

Scoping Analysis of Leveraging IoT with Blockchain for Monitoring and Ensuring Efficacy of Vaccine Cold Chains

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Abstract- *The recent pandemic has brought an unprecedented tangible effect on the adversaries of understanding the importance of Vaccines. Prior to this situation there were scenarios where the drip in Vaccine efficacy has affected the public health sector and even the Government's. Vaccination is the only assertive way of procuring immunization against such deadly pandemics. This study discusses such events which motivated the need of managing and monitoring the vaccine supply chain. The applications of IoT and Blockchain have been depicted and converged in this regard. Blockchain is the apparent solution to manage and monitor the vaccines effectiveness by delivering the same to the public health centers timely. Moreover, the counterfeit vaccines can also be identified. Internet of Things (IoT) has given a significant contribution in terms of fetching the real time readings in many applications. In our study temperature and moisture parameters are collected using Sensors in IoT and then the complete voyage of vaccine cold units will be monitored using Blockchain Transactions till it has been delivered. A framework is proposed on a Ethereum platform and consensus mechanism which will eventually avoid any possible alterations and counterfeiting of the deliverable Vaccine Units ensuring a safe transit which will be accessible and transparent even to the receiving patients, healthcare members along with the Governments body.*

Keywords: *IoT, Blockchain, Cold Chain Units, Consensus.*

I. INTRODUCTION

In today's substantially super conjugated world through Technology, every aspect of one's life is disrupted and often challenged by various factors such as the epidemics and pandemics creating scenario of socio-ecolo-environ factors, especially the recent Covid 19 pandemic. Even today the

world is still in middle of this pandemic, since it's not completely subjugated. As per the current status of the journey of combating the Covid 19 pandemic, World Health Organization (WHO) along few other allies are constantly working on all possibilities. They are indulged in tracking the spread of the Pandemic, timely involving themselves in giving expert opinion to different nations, constant discussion with Health ministries, monitoring and regulating the medical supplies to the needed territories and above all they are highly rigorously involved in consultation to the nations and companies developing the Vaccines. Moreover the concern is more on the safe deployment and maintaining the effectiveness of the vaccines on delivering.

The History of vaccination says for itself that there had been many such instances when the efficacy of the Vaccine units before being delivered to the patients and Health care unit go compromised. And that affected not only the patients and healthcare systems but also the Government as well. The extent of seriousness related to Covid -19 vaccines efficacy is outrageous since this pandemic has not only affected the global village in Economic and Social fronts but also in terms of the Mental Health of individuals specially the ones associated with Healthcare workers. In a study, Artificial Intelligence was used to predict the possible chronic effects of Covid 19 pandemic on the mental health of healthcare staff's. The work deployed a data analysis model using Artificial Intelligence, initially depended on the Self-reported variables and then further implemented on Speech features [25] and variants of Bio Markers [26,27,28]. It also took inputs from the self-declared reports using predictor variables [22, 23, and 24]. This work intended to assist medical practitioners to

complete the work more objectively instead of the presently followed classification technique of Diagnostic and Statistical Manual of Mental Disorders (DSM-5). These facts about Covid-19 and its various effect on Human population has urged the necessity of coming out of it. And there the Vaccines importance is critical which was evident when WHO endowed Emergency Use Listings of few Vaccines. And that is where the importance of monitoring and keeping a track of the efficacy of vaccines becomes critical.

A. Covid 19

In the ultra-connected works of today's, the highly infectious disease which took the form of a pandemic since April 2020 has caused a huge number of deaths as of now. As per the data provided by WHO 1, 114, 19,939 number of lives are affected by this pandemic, of which total number of people who lost their lives is around 2470772 as of 23rd February 2021. Since the start around 223 nations are directly influenced and facing the havoc brought by this pandemic. Various supply chain management system has been on force since the outbreak which is directly handled by WHO.

B. Vaccination and Cold Chains

Covid 19 vaccination is now in use in many parts of the world. The elemental vaccination started in the month of December, 2020. As per the records of WHO, a total of One Hundred Seventy-Five Million (175.3 to be exact) vaccines has been supervised as of 15th February 2021. The Biggest challenge in the immunizing process is the administration of vaccines. The other side of the matter is, if the required temperature is not maintained throughout, it will not only potentially drop the efficacy of vaccines but the authorities won't be even knowing about it. So, a concrete and feasible solution need to be attained.

