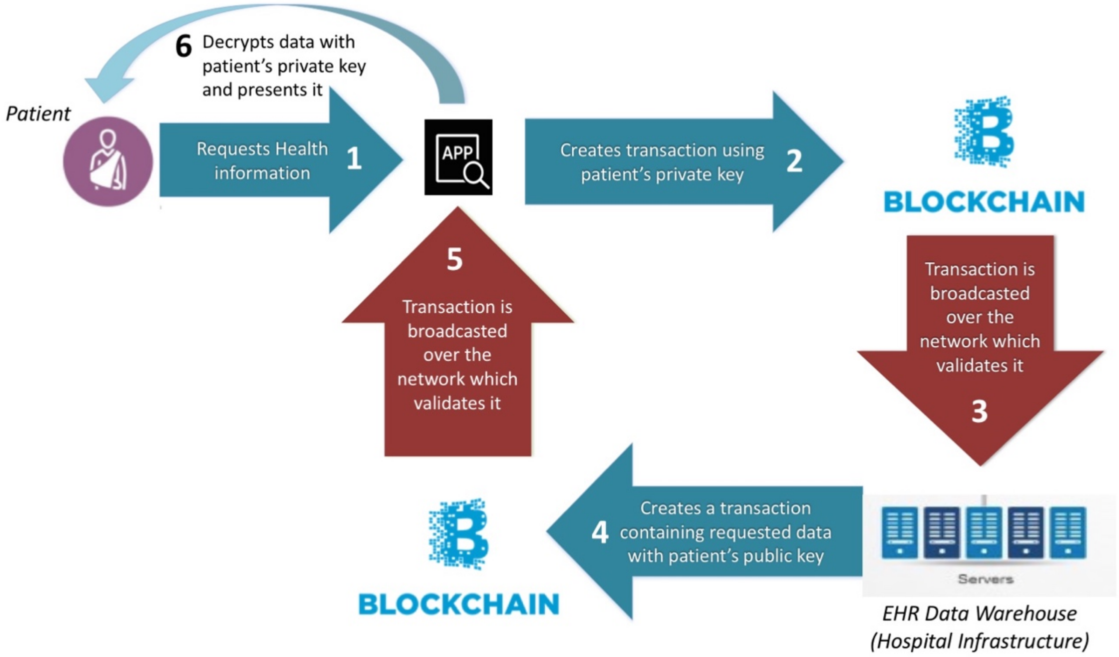
6 Decrypts data with patient's private key and presents it
Patient
Requests Health information 1
APP
Creates transaction using patient's private key 2
BLOCKCHAIN
Transaction is broadcasted over the network which validates it
3
5
Transaction is broadcasted over the network which validates it
4 Creates a transaction containing requested data with patient's public key
Servers
BLOCKCHAIN
EHR Data Warehouse (Hospital Infrastructure)

*Figure 2. Overview of the blockchain infrastructure*

**Mathematics behind the Blockchain**

Elliptic Curve Digital Signature Algorithm (ECDSA) generates the public/private key pairs. The address for a public/private key pair or wallet is obtained by taking the RIPEMD-160 hash of a SHA-256 hash of the public key. When you build a transaction in addition to referencing previous transactions you've received, it contains a script with your private key's signature and the matching public key. This is used to prove the provided public key matches the private key used to make the signature. The transaction, including a record of all inputs and outputs, is broadcast across the blockchain network to be added to a transaction block. Each transaction is hashed using a SHA256 hash function to create its unique transaction identifier to ensure that all data in the transaction cannot be altered without altering the transaction identifier.

## Discussion

The major value additions by incorporating the blockchain technology in the healthcare sector are summarized in the points below:

- Transactions occur in a peer-to-peer fashion and every participant would be able to access the data stored in the blockchain at any point if granted permission from the data owner.
- It is highly secure owing to multiple checkpoints and is failure-proof against denial of service attacks as well as hacking.
- It is an extremely light protocol that does not require huge investments in physical infrastructure — all the computations required for encryption/decryption and logging are distributed among the network participants.

The solution proposed in this paper leverages these features and attempts to bring private health information interoperability highly needed in the existing healthcare environment. It should be kept in mind, that healthcare industry does not know any major blockchain implementations at nation-wide scale, and such attempts might reveal risks and drawbacks that are not clearly seen at the moment. This might include hardware requirements for the patients' devices that are needed to facilitate encryption/decryption process, private key loss or leakage and restoring the access to the private health information and many others.

However, this concept proposes building an ecosystem where everyone involved in healthcare has new roles to play if they recognize the potential of the concept and invest in transformation. Given the enormous possibilities of the blockchain technology, it is only a matter of time, before it becomes a part of mainstream healthcare initiatives and revolutionizes the method in which every patient interacts with their private health information.

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