Using IoT and Blockchain for Healthcare Enhancement

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Abstract. Modern technologies such as Internet of Things (IoT) and blockchain have a valuable contribution in improving healthcare services. This paper aims at achieving and democratizing healthcare services by providing healthcare-as-a-service. It was achieved by developing medical devices with sensors for healthcare. It connects the medical devices such as temperature sensor to the network of medical physicians and nurses through the cloud. This paper presented integration between IoT and Blockchain as a secured platform to mitigate nurses' shortage. Blockchain was used in the proposed operational framework to store and validate patients' records. Remarkable results were found in decreasing the gap in the number of nurses for large scale of patients. Prototypical implementation of this proposed healthcare service was presented with all technical requirements to make it applicable easily.

Keywords: Blockchain · Cloud · E-Healthcare · IoT

1 Introduction

Healthcare is an important field that requires a continuous enhancement. One of its components is nursing human resource. Skilled nurses are considered as a primary pillar of healthcare success. Healthcare faces daily issues. Nursing shortage is a crucial problem in the globe [1]. This issue has been acknowledged by the World Health Organization and other health centers and organizations in all over the world. The shortage is caused by an increased demand for nurses, while fewer people are choosing nursing as a job.

As technology advances, so does its influence in healthcare too. Thus, technology may provide a solution to the problem of nursing shortage through new trends such as cloud computing, internet of things, and the emergence of blockchain technology that could be a technical solution to such common problems. Moreover, blockchain technology can support transparency and accountability of stored data.

Therefore, this paper aims at democratizing healthcare service by providing health-care as a service, which can be achieved by developing medical devices with sensors

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for healthcare and connecting them to the network of medical physicians and nurses through a cloud is utilized. Blockchain is used to store patients' records.

The following sections present a synthetic literature review on the use of blockchain in healthcare, the proposed methodology, and conclusion and future work.

2 Previous Work

Blockchain can be considered as a distributed and secured database in which each block has a hash to the previous block. An enormous body of literature embraces the use of blockchain in healthcare.

In 2014, bitcoin was cleverly proposed in medical research [2]. In 2015, blockchain popularity was increased to be a new economic model [3] and decentralizing privacy [4].

In 2016, blockchain evolved [5], Electronic Patient Record systems (EPRs) [6], to empower the patient-physician relationship [7]. A notable application is Medrec that utilizes blockchain for managing permission in medical domain [8]. Blockchain can be also useful for Interoperability [9]. Blockchain can provide protocols for medical trustworthiness [10] and for transparency [11] as well.

In 2017, blockchain has been evolved rapidly [12]. It has contributed for health care applications [13–15]. That contribution was proven to be very vital for health care [16], thus empowering e-health [17]. Many previous works address challenges and opportunities of blockchain in e-healthcare such as [18–20].

Metrics for blockchain-based healthcare decentralization are [21]:

M1. Compliance of workflow with Health Insurance Portability and Accountability Act (HIPAA)
M2. Scalability through huge populations of participants
M3. Cost-effectiveness
M4. Supporting for Turing-complete operations
M5. Supporting for user identification
M6. Supporting for structural interoperability
M7. Supporting of patient-centered healthcare

In 2018, blockchain gained its fame as a remedy for security and privacy of e-healthcare [22]. Many systems were proposed such as Blochie [23], FHIRchain [24] and Mistore [25].

We notice that most researchers are rushing to build blockchain-based health systems without integrating IoT. Others worked with a different perspective using IoT without using blockchain. Therefore, this paper is proposed to handle this issue.

This research paper integrates these two technologies to improve healthcare in general, and the process of equipping patients in particular.

3 Proposed Methodology

In this section, we present the stakeholders of proposed system. And move towards a mathematical model with operational framework. Furthermore, a brief discussion of how to construct temperature sensing circuit is presented.

The stakeholders are the patients with sensors, their relatives, nurses, physicians and ambulances. Figure 1 illustrates the stakeholders of the proposed system.