One of the largest supply chain in Australia KMPG proposed on the likely possible ways of optimizing the Covid Vaccine Supply Chain System. According to them in an article, there can be five different ways to optimize the supply chain system of Covid 19. These five points include Planning, keeping vaccines at correct temperature, Tracking and Tracing each unit, Ensuring integrity of Vaccine units and post vaccine tracking [29, 53].

C. Proof of Resistance (PoR) to Covid-19 Vaccinations

It is a notable fact that the Covid-19 vaccines are highly anticipated in excitement as it is believed to bring the world population out of misery created by this Pandemic. Having said that, study has shown that more often than not most of the population is reluctant to take this vaccine. It is the primary responsibility of the Government officials, Public Health front line members, scientists and engineers to convince and motivate people by Public Health Messaging (PHM). Anti-Vaccine thought process and belief gets cultivated in the groups and individuals if no adequate steps are taken in advance. Such thoughts could be because of the dis-trust in the authorized body's conventional strategies[30, 31].

D. Strategy to overcome

One possible scenario to elevate the proof of hesitancy (PoH) to proof of delivery chain (PoD) is by bringing transparency into the complete vaccine supply chain system. By having transparency about the vaccines credibility in terms of ensuring the parameters valid say Temperature, Humidity maintained throughout the process. That will keep each vaccine unit under the eyes of Health Care Members, targeted individuals and even the Central Authorities like Government and Health Ministries.

Henceforth our proposed framework is more like a Hybrid model comprising of Internet of things (IoT) and Blockchain Technology can be used in two separate phases.

E. Characteristics of Vaccine Study

In our study we have studied various types of Covid vaccines available. And from our study it was observed that the would be Vaccines in the United States only can be categorized into three variants. Table I is depicting all the three variants of vaccines which are on the surge of getting into third phase (large scale) of clinical trial in the United States (US), the key components on which they work upon in a human body and the source from where they are developed.

TABLE I. VARIANTS OF COVID-19 VACCINES IN US

<i>Variant Name</i>	<i>Key Component</i>	<i>Source</i>
<i>mRna</i>	<i>T-lymphocytes, B-lymphocytes</i>	<i>Covid Virus</i>
<i>Protein Subunit</i>	<i>T-lymphocytes, antibodies</i>	<i>Protein of the Virus</i>
<i>Vector</i>	<i>T-lymphocytes, B-lymphocytes</i>	<i>Weaker Virus(Viral Vector)</i>

However, on a generic front, globally, different countries are steadily developing the potential Covid-19 vaccines. All these vaccines are primarily meant to train the human body and its Immune system to precisely identify and obstruct the virus causing Covid-19.

These potential vaccines are understood on the basis of the following classifications explained by World Health Organization [37].

- 1) Inactivated Vaccines: This utilizes a form of virus which is weak. Such a form is expected not to cause any type of disease but on the contrary it generates a stronger immune response.
- 2) Protein Based: It uses innocuous speck of proteins which exactly resembles the Covid 19 virus and thereby generating a stringer immune response.
- 3) Viral Vector Vaccines: it make us e of another virus which is harmless but at the same time it is responsible for generating corona virus proteins in the human body to develop immune response.
- 4) RNA-DNA Vaccines: This also focusses on developing proteins in a human body from genetically engineered RNA / DNA.

Constructively, as of 24th February, 2021 on closely studying the status of Covid 19 vaccines in the periphery of World Health Organization's evaluation process there are few vaccines whose dossier is accepted for review and the Assessment Status is finalized.

TABLE II. STATUS OF COVID 19 VACCINES AS OF 24TH FEB 2021

Vaccine Manufacturer	Vaccine Name	Dossier Status	Assessment Status	Anticipated Date
Pfizer	COMBIVAX Tozinameran (BNT)	Finalized	Finalized	31-Dec-20
SK BIO/Oxford	AZD1222	Finalized	Finalized	13-Feb-21
Serum Institute-India	Covidshield	Finalized	Finalized	15-Feb-21
Stapharm	SARS-CoV-2 Vaccine	Finalized	In Progress	Early March, 2021
Moderna	mRNA-1273	Finalized	In Progress	Early March, 2021
Janssen	Ad26 COV2 S	Finalized	In Progress	In March, 2021

