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► To cite this version:

Surekha Thota, Gopal Krishna Shyam. Blockchain Based End-To-End Tracking System for COVID Patients. 4th International Conference on Computational Intelligence in Data Science (ICCIDS), Mar 2021, Chennai, India. pp.177-186, 10.1007/978-3-030-92600-7_17 . hal-03772942

HAL Id: hal-03772942

<https://inria.hal.science/hal-03772942>

Submitted on 8 Sep 2022

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Blockchain based end-to-end tracking system for COVID patients

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Abstract. COVID-19 pandemic had disrupted the health, social and economic stability throughout the world. Centers for Disease Control and Prevention (CDC) had proposed various strategies to minimize the spread of virus; the government is implementing these strategies to take good care of victims. Depending on the severity of symptoms, COVID positive patients are either home quarantined or admitted to the hospital. Two essential facilities that ensure a hassle-free journey for COVID patients are i) publicly available transparent hospital management system that publishes the availability of COVID beds. ii) a transparent list of suppliers that delivers food and medicines to the home quarantined patients. Our proposed model i) builds an end-to-end tracking system for COVID patients ii) enables patients to choose their preferred hospital by checking the availability of beds and iii) guarantees a fraud free vaccination system.

Keywords. COVID · coronavirus · blockchain · hospital tracker

1 Introduction

COVID-19 pandemic has taken the lives of many people all over the world. Millions of people are infected globally with coronavirus; the infection rate is increasing exponentially. This pandemic has not only disrupted the health but also left uncertainty in the world's economy. Researchers are identifying ways to stop this prolonged uncontrollable spread of the virus. They are trying to discover the vaccine to protect the human body against coronavirus. Centers for Disease Control and Prevention (CDC) and the government are enforcing various strategies to minimize the spread of the virus.

Some of these strategies are implementing strict lockdowns, maintaining social distancing, promoting regular handwash, and mandating people to wear masks, closing infected areas by indicating them as red zones. Implementing these precautionary measures could delay the exponential rise of infected cases. This delay gave sufficient time for the government to create the following facilities:

- manufacture COVID-19 test kits and PPE kits
- build rehabilitation centres
- increase hospital beds and ventilators

India is the second-largest populated country in the world. In such a highly populated country, it is difficult to provide treatment for all the COVID victims. The following are some of the challenges faced by the government, hospitals, and the public

(a) Challenges faced by the Government

- Lack of Facilities: During the initial days of COVID, the country struggled with insufficient COVID-19 test kits, PPE, sanitizers, masks, hospital beds, and ventilators. The situation had improved drastically with time.
- Lockdown:
 - The economy was deprecated as many businesses were closed due to lockdown.
 - Unemployment due to shutdown of educational institutions, shopping malls, and cinema halls etc
 - Migrant workers moved to their natives during the lockdown and hence industries struggled due to the unavailability of workers.

(b) Challenges faced by Hospitals

- Doctors, nurses, and hospital staff are at high risk
- COVID patient's inflow is more compared to patients who are getting discharged

(c) Challenges faced by people

- During the lockdown, the government and NGOs distributed subsidized food to the daily wagers and people below the poverty line. Still, they faced a lot of economic distress as they could not go to their work.
- Due to the sudden loss of jobs, people who want to go back to natives faced transportation issues.
- Employers are battling for existence, whereas employees are suffering from job loss or salary deduction
- Patients with mild symptoms are home quarantined and need to have a supply of necessities like milk, medicines, and food.
- Patients with moderate to severe symptoms, elderly, people with other ailments like diabetics, blood pressure need to be admitted to hospital. Governments are trying their best to accommodate and provide treatment for all the people who have moderate to severe symptoms. Initially, there was no transparency in the vacancies of beds and ventilators; patients were going from one hospital to another in search of the hospital bed. Later the situation is improved with the COVID positive hospital bed management system (CHBMS) [6].

Our paper aims to propose a solution that considers the user's preferences when multiple vacancies are available for hospital beds. It also tracks end-to-end details of COVID patient.

2 Literature review

It's a well-known fact that the COVID-19 infected cases will be increasing till the right medication and vaccination are discovered. India is the second highly populated country in the world, it is challenging to provide a medical facility to 1.38 Billion people. In India, as of today, there are two ways a COVID patient can get admitted to the hospital.

1. Private quota – Patients can directly contact the hospital and get admitted. Medical expenses for treatment have to be borne by the patient.
2. Government quota - Patients get admitted through Government referral. As per circular dated 4th of August 2020 from Commissionerate health and family welfare services, Government of Karnataka, all the referrals from BBMP (Bruhat Bengaluru Mahanagara Palike) admissions are done through COVID positive hospital bed management system (CHBMS) [6] [7].