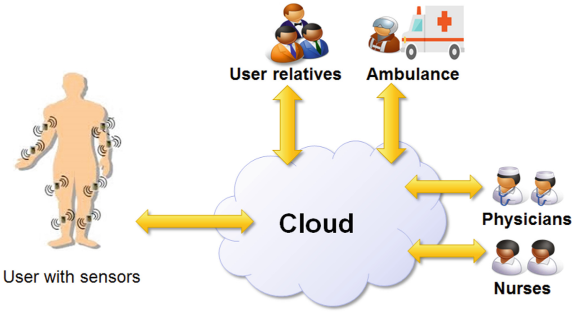

Fig. 1. Stakeholders of the proposed system

The proposed system proposes that the patient is equipped with sensors. Physicians and nurses are linked to monitors to track the status of the patient. In emergency cases, the system sends a message to the ambulance and/or patient's relatives.

To make is easy for pondering the communications among sets of stockholders, Table 1 shows cardinality of stakeholders.

Table 1. Nomenclature

Stakeholder set	Cardinality of:
B	Beds
D	Physicians/Doctors
N	Nurses
P	Patients

Assume that there are P patients, N nurses, and B beds in hospital. There are many scalability dimensions for example from beds to patients (BP Scalability, the B÷P ratio), and from patients to nurse (PN Scalability, the P÷N ratio).

BP Scalability does not concern us, as it defines the physical capacity of hospitals. PN Scalability, however, can scale up and be enhanced with the technology presented in this paper.

Figure 2 shows a proposed framework, inspired by [26]. At the beginning, CARE can be redefined to stand for medical Countermeasure (C), based on Analysis (A) and Repository (R) of Events (E). Nurses are tracking the status of enrolled patients. All events are stored in the blockchain repository. Events undergo an analysis process which is recursive by nature. This means that most operational time is attributed to the analysis phase. Analysis log data are stored in the blockchain repository too. Countermeasure corresponds to the action to be taken.

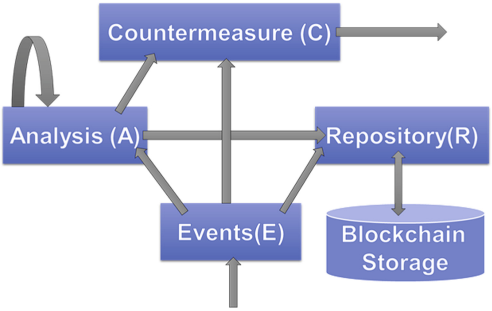

Fig. 2. Proposed operational framework

Figure 3 shows temperature sensing circuitry. The components are ARDUINO Uno board, breadboard, temperature sensor, Wi-Fi, wires and resistors, Light Emitting Diode (LED), and Micro-USB cable. To build the circuit, there is a good tutorial [27].

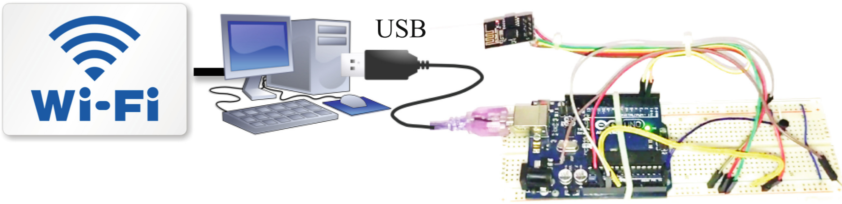

Fig. 3. Temperature sensing circuit

The IoT circuit for temperature measurement is connected to internet. A channel in thingspeak.com is created and linked to the circuit to get readings from the ARDUINO device. ARDUINO device is more available and durable in the market rather other devices according to regional market.

Figure 4 shows the architecture of the proposed system. The first run of blockchain will be mining the Genesis block. Then the proposed system displays the hash of the Genesis block.

