World Journal of Engineering Research and Technology
WJERT
www.wjert.org
SJIF Impact Factor: 5.218

SECURED DECENTRALIZED MEDICAL HEALTH RECORDS USING BLOCKCHAIN TECHNOLOGY

Hussam Elbehiery[1]* and Ghada Abdelhady[2]

[1]Ahram Canadian University (ACU), Egypt.

[2]October University for Modern Sciences and Arts (MSA), Egypt.

Article Received on 01/08/2018 **Article Revised on 15/08/2018** **Article Accepted on 01/09/2018**

***Corresponding Author**
Hussam Elbehiery
Ahram Canadian University (ACU), Egypt.

ABSTRACT

The current state of electronic health records is centrally-stored by medical institutions. In addition, medical privacy laws have restricted health records to be only obtainable by the patient, giving healthcare providers primary stewardship of patient data. While demand for medical data continues to increase, there is just a lack of reliable, quality data for medical research and Artificial Intelligence. And despite the large amount of data being produced, the actual data that can be applied is limited Which goes back to the core problem of valuable healthcare data being solid and distributed among various institutions. MedX is an open-source healthcare data ecosystem built on the blockchain. It compiles a complete indexed history of all patient medical information; validating and securing every change along the day. It can safely secure and integrate scattered data from various institutions, and also collect data from devices like the smartphone. Patients manage their personal medical records based on individual needs, setting grounds for exercising ownership and control over personal medical records. Patients have full access to their data and can assign access permissions for medical institutions and allow authorization for those who can write data on MedX. Also other participants-individuals, doctors, research institutions, private corporations and all parties tied to medical industry interested in obtaining medical information will be able to access with permission.

KEYWORDS: Blockchain, cryptocurrency, Ethereum, FHIR, HL7, MedX, PGHR, and PHR.

INTRODUCTION

MedX offers a healthcare data exchange platform/ecosystem that will promote interoperability and allow all entities patients, practitioners, medical institutions to freely take part in exchanging data. We believe that the MedX platform will revolutionize the healthcare industry by redistributing the rights to data ownership and viewing permission of healthcare data. In addition, software engineers and developer communities can build new services with the MedX platform API and SDK to exchange data with the platform and drive innovations in the healthcare applications market.

MedX will issue XMED token, the cryptocurrency used on this platform, to build a competitive ecosystem.[31,34] MedX users will be incentivized for their contribution on the MedX platform. This will reward participants ranging from patients to healthcare providers with XMED. XMED can also be used to complete transactions for medical and pharmaceutical expenses, insurance premiums, etc. at institutions associated with MedX.

Individual medical institutions have the sole authority to medical data of patient, prohibiting any exchange of medical data outside of the specific institution, with the exception of patient's request for personal information. It is extremely difficult to utilize data because the records are not compatible between different hospital systems. With increased demand for medical data exchange by professionals in the medical field and also patients, various entities have made attempts to gather health information. Examples of these efforts include the Blue Button Connector, a US government led project, Apple's Mobile Healthcare Application, and Samsung's Mobile Healthcare Application.[3] Although many other services are being introduced, digital healthcare services have not yet satisfied the requirements for an ideal healthcare information system, such as security, reliability, and transparency.[1,2]

As a result, they have not received active participation from healthcare service consumers, healthcare service providers, and the healthcare industry in general.[4] However, the MedX team is certain that it can create a system that can satisfy all requirements of an ideal healthcare information system by using blockchain technology, which is rapidly developing in finance.[27,28] Taking one step further, we hope to bring an innovation in the industry of healthcare by providing a platform that can offer services or applications related to health and medicine by using healthcare data and by building a system that supports patient centered care, precision medicine and predictive care.

Problem Overview

Anyone who has ever visited more than one hospitals have experienced taking one medical examination, then repeating the same test that was previously done at a previous hospital. It is because in many cases, your information in the previous hospital is not transferable to a different hospital. Inefficient exchange of medical information becomes prevalent as the current system is centered on medical institutions. Along with government regulation considers private healthcare information as highly classified information.

HIPAA (Heath Insurance Portability and Accountability Act) of the United States, states the regulations which all medical service providers and medical institutions should oblige for the protection of medical information.[5] According to HIPAA, the party which can deal with medical information is highly limited. Sharing medical information is allowed to a minimum level, only in cases when it is necessary to share. As a result, medical information is managed by the medical institution in which a patient was treated or by insurance companies.