The protocol for filling the Government quota seats are as follows:

- On validating and approving the details of the patient, the special commissioner(Health) shall block the bed in the CHBMS portal preferably in Government Medical Establishment.
- The information on allocation of beds will be intimated to patients and hospital for further action.
- The admissions and discharges through government referral should be recorded through CHBMS [6] [8]. The dashboard of bed availability is shown in Fig.1.

Fig. 1. COVID-19 Hospital Bed status – BBMP

Government Quota Covid-19 Beds
(As on 05 January, 2021)

Sr. No.	Facility	Allocated	Occupied	Available
1	Government Hospitals	965	192	773
2	Government Medical Colleges	549	199	349
3	Private Hospitals	0	0	0
4	Private Medical Colleges	0	0	0
	Sub Total (Hospitals)	1,513	391	1,122
5	Government Covid Care Centers (CCC)	100	75	25
	Total (Hospitals + Govt. CCCs)	1,613	466	1,147

Private Arrangements By COVID-19 Patients

Sr. No.	Facility	Nos.
1	In Private Hospital - Private Bed	1,554
2	In Private Covid Care Centers	115
3	In Home Isolation	5,545

Domain and technology go hand in hand. Blockchain's greatest characteristic stems from the fact that its transaction ledger is open to all. Hence, we can apply blockchain to provide an end-to-end tracking system for COVID patients. Research is being carried out on how blockchain technology can help to ease the administration during COVID pandemic. The framework proposed in [1] detects the unknown infected cases and predicts the contagion risk. It aims in building a blockchain-based P2P-Mobile application for helping the citizens to detect the sources of contagion in a crowd.

Blockchain-based infectious disease reporting system built-in [2] eliminates intermediaries and accelerate the process. It removes the possibility of data falsification and provides transparency to the monetary donation system. The author of [3] tries to explore the medical applications powered by blockchain and how these trustless systems can resolve the tension between maintaining the privacy and addressing public health needs in the fight against COVID-19.

Paper [4] proposes an architecture by integrating blockchain and AI-specific for COVID-19 fighting. SWOT analysis on blockchain-based prediction model in healthcare is carried out in [5]. It assures that blockchain plays its role to improve COVID-19 safe clinical practice. For COVID-19 test-takers [9] implements immunity certificates and digital medical passports (DMP).

The existing hospital tracking systems are confined to a specific hospital in a region or state. But the proposed solution is a global tracking system through which patients can easily track the availability and look for nearest possible hospitals. It also helps to connect various service providers and patients.

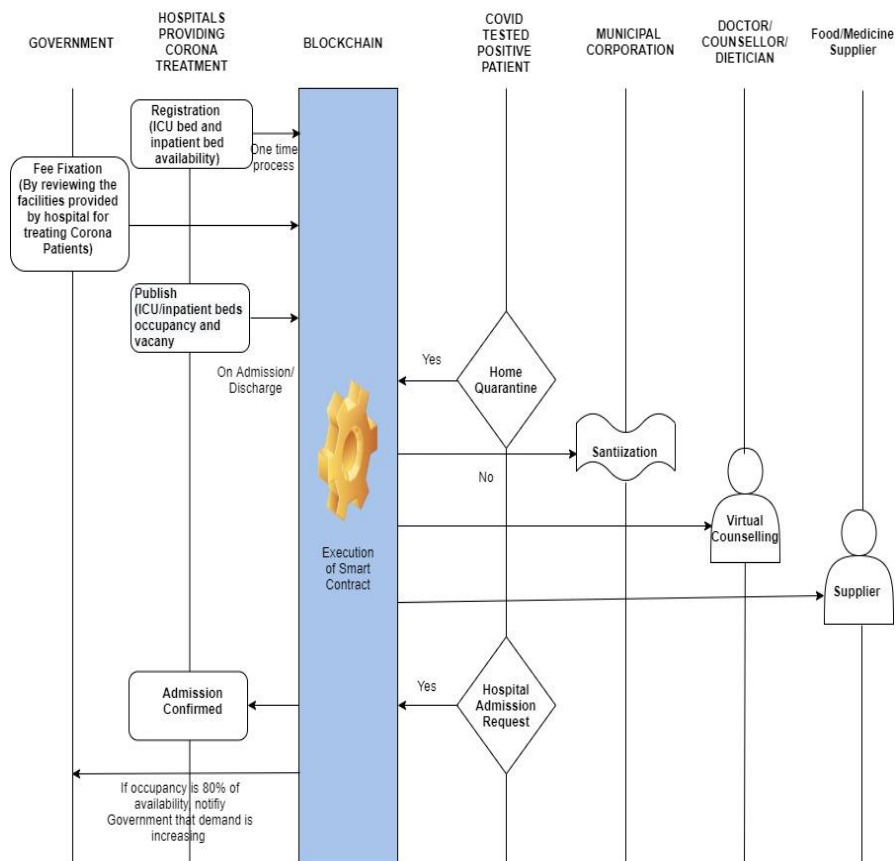
In this paper, we take a step ahead to propose a blockchain based COVID Hospital tracker that provides transparency between the hospitals, medical stores, food suppliers, government, municipal corporations, and patients. Blockchain adds an unprecedented layer of accountability, holding patients, Government & Hospitals so that they act with integrity towards community. This immutable, decentralized and tamper proof nature of blockchain makes it safe from falsification of information and attacks. This considers patients preference, especially when multi-vacancies are available in various government hospitals.