TABLE III. THREE* COVID 19 VACCINES, AVAILABILITY, SOURCE OF ORIGIN AND REQUIRED TEMPERATURE

Vaccine Name	Required Freezer Temperature	Max storage Time	Country of Origin
Pfizer	-80°C and -60°C	~30 days	US
Moderna	+2°C to +8°C	~30 days in refrigerator	US
Covidshield	+2 °C to +25°C	6 hours*	India

Vaccines Status_Total Count as of 24th February 2021. Upto this date there are 84 vaccines candidates under consideration. Of which only eleven are approved by at least one of the countries. Around 20 Vaccines are on the edge of getting approved as they are in the third phase of the Trial. 39 vaccines are in second phase and 29 Vaccines are in first phase of clinical trials. Table 4 illustrates a complete summary dataset

TABLE IV. VACCINE STATUS AS OF 24TH FEBRUARY 2021

Total Approved = 11 Vaccines
Phase-I Trials = 29 Vaccines
Phase-II Trials = 39 Vaccines
Phase-III Trials = 20 Vaccines

Internet of Things (IoT)

Supply chain management systems (SCM) need to be more technology driven in the 21st century when we are already in the moon light of Artificial Intelligence. IoT, as known, is the recent developments in Information technology. It is an obvious task of the organizations to unceasingly upgrade their SCM so as to make their logistics and services reach to correct audiences on time without any counterfeit [39]. There are few research scholars who are doing studies on IoT using bibliometric techniques [40] [49]. IoT basically gives the extra hand in closing the lore interlude in the modern supply chain

management by acquiring granular real time facts among each units, processes, and individuals in real-time. The concept of IoT is basically interpreted in three different forms, one (I) is middleware based often termed as Inter oriented, second (II) is sensors and devices based which is termed as things-oriented and thirdly (III) knowledge based which is predominantly understood as semantic oriented [41]. More importantly IoT can play a vital role in managing and maintaining the functional efficacy by rolling out the information flows from various sensors and smart devices [44]. The reports suggests that the contribution of IoT in Industrial market will elevate from 77.3 billion USD in the year 2020 to 110.6 billion USD in the year 2025 [45]. In our study IoT has the potential to make significant contributions in terms of monitoring the vaccines supply chain system. An application based surveillance system can keep a track of the vaccine cold chain systems providing periodic updates on the parameters taken care by the sensors. These parameters can be regularly monitored and updated to different entities throughout the voyage.

Blockchain Technology

In our study the conclusive thoughts were gathered and the measure of effect of Blockchain in terms of fighting with cold chain system is clinical. In an ever prolonged way of managing the pandemics, Blockchain can be effective in contact tracing of patients. During the course of the pandemic, several proposals were published which focused on managing the contact tracing of pandemic affected patients thereby to be alive in the fight of upcoming waves of Covid-19 pandemic. In that perspective a new framework by integrating blockchain along with the contact tracing applications becomes highly effective as it can manage the privacy of the patients in a big way [46].

In another study the use of non-pharmaceutical interventions (NPI's) has already been started and implemented in various countries across the globe which mainly focuses on deteriorating the spread of the virus or pandemic in place by lowering the contact rate of patients due to pandemics in the Public [49].

All these works has been proposed before the arrival of Covid 19 vaccines. Even now since the availability of vaccines in the Healthcare the cold chain management can be a greater concern since there were many instances in history where the efficacy of vaccines were not managed. Blockchain along with other existing technologies can play a commentative role in managing the True Efficacy if these vaccines. Henceforth, in our work, the prime development is by collaborating Blockchain with IoT for having a fruitful but effective Vaccines Monitoring system.

II. RESEARCH PROBLEM AND OBJECTIVE

The availability of Covid-19 vaccines till now are by far truly the result of the joint effort put up by different countries. Any blockchain application need to superintend all the made transactions and should monitor and regulate the economic aspects carefully.

Blockchain complements well with various existing technologies such as Artificial Intelligence, Cloud Computing, Machine Learning and Internet of things. Such coalescences are all the more promising when it comes to fact of handling the Vaccines Cold chain, especially in ensuring and thereby monitoring the efficacy of vaccines at the time delivery to the end recipients.

This research work looks forward aiming the possibility of bridging the gaps in ensuring the efficacy of Vaccines at the time of delivery. Our work revolves in the proximity of using Blockchain and Internet of Things.