Other countries have accepted similar regulation like the HIPAA, so it is highly likely that medical information exchange will not be swiftly executed in most countries. Another factor that makes exchange of medical data difficult is the lack of digitalization of data. According to a research by US Center for Disease Control and Prevention, only a half of total medical institutions has an EMR/EHR system which has complete functionality.[6]

Under the current state of centralized repository of medical data, there is no guarantee in the integrity and security of patient data. Moreover, risk in terms of data loss or hacking is inevitable. In this situation, individuals cannot autonomously utilize their medical information, have little trust in data credibility, and are exposed to high risk of personal information leakage. In fact, the number of healthcare data breaches is only increasing. In 2015, more than 112 million healthcare records were breached just in the United States and annual financial loss is recorded to be over $6.2 billion.[7,8]

Restrictions in healthcare information exchanges also limit healthcare providers and medical experts from performing the best care, and unnecessary repeated tests and attempts for data reconciliation can cost a lot of time and money ‘A research has shown that when healthcare information exchange is well conducted, the overall laboratory tests and radiology examinations can be reduced by more than 50% in the emergency department.[9] The current healthcare data system, specifically the insurance industry, is dealing with losses every year due to its inability to prevent health insurance fraud. It costs more than $487B worldwide,

and records from 2011 show that, in the US, this cost consists of one fifth of all medical expense.[10,25] In addition, falsification or forgery of information by healthcare providers happens quite frequently. However, there are lacks of system today that prevent this broader societal issue.

The existing problems of the process of collecting healthcare data do not end here. Digital health data is highly sought after by biomedical and public health researchers and other business stakeholders in the healthcare industry.[11] In order to conduct precise evidence-based research, experts require high-quality, organized records for analysis, but in most of the cases, data is transferred without informing patients, resulting in the growth of concern about this. Furthermore, the rights and issue to personal healthcare data is increasingly drawing attention because medical institutions are abusing their rights and make information exchanges without informing patients.[12,26]

Currently, in the US, certain cases allow for sharing of information that has been de-identified. But it has become very easy to re-identify the exact patient, with all of the personal data available and with the help of social media.[13,14]

Medx, Suggested Medical Information System

There have been many attempts to liberate and analyze the current health record system kept by large medical organizations. It remains difficult, as the healthcare data industry serves multiple entities, all with different interests.

Fig. 1: Med X parties.

The suggested system (MedX) uses blockchain technology that re-envisions the healthcare data system to be consumer-centered. It will provide an ideal Personal Health Record (PHR) platform that brings reliable and transparent dataset for medical records. MedX is more than a data exchange service.[15] It is a healthcare data platform that opens the possibility for variety of services Developers will be able to use the open-source API and SDK to create services using the MedX platform MedX uses a cryptocurrency, token (XMED), that will build a medical information economic ecosystem in which consumers are at the core.[24] It also provides a unique opportunity to receive incentive for participating on this healthcare data platform. The characteristics of suggested system MedX are as next sections:

Maximum Security

According to the HIPAA privacy rules, all medical information must be kept confidential. The current state of electronic healthcare data is collected and stored by individual healthcare providers, risking and opening the various people involved in healthcare to have access to the data.[16] MedX hopes to block the possibility of these leaks and reduce access to private health data by taking the rights from big corporations and giving it to the individual patients. Patients themselves will have the authority to access, decrypt and collect all of their healthcare information with the blockchain technology. This will minimize the number of people involved in collecting private healthcare data and also lower the risk of leaking of healthcare data. In addition, it will prevent the recurring cases of thousands of medical data breaches through attacking of large medical institutions.[17,29]

High Reliability

MedX stores healthcare information in a decentralized data storage. In order to prevent data loss, it will continuously generate backup data, verify the integrity of the data and when modulations are surfaced, recover the original data by using the backup data. Making it difficult for users to easily delete and modify data will ossify the integrity and reliability of medical data stored on MedX. It allows only verified medical practitioners through the healthcare provider's credential system and further strengthens the reliability of our system by keeping a record of the specific writer and confirm through blockchain. Only when given the authority can a medical practitioner view the healthcare data of another person.

High Level of Transparency

MedX records the activity of those who write/read/access that information on the blockchain.[35] MedX will transparently provide information on when, where and for what purpose the healthcare information was used. By allowing consumers to have authority and

manage personal healthcare data, MedX can fundamentally stop exploitation of healthcare information.

High Interoperability

MedX is an open-source platform. Standardized data such as medical images or genetic information can be easily interoperable and transferred through MedX. For data that not yet has a standardized format like medical records, laboratory results, and test results, etc., in order to support this, MedX plans to provide API/SDK for diverse formats, starting with the most widely used HL7 FHIR (Fast Healthcare Interoperability Resources), and also allow anyone to develop a code supporting other formats.[18] With high level of flexibility and scalability as a basis, MedX offers interoperability that tops any of the current healthcare information system.

High Accessibility

MedX stores all healthcare information in a decentralized database, where users can easily access it anywhere through the Internet. Healthcare data is restricted outside the medical institution and there are still limitations in some cases where services to access healthcare data are provided. MedX provides a system that separates itself from any single medical institution, no longer relying on big institutions to provide access healthcare information to customers and practitioners.

Patient-Centered Healthcare Information System

MedX will use blockchain- the symbol of decentralization- to disrupt the current healthcare data system and to achieve data integration. MedX not only allows for storing healthcare data produced by a medical institution, but also collectively stores Patient-Generated Health Record (PGHR). Information produced outside of the hospitals, along with data recorded by patients themselves can all be stored in MedX. Integrated healthcare data can be widely used for, from general treatment at local hospitals to personalized mobile healthcare services.