3 METHODOLOGY

This paper proposes a blockchain-based transparent health care facility for people who seek hospital admission. We aim to build a blockchain based COVID Hospital tracker to ensure transparency between the hospitals, government, municipal corporations, and patients. In this proposed model, the government, hospitals, municipal corporations, and patients are various stakeholders and they represent different nodes in the blockchain. We track the patient's journey right from visiting test centers till vac-

cination. This system ensures transparency in displaying the bed availability by hospitals and eliminates any fraud or falsification of data. It not only verifies the authenticity of hospitals but also provides opportunity for the patients to choose his hospital of interest for treatment. The sequence diagram of the proposed methodology is represented in Fig. 2.

Fig. 2. Blockchain based end-to-end COVID tracking system



The following are various modules present in our COVID Hospital tracker.

(a) Registration

Hospitals providing COVID treatment must register to this blockchain. The authenticity of hospitals is carried out by MOH (ministry of Health). We intend to make this solution feasible beyond COVID. Hence the COVID and non-COVID beds are tracked separately. At the time of registration, hospitals should provide the total number of

- COVID-ICU beds

- COVID-Inpatient beds
- Non COVID-ICU beds
- Non COVID-Inpatient beds
- Ventilators

The below algorithm 1 depicts the sequence of steps involved in registering hospitals to the blockchain.

Algorithm 1: Hospital Registration

```

Input : caller, MOHEA
if caller == MOHEA and HospitalID is valid then
    Trigger an event to notify all listeners about the addition of new hospital
else
    Throw an error and rollback
end

```

(b) Publish Bed Availability

This model publishes the number of vacant general beds, ICU beds, and ventilators at each hospital along with Government and private Quotas.

- All hospitals have to provide the admission and discharge details daily
- The status of bed availability is kept transparent to patients
- To make this solution feasible beyond COVID, we monitor the number of COVID and non-COVID beds separately.

Hospitals must daily submit the below details

- COVID-ICU bed occupancy
- COVID-ICU bed vacancy
- COVID-Inpatient bed occupancy
- COVID-Inpatient bed vacancy
- Non COVID-ICU bed occupancy
- Non COVID-ICU bed vacancy
- Non COVID-Inpatient bed occupancy
- Non COVID-Inpatient bed vacancy
- Vacant Ventilators

The below algorithm 2 depicts the steps involved in publishing the hospital availability.

Algorithm 2: Publish Availability Hospital Update

```

Input : caller, HospitalEA
if caller == HospitalEA then
    Update the COVID_ICU_bed_occupancy, COVID_ICU_bed_vacancy,
    COVID_Inpatient_bed_occupancy, COVID_Inpatient_bed_vacancy,
    Non_COVID_ICU_bed_occupancy, Non_COVID_ICU_bed_vacancy,
    Non_COVID_Inpatient_bed_occupancy,
    Non_COVID_Inpatient_bed_vacancy, Vacant_Ventilators
else
    Throw an error and rollback

```

end

(c) Test Result tracking

- Each test kit is uniquely identified by a test kit serial number,
- This module tracks the patient's details with the test kit serial number and test results.
- If the patients are tested positive, the patient details are with health counselors, municipal corporators, medical and food suppliers.

The below algorithm 3 depicts the sequence of steps involved in patient registration and mapping patient to test kit. Whereas the algorithm 4 depicts the sequence of steps involved in test result tracking.