IV LITERATURE STUDY

There is a considerable history of research based works to monitor the longing transportation of vaccines from one demographic to another. Moreover there are certain web and mobile based applications also, strengthening the reach of such vaccines to even cornered users.

One of the latest as per the best of our review conducted was a standalone way to contiguously keep a note of each and every physical expedition of vaccines, which includes a periodic contemplation of the temperature and humidity of the vaccine units. This cold chain observation used a unique way of using IOT based sensors for the same [1].

Around 25 articles were considered for the review and of which the filtration was based on consensus basis. Around 11 of which just gave different dimensions in which Blockchain can be utilized. We focused on Healthcare problems, as our objective was to propose a framework for Covid -19 vaccines. Twelve research articles were handpicked based on the adopted methodologies around the Covid-19 pandemic period particularly for the healthcare sectors. So the complete study is better understood as two phase study, wherein the first phase we try to wrap the contribution of Blockchain in Healthcare. Later in the second part role of IOT will be elaborated keeping in view its contribution in combating issues in handling Vaccines.

So when we talk about the Blockchain, it's vital to understand its pivotal role in technology. In the recent years, Blockchain grew into a promising tool, a resource which could be elementary and fruitful in dealing with larger sections of issues especially in this era of digitalization. Numerous ideas and proposals are available describing its contribution in combating Covid 19 pandemic.

It is quite inevitable that blockchain is expected to play a significant role in Covid -19 Pandemic. Even the post pandemic times would be highly promising with the evolution of Blockchain in different scenarios [3].

When we think about any pandemic or a disease its worthy to take a note of the balancing factor between availability of related vaccines with the efficacy of such vaccines when injected to a patient. The underlying fact of the matter is very critical to study and for a research. As per study conducted, in the 2018 itself, children who were deprived of getting the normal immunizing vaccines touched the figure of 13.5 million, adding to it the figure who died because of the

unreachability of such vaccines touched around 1.5 million [4].

When we studied vaccines it was fascinating to know certain facts published by World Health Organisation. Regarding the storage and conveyance specifications of the vaccines, released by world health organisation, which states that if the vaccines are kept beyond the temperature range of 2 degree to 8 degree celsius then only the virtue of vaccine is expected. If the specified temperature range is violated even for a shorter period of time, it will make the vaccine lose its puissance.

One of the major culprit contributors for this ineffective outreach of vaccines is identified as dereliction of cold chain in vaccines [5]. However there are many factors which alter the plain sailing management of cold chain system. Such factors include demographical, physical, social and economic front which combinely result in loss of 50% of the total vaccines. Interestingly the WHO has extended the guidelines along with equipped devices for unceasing scrutiny of the cold chain. But this was identified as rewarding only in developed countries, however in the case of undeveloped or developing countries about Thirty percent (30%) of the equipment's were not functioning or they got expired before it was available for use [6]. And the study led to a conclusive evidence and which also is an open fact that unlike in developed countries, the developing and undeveloped countries incur loss of about thirty nine (39.54%) percentage of vaccines at the delivery site due to less trained persons in such countries. At the same time Transportation of vaccines also incur a huge loss which is studied to be around Thirty Percent (30%), because of unregulated monitoring of the Vaccine units usually placed inside cold boxes [7].

That brings the concern lean towards the prospects of benefitting the Undeveloped or developing countries in terms of delivering the vaccines with best of the efficacy to the victims of a pandemic. For the contiguous and efficient monitoring of the cold units being transported quite a number of applications both mobile and web based has been researched upon [8, 9, and 10].

To the most part of these research works, data centric approach was identified by our study which was used to collect the information's fetched from the units about its coverage and hence the unreachable demographics were known. Unfortunately a cognitive approach to balance this issue by elevating the coverage of vaccines was not implemented.

The evident reality is that Blockchain is highly capable in sense that it's the most upright method of collecting such data, since Blockchain as its property says the data is undoubtedly unshakeable since it uses a decentralized ledger [11] [54].

R. Anderson, *et al*, proposed a method wherein the glaciation status of the cold chain units of vaccine was monitored but the only limitation to this was it fetched the information of only the sites where the unites are kept for delivery called as Delivery Station (DST). This was not compliance to be used for handling the status during transportation of the vaccines [12]. One system which functioned on Wireless Fidelity (Wi-Fi) enabled system instead on was also proposed which used a

Cloud based Sensors to store all the information specifically the data coming from all the cold chain units. It doesn't encompass the individual message sending capability [14]. But ultimately the downfall of such a system is obviously the fact that Internet availability at every location during the entire transportation of vaccine is also not feasible.