Platform Structure

The MedX platform consists of three layers: Core, Service, and Application.

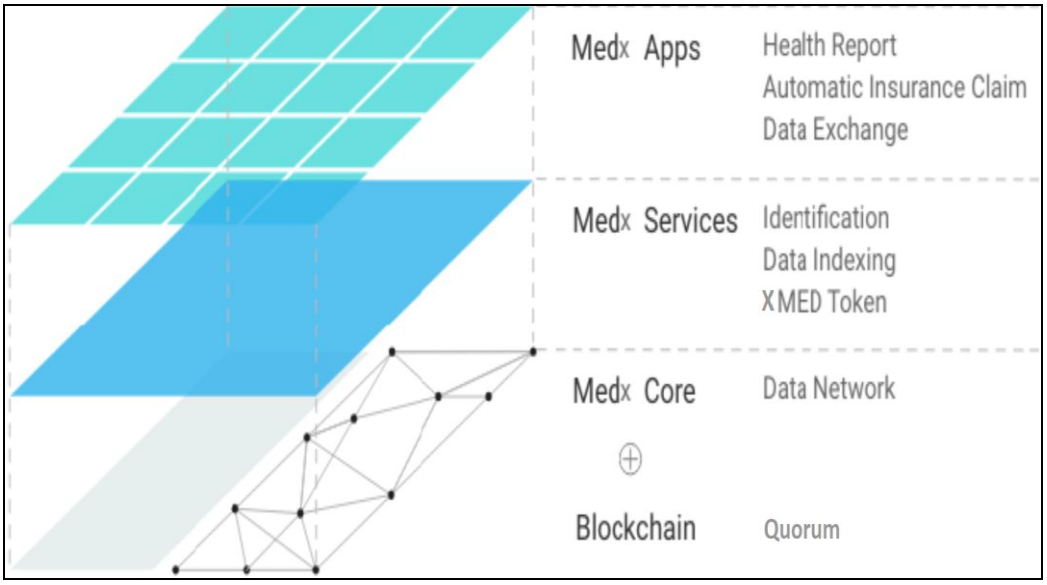

Fig. 2: Med X layers.

Through the Med X Application layer, various applications, from web, mobile, etc., can manage and utilize the healthcare information. These applications are accessible through the Service Layer of the platform. SDK has been offered, which will help create applications that can be linked to the Med X platform.

First Layer: Medx Core

The Core layer is a healthcare data network, a distributed database that uses the latest encryption technology to safeguard data. Since the amount of data that can be stored in the blockchain is very limited, separate storage is required to efficiently store healthcare information and this separate storage is provided in the Core layer.[36] The data generated and transferred by applications using MedX-provided SDK is first encrypted with individual private key only the owner of the data can decrypt it. The Core layer is accessible through the Service layer and provides a backup and recovery system so that data can be safely stored without being lost.

Second Layer: Medx Service

MedX's Service Layer provides fundamental services that connect the Application Layer and Core Layer. The Service Layer uses information based on blockchain, and allows for data input/output through connection with the Core Layer. Internally, it can be divided into EVM (Ethereum Virtual Machine) based Smart Contract and Connecting Application and Core layers.[23,30] MedX hopes to minimize operational costs by minimizing data stored on the actual blockchain, including Smart Contract data.

Third Layer: Medx Application.

Through the MedX Application layer, various applications, from web, mobile, etc., can manage and utilize the healthcare information. These applications are accessible through the Service Layer of the platform. SDK has been offered, which will help create applications that can be linked to the MedX platform.