After that, the system interactively asks about some data and encapsulates the answers in the blockchain. These data are:

a) Patient's Full Name
b) Patient's Address
c) Hospital
d) Disease
e) Medication given
f) Final Bill Amount

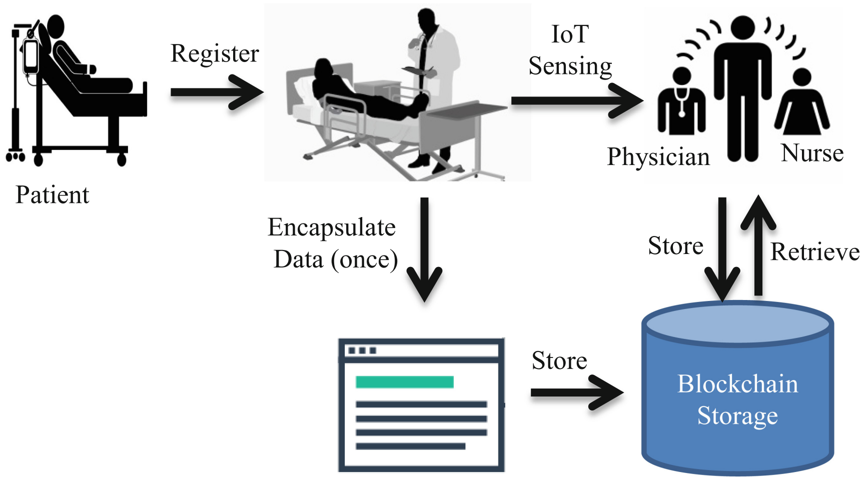

Fig. 4. Architecture of the proposed system

4 Experiments and Results

The implementation of the private blockchain is achieved in Java as listed in the appendix. Figure 5 shows the blockchain structure.

The first run of blockchain will be mining the Genesis block. Then the proposed system displays the hash of the Genesis block, which happens to be:

00000d99d5b74ae4083b0dc72eb037911c7e4fc3b57cdf96

It has 5 leading zeros (nonce).

After that, the system interactively asks about some data and stores the answers/patient records in the blockchain.

For the first patient, a block is mined, with hash:

000007e79730cbf13d1d35cf7138b6248b2df3e6093583e6

It has 5 leading zeros. For the second patient, a block is mined, with hash:

00000b632ec77b8a4eae6c78b08932624e84ab3814e13dc9

It has 5 leading zeros. After each data entry, the blockchain can be validated.

Table 2 shows computational time in nanoseconds for creating blocks on Acer Extensa laptop, running 32-bit Windows 8.