Algorithm 3: Patient - Registration

Input : caller, TestcenterEA
if patient has valid PatientID then
 Map PatientID to TestkitID
End
else
 Throw an error and rollback
end

Algorithm 4: Test result tracking

Input : caller, *TestcenterEA*
if caller == *TestcenterEA* then
 if patient == *PatientID*
 PatientID_Testresult = *Testresult*
 Trigger an event to alert the test results to the patient
 if *PatientID_Testresult* = "positive"
 Trigger an event to alert Municipal corporations, Doctor,
 counsellor or Dietician, food or medicine supplier.
 end
 end
else
 Throw an error and rollback
end

(d) Home Quarantine

- Patients who tested positive are home quarantined if they are pre-symptomatic or asymptomatic.
- Home quarantine information is shared with virtual counselors, pharmacies, dieticians, and municipal corporations to provide moral support to the infected people.

- During this quarantine period, they need home delivery of milk, groceries, vegetables, and medicines. So, details of the nearest suppliers are provided to them.
- The status of the home quarantine patients is tracked along with the symptoms they have and the medication they follow.

(e) Admission Requisition and allotment

- Patients having moderate to severe symptoms or other ailments may get admitted to the hospital.
- If the patient prefers admission through government referral. On validating the details of the patient, the special commissioner (Health) shall block the bed in Government Medical Establishment.
- If the patient prefers admission directly to a private hospital, he can visit the dashboard prepared in 3.2 and decide the hospital he wishes to admit.
- Based on the availability, hospitals confirm the request.

The below algorithm 5 depicts the sequence of steps involved in patient admission to hospital

Algorithm 5: Admission to hospital

```

Input : caller, PatientEA
if caller == PatientEA then
    Patient_preference = HospitalID
    If HospitalID has vacant beds
        Allot bed from HospitalID to PatientID
    else
        Throw an error and rollback
end

```

(f) Notification

In a particular city, if the bed occupancy reaches 80% of availability, then a notification can be sent to the government health officials about the rapid filling of seats so that they can plan for arranging more beds.

(g) Certification of discharge

The recovery status is noted along with his quarantine period

(h) Vaccination

In addition to end-to-end tracking, our model includes a transparent vaccination system. Individual wish to take vaccine can reserve the slot by specifying the choice of the vaccine. This Blockchain vaccination module eliminates frauds involved in enhancing your rank for vaccine eligibility. The patient's identity is mapped with the vaccine serial number, date of vaccination, and vaccine. While traveling overseas, this mapping acts as a passport for COVID vaccination.

4 Results

In this section, we discuss the implementation details and results of the proposed transparent end-to-end tracking system for COVID patients and a fraud-free vaccination system. It is implemented on an Intel(R) Core(TM) i5-1035G1 CPU@1.00 GHz, 8 GB RAM and 64-bit operating system. Smart contracts were coded in remix IDE using solidity programming language. These smart contracts are deployed in a private Ethereum blockchain network created using Ganache. To support payment on the network we have used Metamask wallet. Fig.3. depicts a sample tracker of a patient who got admitted to private hospitals and also the sample record for the vaccine tracking system.

Fig. 3. COVID + Tracker and COVID Vaccine Tracking System

COVID+ Tracker

Details of Patient

Unique ID :6541 1255 XXXX XXXX
Name : Bob

Details of Test Kit

Test Kit Serial Number :9876 5432 XXXX XXXX
Date of test : 25 December 2020
Test Location : PQR Hospital

Home Quarantine : No
Beginning of Quarantine period : 26 December 2020
End of Quarantine period : 12 January 2021

Admission Details

Private/Government Referral : Private
Unique hospital ID :6754 5234 XXXX XXXX
Hospital Name :ABC Hospital
Date of admission :27 December 2020
Date of discharge :04 January 2021

COVID Vaccine Tracking System

Details of person taking Vaccine

Unique ID :6541 1233 XXXX XXXX
Name : Alice

Vaccination Details

Vaccine Name: XYZ
Vaccine Serial Number: 1234 5678 9876
Date of vaccine: 06 January 2021
Front line Worker: No

5 Conclusion

Today's Hospital Management systems are limited to a particular hospital and are not transparent. The proposed COVID hospital tracker powered by blockchain technology brings transparency among government, patients, hospitals, municipal corporations, food, and medical suppliers. As the complete process is automated, the processing is faster without delay. This proposed solution can work beyond COVID. We also have introduced a transparent vaccination system that eliminates fraud during vaccination.

As part of the future scope, we draw some conclusions, by analyzing and implementing AI and ML algorithms on the recordings of COVID symptoms, medicines used, and the recovery details.

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