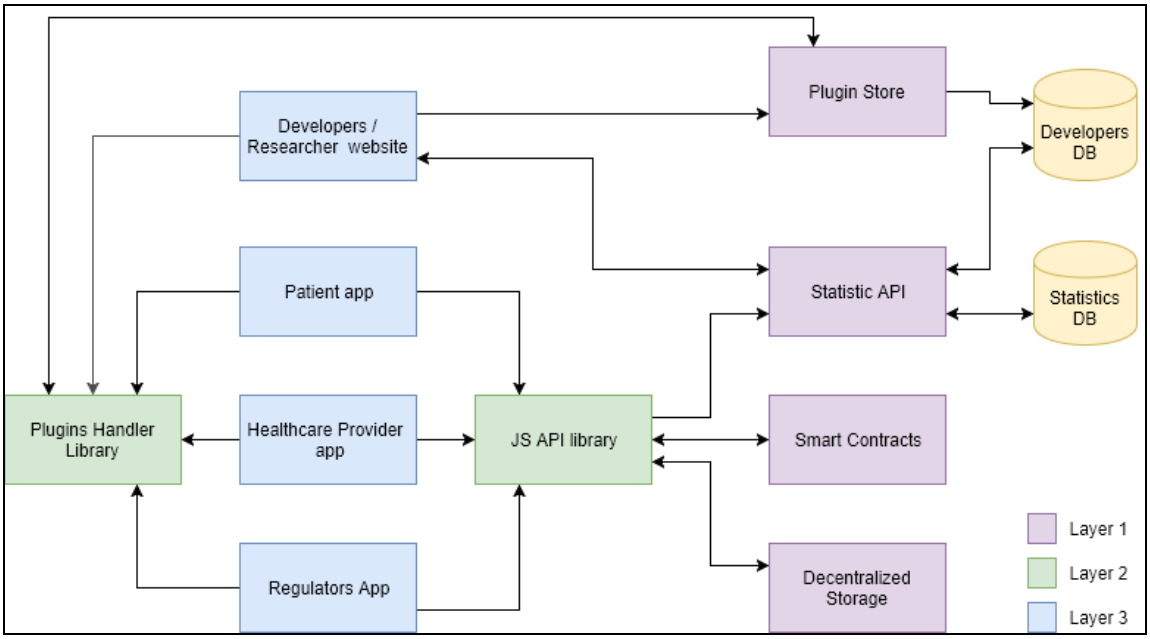

Fig. 3: System Overview.

Platform Components

The MedX platform is an EVM-based decentralization application (DApp). Therefore, with time, cost, versatility, and reliability in mind, it is the most productive to develop MedX as a DApp based on EVM instead implementing the whole blockchain network. EVM is supported by multiple blockchain platforms such as Ethereum (ETH) as well as Quorum and EOS,[20,21] opening the possibility for middle to flexibly choose the best platform depending on the situation.[19] The advantage of using Quorum is that it has the positive characteristics of both Bitcoin (BTC) and Ethereum and it is currently the most scalable public blockchain due to the use of PoS (Proof of Stake) consensus algorithm.[37,32]

The MedX platform mainly holds three categories of information: XMED balance, personal information, and healthcare data. It would be optimal to be able to hold all these information on the blockchain, but due to practical constraints such as cost, storage capacity and performance, large data including personal information, healthcare data, etc. should be encrypted and saved outside of the blockchain. Only the hashed value of these data will be recorded onto the blockchain.

Platform Used Technologies

Blockchain

Fundamentally, a blockchain is a shared database, consisting of a ledger of transactions. Much like a bank, the ledgers of simple blockchains keep track of currency (in this case, cryptocurrency) ownership.[32,35] Unlike a centralized bank, everyone has a copy of the ledger and can verify each other's accounts. Each connected device with a copy of the ledger is called a "node". BlockChain eliminate the problem of trust that affects other databases in the following ways:

- **Full decentralization:** Reading/writing to the database is completely decentralized and secure. No single person or group controls a blockchain.
- **Extreme fault tolerance:** Fault tolerance is the ability of a system to handle corrupt data. While fault tolerance is not unique to blockchains, it takes the concept to its logical extreme by having every account sharing the database validates its changes.
- **Independent verification:** Transactions can be verified by anyone, without a third party. This is sometimes referred to as "disintermediation".