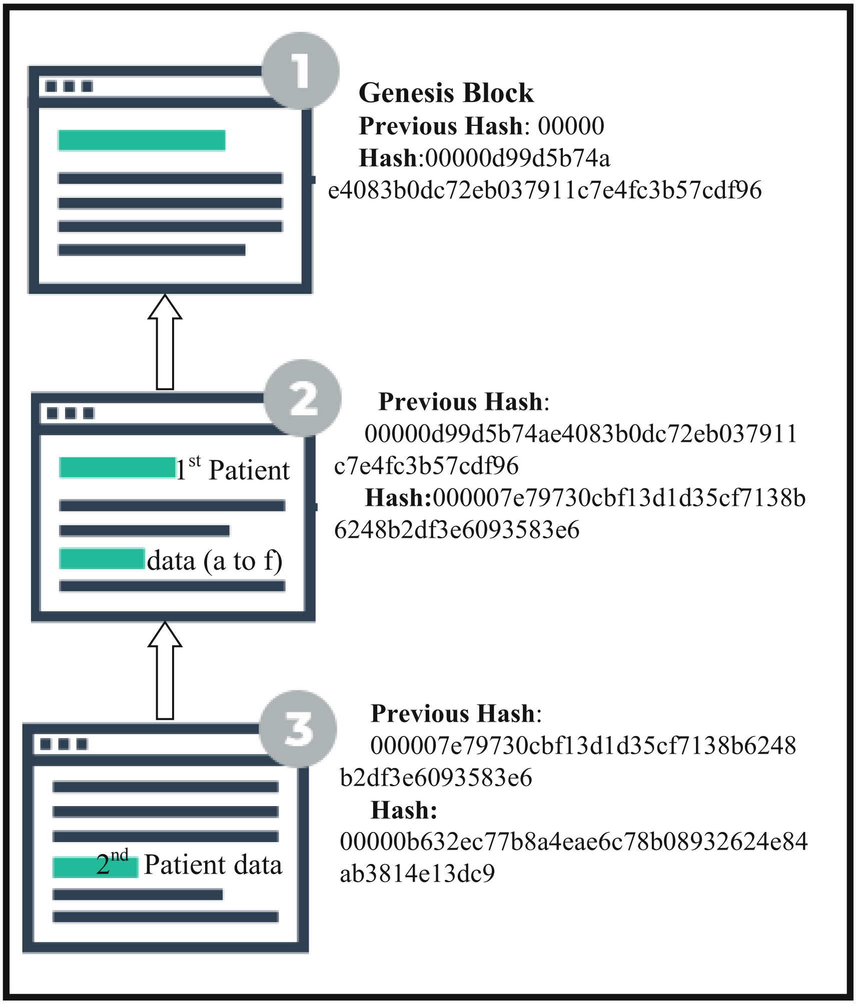

Fig. 5. Blockchain structure

Table 2. Creation time of blocks

Block	Time in seconds
Genesis block	0.747965977
1st patient block	5.210931889
2nd patient block	4.2750578509
3rd patient block	12.061223465
4th patient block	8.542168901

For testing a sensor-based data for randomly generated 100 patients, the results show that the average of creating blocks is about 6 s per patient. This is compared to manually temperature measurement time which is 24 s per patient. With large scale of patients, this accumulative difference will make a noticeable significant. This proposed system does not validate its scalability by minimizing the elapsed time for measuring patient temperature but also handling the nurse shortage noticeable.

5 Conclusion and Future Works

This paper proposed healthcare-as-a-service using IoT and blockchain. A temperature sensing circuit is designed and linked to thingspeak.com by using wi-fi. Nurses are tracking the sensing signal on monitors. The paper also presented how the blockchain is used to store the health records. The proposed system is enhanced by time reduction and minimizing nurse human resource. It is very easy to use integration of other medical data such as pressure and, vital signs in general.

A possible future direction may integrate big data and mobile based application to monitor the patient's status with the IoT equipment to come.

Other possible directions are to secure the blockchain [28] and to investigate the integration between the IoT and the blockchain [29].

Appendix A. Blockchain Implementation in Java

```
import java.util.Date;
import java.time.format.DateTimeFormatter;
import java.time.LocalDateTime;
import java.security.MessageDigest;
public class Block
{
    public String hash;
    private String data;
    private String timeStamp;
    public String previousHash;
    private int nonce;

    public Block(String data,String previousHash ){
        this.data = data;
        this.timeStamp = CarePlus.time;
        this.previousHash = previousHash;
        this.hash = calHash();
    }
```

```
    public String calHash() {
        return Sha256(previousHash +timeStamp +
            Integer.toString(nonce) +data);
    }
    public void mineBlock(int difficulty) {
          String difstr =getDificultyString(difficulty);
    while(!hash.substring( 0,
                difficulty).equals(difstr)) {
            nonce ++;
            hash = calHash();
        }
        System.out.println("Block Mined Successfully! Hash: " + hash);
    }

    public static String getDificultyString(int difficult){
       return new String(new char[difficult]).replace('\0', '0');
    }

    public static String Sha256 (String data){
       // return java.security.MessageDigest of the data
    }
}
```

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