R. Chaudhri, *et al*, devised a cold chain monitoring system based on a sending system working on cellular network to broadcast temperature and static location information using Short Message Services (SMS). This observatory system is called as FonAstra cold chain system [13].

Out of such contributions to the recent Covid-19 pandemic we came across two such studies which used Blockchain technology for diagnosing Covid-19, one based on CT (computed tomography) images [17] and one based on Blood samples [18].

In one of the study Blockchain was proposed to be used as Distributed platform to fetch and store the medical health records (MHR) of a patient in a hospital. Then that data recorded using the IOT devices, for any further consultation with a doctor of an associated Hospital, will be sent to the Hospitals privately configured Cloud. The Ethereum platform is recommended in this study for building the blockchain application along with possibility of both public and hybrid blockchain schema is also discussed [19][20].

V. PROPOSED FRAMEWORK

Our proposal is functioning on the fundamentals of Block chain's Immutable feature and the complete process is sectioned into three separate phases.

Phase I: Data Acquisition

Phase II: Vaccine Units and Beneficiary Tracking

Phase III: Monitoring Vaccine voyage and Self Report Generation

Data Acquisition: Before discussing each of the complete sections individually, let's understand the fundamental working structure of the system. The blockchain system for the Vaccine Utilization and distribution will look as shown in figure 1.



FIGURE I. BLOCKCHAIN SYSTEM FOR VACCINE REGISTRATION, VACCINE USAGE, TRACKING AND ADMINISTRATION.

The proposed framework makes use of a distributed ledger as a Blockchain System is supposed to do. That is primarily used for keeping the record of the data received from the IoT devices used in the Vaccine Carrying and storage units. The IoT Devices and Sensors comprises particularly the Temperature sensor and Humidity Sensor of each vaccine carrying unit. The Vaccine Developing laboratories are marked as Vaccine Creators in Figure I, they are supposed to register the packed and fabricated Vaccines units prior Distribution. The registered devices are kept at the required temperature at the storage Units at a different location perhaps.

Vaccine Units and Beneficiary Tracking: Simultaneously, the complete process to demonstrate the registration process of Vaccines with beneficiary is shown in Figure II.

The patient or beneficiary initially initiates the process of registration by putting up a request for Vaccine Registration. However, the primary objective of registration process in this framework apart from being able to tracking of vaccines and beneficiaries, is keeping identity of beneficiaries as well as to avoid any alterations in the transactions.



FIGURE II STEP BY STEP PROCESS TO REGISTER VACCINES AT BENEFICIARY WITH THE BLOCKCHAIN SYSTEMS.

Each patient or the Beneficiary will also be registered at the medical health center before benefitted with the vaccines. Each registered beneficiaries are enrolled in the blockchain system with a Unique Identification Number (UIN). Initially, a Personal Secret key (PSK) is generated at the Beneficiaries end, this key is bases on the Unique Identification Number (UIN) of the patient.

After the secret key, a Hash Value is generated by the Blockchain technology. Each hash values signifies each registration. Based on the Hash Values generated,, a Blockchain Transaction is created and transaction hash values is sent as the stored data to the beneficiary by the Blockchain System[30].

To keep the personal identity of each patients intact and at the same time also identifying each correctly, a Merkle Tree Proof [48][21] concept is used here. The root node of the Merkle Tree will keep the Hash called Blockchain System Hash (BS_Hash) generated by hash of UIN and the PSK generated by the beneficiary / patient[32][33].