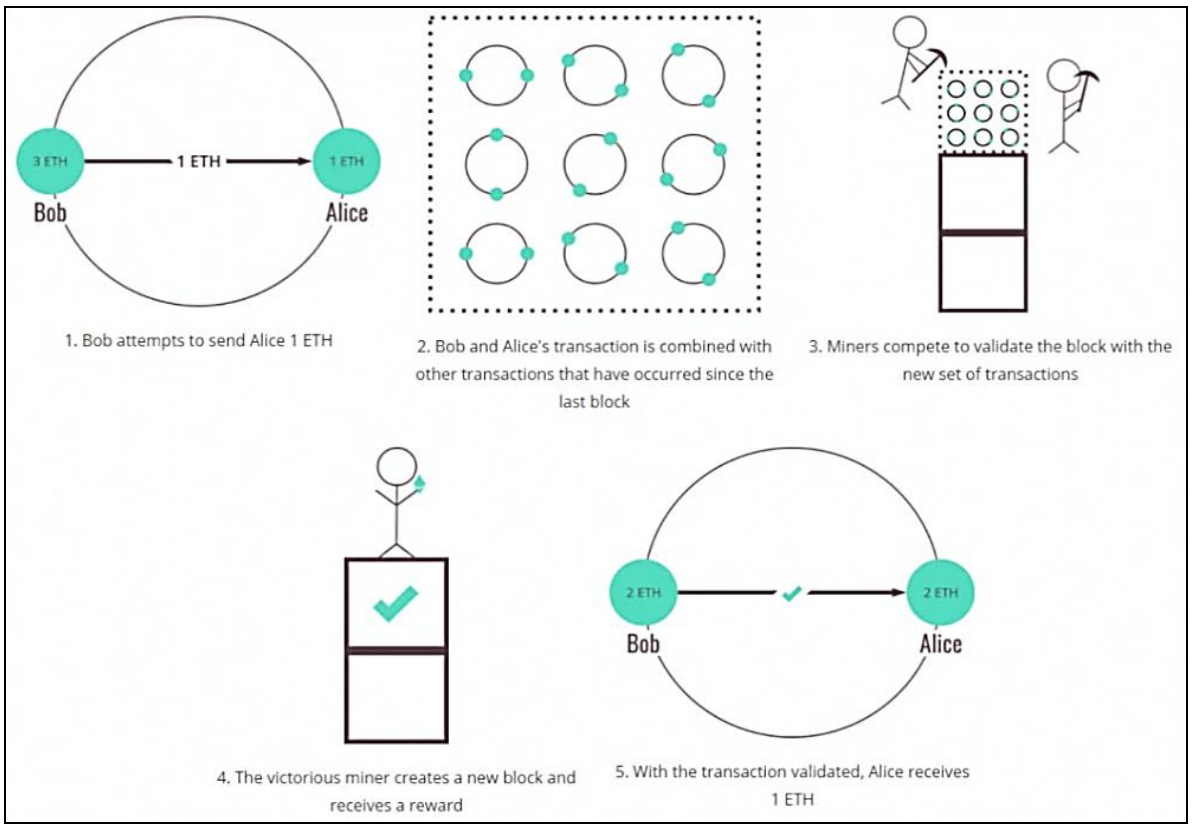

Fig. 4: Blockchain consensus.

Interplanetary File System (IPFS)

IFPS has since become thought of as the Distributed, Permanent Web; "IPFS is a distributed

file system that seeks to connect all computing devices with the same system of files. IPFS could become a new major subsystem of the internet. If built right, it could complement or replace HTTP. It could complement or replace even more. IPFS is a versioned file system that can take files and manage them and also store them somewhere and then tracks versions over time. IPFS also accounts for how those files move across the network so it is also a distributed file system. IPFS has rules as to how data and content move around on the network that are similar in nature to bit torrent.[22]

HL7 FHIR

FHIR is based on modular components called "resources." and these resources can be combined to solve clinical and administrative problems in a practical way. FHIR is still being developed by HL7, but the second Draft Standard for Trial Use became available in 2015, and the first normative edition is planned for 2017. The FHIR standard is based on the following simple five key points: Faster to learn and implement, Lower cost, Scales well from simple to complex, Flexible, and Free.

Potential Use Cases

Personal Health Report

Patients can have complete record and control of the medical history. Patients will be able to use the information during clinical care and use it for personalized healthcare services, including customized medical AI application. This is an example of recurring topic in the field of medicine - on the requirements and standards for ideal personal health record (PHR). Patients can now accurately understand individual health conditions more easily and keep record of when and what medical procedures took place in the hospital. In addition, the exact name and ingredients of medication prescribed and any side effects can be recorded. Patients can also compare previous health conditions to the present, allowing for enhanced care of individual health.

Automatic Insurance Claim

Based on the medical data collected through MedX, insurance claims and evaluations can be automated with "Smart Contracts". Patients will no longer need to call/ visit medical insurance companies to ask if certain diseases, treatments, checkups will be covered. Also eliminated need to submit a claim to the insurance company post treatment. Through "Smart Contracts" used after the treatment, medical data delivered through MedX will automatically be billed to the patient's insurance plan.

Peer To Peer (P2P) Healthcare Data Market

MedX offers patients to exchange healthcare data with medical researchers, institutions, companies, etc. through a P2P healthcare information market. Until now, large medical institutions and companies have privatized the monetary benefits of monopolizing and distributing healthcare information, but MedX provides services that can be returned to the patients. Through MedX, patients will now be aware of the value of healthcare data which will motivate them to actively participate in MedX. Medical researchers will be able to more easily access accurate and wholesome medical information, which could lead to acceleration in the development of medical care and create a virtuous cycle structure that will return benefits to the patients.

Artificial Intelligence

The intersection of medicine and AI is creating changes across the medical spectrum, from highly complex domains, like medical examination and medicine development, to more simple health management. Advancement in Al depends on the quality and quantity of the data, and developers will be given the opportunity to access more quality data through MedX. Through this exchange, AI will be a promising service.

Clinical Trial

MedX can be used as a platform for clinical research in medical research institutes and pharmaceutical companies. It can be used in the process of screening the patients and be an asset to research as a whole. ‘Smart Contract’ allows both researchers and practitioners to have an access to research data anywhere at the same time. MedX can open more opportunities for objective research.

Telemedicine

Patients have a variety of needs for medical services. However, there are currently physical and temporal barriers that prevent patients from receiving the right medical service. Through MedX services, patients will be able to connect with their desired practitioner and receive medical service 24/7 anywhere around the world, making it easy for live, real time healthcare services.

Social Networking Service (SNS)

MedX will create communities specifically for patients, especially those with rare diseases. Patients who must fight the same illness can benefit from sharing information and establishing relationships. In addition, Medical providers and researchers who are interested

in the disease can naturally engage with the community, enriching the experience of righting diseases.

Suggested System Implementation

Patient Scans the Qr-Code Of The Doctor

Fig. 5: Patient scans the QR- code of the doctor.

Patient Choose the Records That He Want To Grant Access For

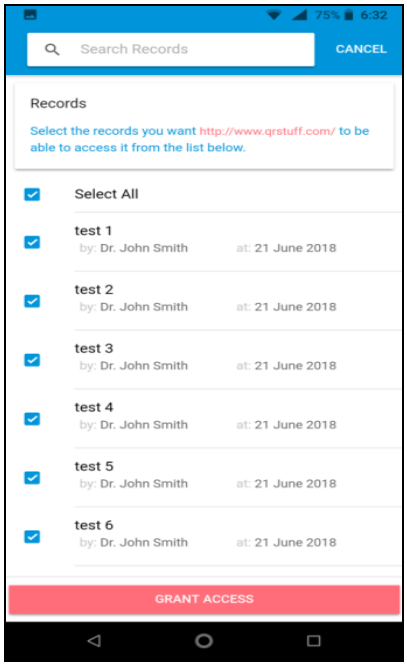

Fig. 6: Patient choose the records that he want to grant access for.

Patient View His/Her Current Records

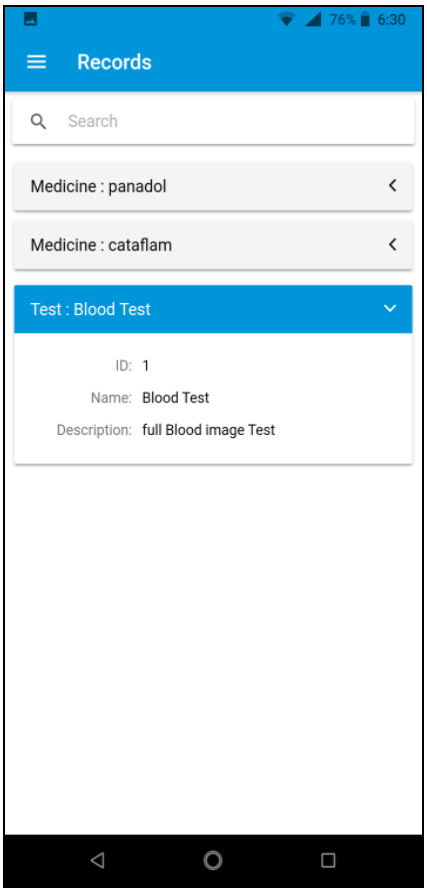

Fig. 7: Patient views his/her current records.

LOG IN

Fig. 8: Log in.

Patient, developer, practitioner and organization can log in with the already specified email and password while signing up. All the roles should needs creating an account in the log in page to be able to sign up.

- **Patient Sign Up**

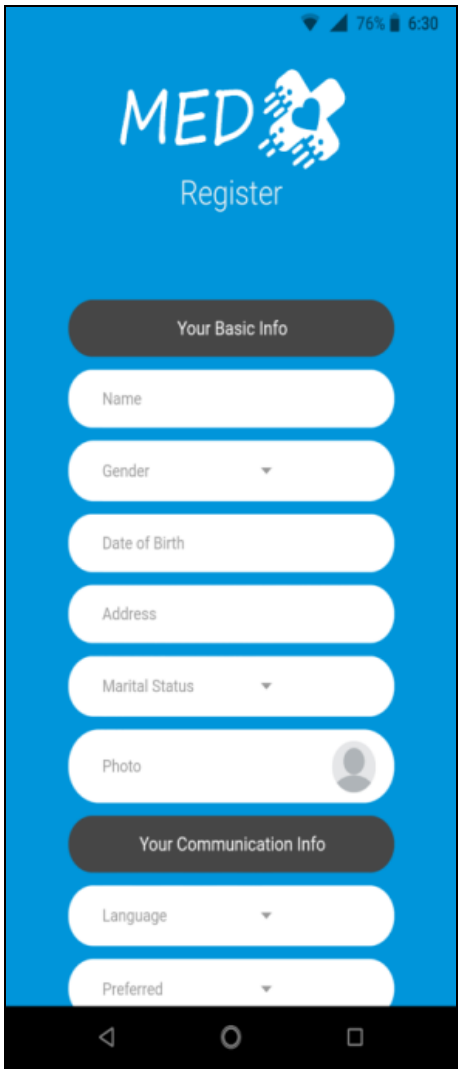

Fig. 9: Patient sign up.

Practitioner Sign Up

Fig. 10: Practitioner Choose his/her role.