$$BS_Hash = Hash (Hash (UIN), Hash (PSK))$$

The root (BS_HASH) becomes the onus of a blockchain transaction digitally signed by the beneficiary and it is saved in for the Vaccine Log file (V_Log) deployed on block chain, indicating the preparedness of receiving the vaccine. At the receiving side, a mobile QR Code is generated using the Hash Values, which in turn generates updates in the form of notifications (including UIN & VUIN) and send it to all the actors of the blockchain system From the Vaccine storage units, the Vaccines units are distributed using the Vaccine Carrying Units. Every vaccine Unit is allocated a Unique Vaccine Unit Identification Number (VUIN)[22][34]. A set of IoT sensor devices are also installed in those carrying units. The data is also kept in the distributed ledger. The regular updates from the sensor devices is sent to all of the primary entities in the system, comprising of the Health Care Centers, Beneficiaries, Administrators, Doctors through SMS to the registered contact number. Based on the medical history of the patients, Doctors or Medical Health Supervisors / Nurses will validate each beneficiary and will also validate the Vaccines Unit[35]. This will store the mapping of UIN with VUIN in the blockchain system. The vaccines units with VUIN will also be mapped with the current Temperature and moisture reading from the IOT Sensor devices [23][31]. The mapping of Beneficiary or patients with the Vaccine carrying units is shown below in Figure 3.

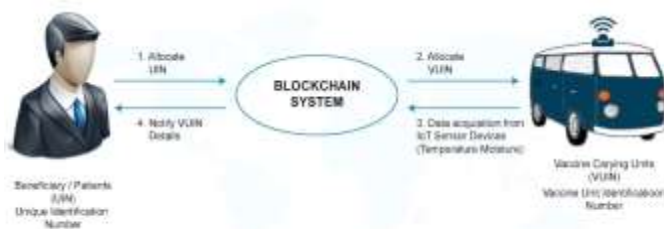


FIGURE III. MAPPING PROCESS OF UIN WITH VUIN

This will keep a clean record of the patient detail with the Vaccine details in the ledger.

Key Findings: The beneficiary can see the updated detail about the Vaccine Unit which is yet to be given to the patient. If the observed temperature from the complete log is following the minimum requirements, then the patient can accept the vaccine or he/she has the choice to reject and report it to the System. This is available as Self Reporting option in the Blockchain System[24][26].

Secondly, once the data is fed into the blockchain such as mapping of UIN, VUIN, and IOT sensor readings, this will remain unaltered till the delivery of vaccines. Hence, the tracking is genuine.

On the top of everything the Vaccine producer must create a template depicting a set of guidelines for storage parameters in

terms of temperature for the safer distribution and storage of Vaccines so that the efficacy of vaccines is maintained till the time of delivery of vaccines. Each of the set of guidelines is stored in the smart contracts for each IoT sensor devices in the Vaccine carrying units, and the same is verified each time a new reading is received.

Set_k: MinTempValue(T1)

$$\leq \text{MonitoredTempValue}(T) < \text{MaxTempValue}(T2)$$

The IoT devices are responsible to sign blockchain transactions containing the monitored data. By storing the monitored values and the rules on blockchain, the immutability and integrity of the data is assured [36].

Monitoring Vaccine voyage and Self-Report Generation Self-Report Generation: The target in this case is to limpud the extent in which the defined guidelines for vaccine storage and manipulation are fulfilled during the entire voyage coverage.

This can be attained using smart contracts that gauge persistently the received immutable data / readings from IoT sensor devices installed at Vaccine storage units or at the freezers used in the Voyage against the defined conditions rules stated in (1). The complete framework for monitoring every voyage is shown in Figure IV. To understand the monitoring process, all the devices are registered at first with Blockchain System for preparing Smart Contracts. The eight step process can be seen like the following:

- Step 1: All the Vaccine Units, Freezers and devices for storage are registered first with Blockchain System
- Step 2: Register all the IoT Sensor devices with the system from, I (Storage and Distribution Units)
- Step 3: Update New Devices if Any and update the Guidelines from the Vaccine producers from, I (Storage and Distribution Units)
- Step 4: Register IoT Devices from, III (Healthcare Centers)
- Step 5: Update New Devices if Any and update the Guidelines from the Vaccine producers from, III (Healthcare Centers).
- Step 6: Monitoring and Comparing IoT sensor data with the set guidelines by Vaccine producers.
- Step 7: Dispatching regular and timely updates to I, II and III
- Step 8: Monitoring Vaccine and Beneficiary updates.



FIGURE IV. MONITORING VACCINE VOYAGE DISTRIBUTION

Finally based on the delivery of vaccines, the beneficiary can generate a report by considering the observed parameters in step 6. Accordingly the patient can self-approve or disapprove the consumption of such vaccines if it does not meet the minimum temperature requirements during storage and distribution. Moreover, the Medical Health centers (MHC) can look upon the efficacy of such vaccines before clinical distribution to patients[27][38].