Doctor View Patient List

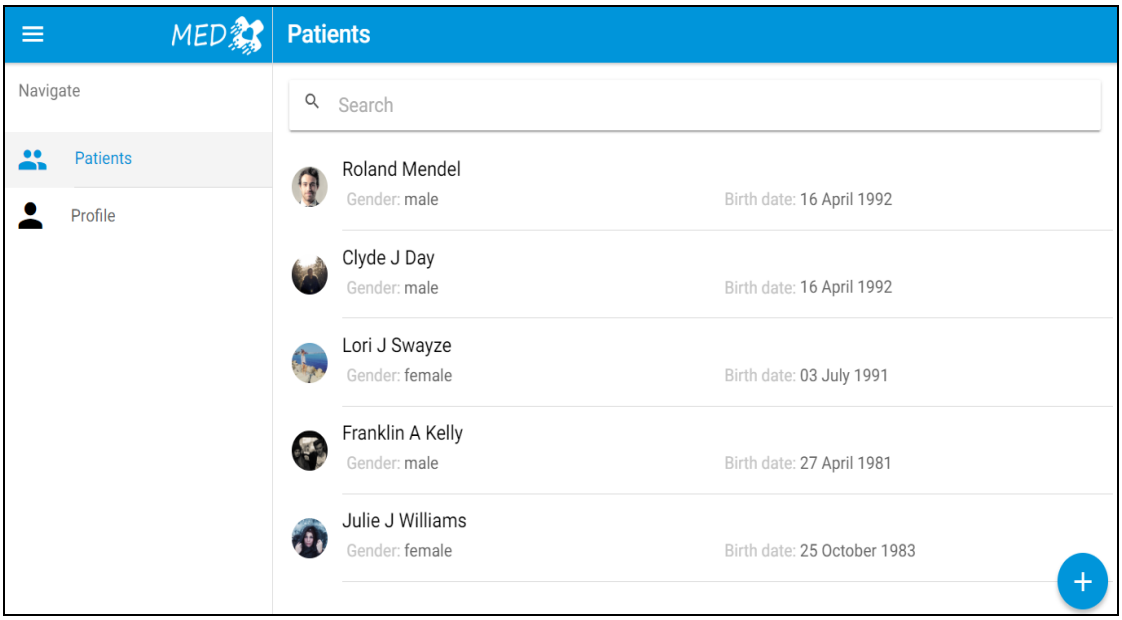

Fig. 11: Doctor View the list of patients that he has access on their records.

Doctor view the list of patients that he has access on their records. Doctor can view a list of all the patients that he has access to their records with all the data that can make it easier to identify the patient as (name, photo, gender, birth date) and he can filter them by search in them.

Every User Can View His Profile

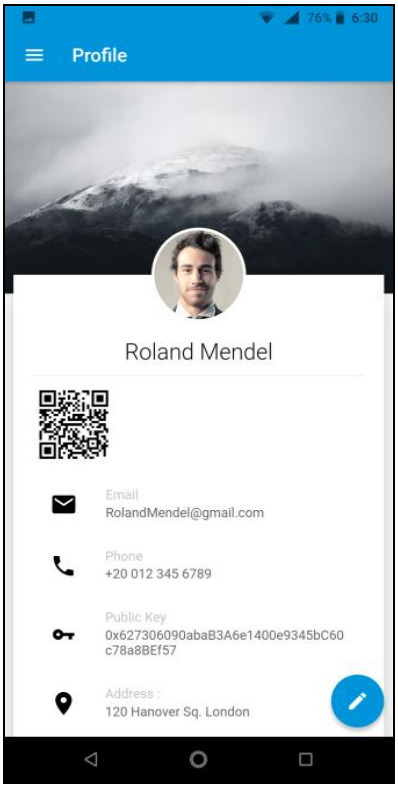

Fig. 12: Every user can view his profile.

Query Appear In Published Queries

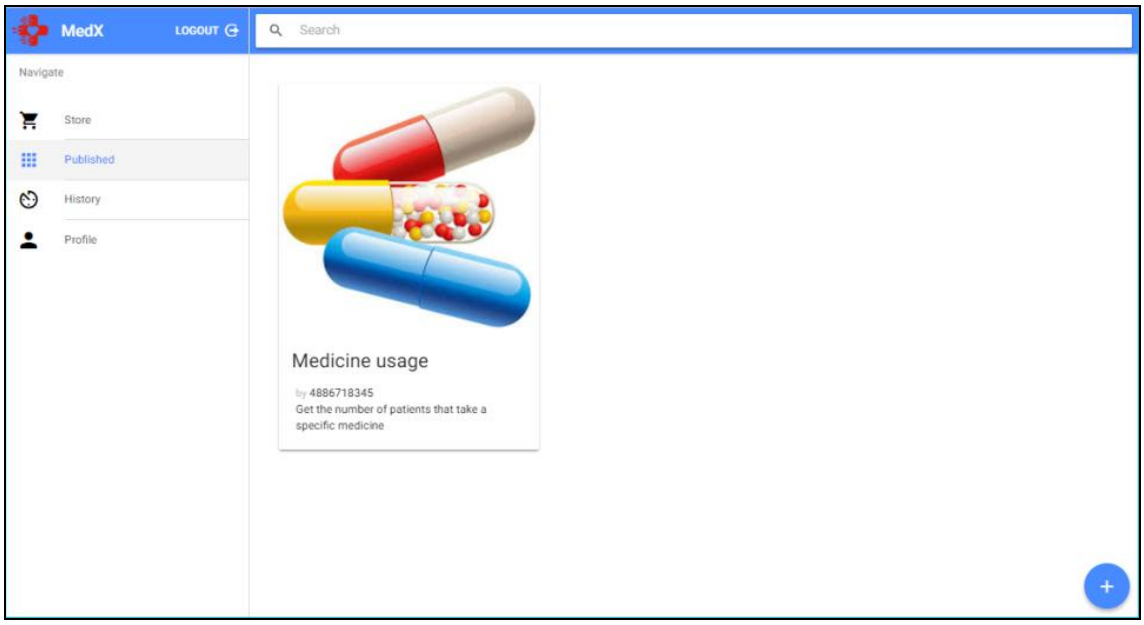

Fig. 13: Query appear in published queries,

The published queries page appears all the queries that the developer has made by himself and he can edit it. A search in the mongoDB done to all the queries in the database. The entire query that their publishers match the user will be fetched.

Researcher View His Bought Query In His History

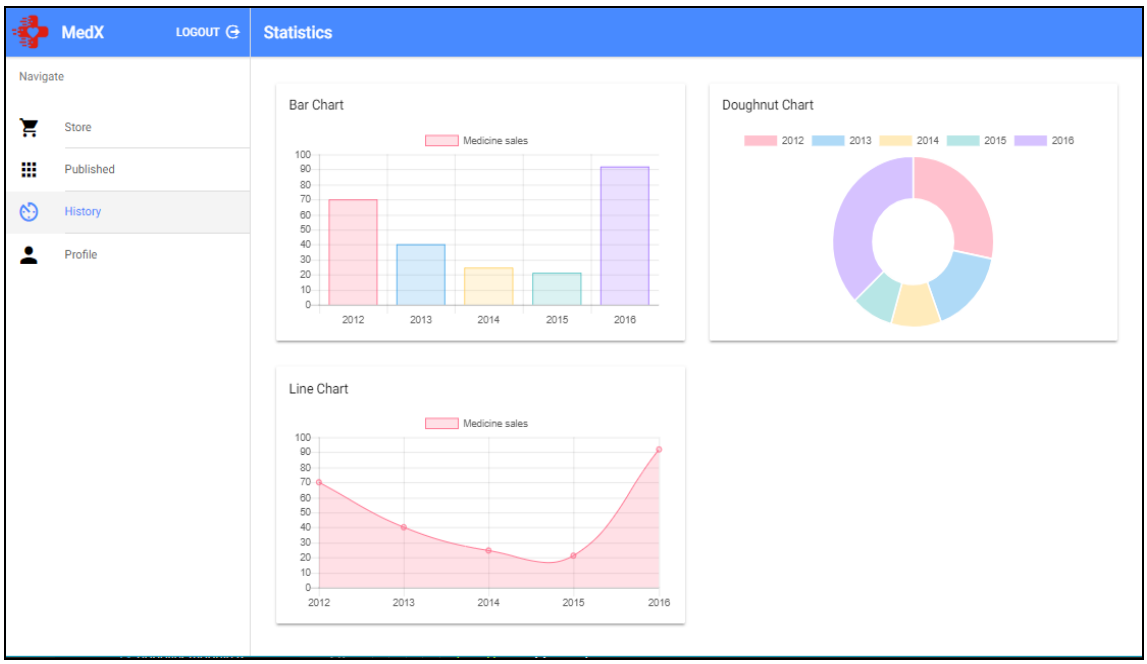

Fig. 14: Researcher View his bought query in his history.

Researcher view the executed query result in his history page and like that he owns the result for ever. The history page views all the executed queries of the researcher or the developer.

They view the query result with different representations and he will be able to choose the favorite representations of charts in the future work.

CONCLUSION

MedX believes block chain technology is the key to solve the medical industry problems. Blockchain, the core technology behind crypto-currencies like Bitcoin, Ethereum, and Quorum, helps ensure credibility in digital data.[33] Unlike existing institutions that save transaction records on a centralized server, blockchain distributed transaction records to all network users and has a distributed validation mechanism. Data forgery and hacking can thus be prevented while ensuring transparency and credibility. So it is intend to make an ecosystem for every entity in the medical industry. The developer can make plugins with certain functionality that will benefit the industry with a balance of patient and industry benefits using the provided API and SDK that we will provide. In the next phase, the government role with its own application to be able to work as governing regulator and issue certificates for the medical entities in the platform will be added as: Developers, Patients, Doctors, Medical insurance companies, Hospitals, Different medical facilities (labs , scan centers ……...etc.), and making a plug in store for the developers community. Also the next phase will support multiple medical standards (CDA - FHIR - HL7 Version 3) by converting all the standards to the FHIR that we are globally using.

ACKNOWLEDGEMENT

This research was supported by **Ahram Canadian University** (**ACU**) and **October University for Modern Sciences and Arts** (**MSA**). We would like to thank our colleagues from *Faculty of Computer Science and Information Technology* and *Faculty of Engineering* who provided insight and expertise that greatly assisted the research.

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