Implementation and Analysis

Work on Latency and throughput is a potential work in this domain. Depending on the maximum reach of price of a cryptocurrency in terms of availability for each transaction in a smart contract called as Gas Limits, may result in deprived scalability evaluated by the Gas limit on each block and as well as depicted by the block mining frequency in Blockchain. The consensus mechanism may also be deployed in order to increase the efficacy of the complete blockchain system. This will reduce the latency and thereby assist in increasing efficiency of the Energy consumption. Ethereum is compatible with various consensus algorithms so as to better the performance against combating covid 19 pandemic[28][29]. However, for studying the feasibility of the proposal, we have deployed a smart contract first. This smart contract is availed for the registration of all the main entities I, II and III shown in Figure IV. The vaccine creator which develops the vaccine and sets the guidelines will also initially set its own Ethereum signing address for the transaction which sets off the smart contract deployment. The Blockchain transaction for the same will be as follows:

TABLE V: REGISTERING SMART CONTRACTS IN BLOCKCHAIN SYSTEMS

Functioning	Smart Contract Implementation
Address for Signing (by Vaccine Creator)	0xG4562hU782564DF357r9vM451a3458B54T897CGF
Blockchain Transaction Details	transaction hash: 0x1gh4e3480pd86d89d7b456ghj985648970b9874j685a9e6h8n0kk6kjhg9856 from: 0xG4562hU782564DF357r9vM451a3458B54T897CGF to: VaccineLog.constructor transaction: cost 2564897 gas input: 0x568.....65324

Next we need to register a Medical Healthcare Center (Doctor's) for registering a Medical Unit as it is going to receive the Vaccines Units from the Distributors. Hence a medical Doctors who will administer such vaccines are registered on the Blockchain System as shown below in Table II.

TABLE VI: REGISTERING DOCTORS OF SMART CONTRACTS IN BLOCKCHAIN SYSTEMS

Functioning	Doctor / Medical Health Center (MHC)
Address for Signing (by Vaccine Creator)	0xG4562hU782564DF357r9vM451a3458B54T897CGF
Blockchain Transaction Details	transaction hash: 0x324knde6hj61sd6w06a6es56e36s5648sd8d3de336a2395dafd89a63s3akj8 from: 0xG4562hU782564DF357r9vM451a3458B54T897CGF to: VaccineLog.registerDoctor's(address): 0x125495F8H2s0643D2z8970k8A235g897a60FGA0D transaction: cost 568713 gas input: 0x897.....86c6sd

After the Doctors from MHC are registered then, the smart devices used for maintaining the temperature of the Vaccine units at the Storage and Distribution points also such as Freezing Units are also required to be registered in the Blockchain System [39].

TABLE VII: REGISTERING FREEZING UNITS FOR DISTRIBUTION

Functioning	Freezers in Transport
Address for Signing	0xG4562hU782564DF357r9vM451a3458B54T897CGF
Blockchain Transaction Details	transaction hash: 0x6ja89h084625hja435jhaaga34ah456a5a37a354qa6548d3dw65w23gt235132g from: 0xH7983hj558567YY354j5hG123m3568K465506JHG to: VaccineLog.registerFreezer(address, string): 0x986756J8F9n5642L5w4542a9E875k454a46K6HOE transaction: cost 951357 gas input: 0x861.....00000

TABLE VIII: REGISTERING BENEFICIARIES FOR RECEIVING VACCINES

Functioning	Registering Beneficiary
Beneficiary's Address for Signing	0xK7951IU253517UH321o9m1798d4357K45F387FHK
Beneficiary Hash	Merkle Root:0xlke5686565496w54g5eg46568wrrwg6w4565p3a6ad9fa8923sd6s5afj6s956s98
Blockchain Transaction Details	transaction hash: 0x56w9w985j9wd909w6584686wgh5268654s4ew468654w468g5w67b53g46w4658n from: 0x04654sI565468OE436j3sK568n5698U846836KDW to: VaccineLog.registerBeneficiary: 0x468765K4H5h9538Y8d6587s9K598k125j54I9D0U transaction cost: 654798 gas input: 0x612.....000644

VI. CONCLUSION AND FUTURE SCOPE

In this research work we have introduced a Blockchain system for the absolutely transparent and immutable way of monitoring the efficacy of the vaccines units and also tacking of the vaccines and beneficiaries in the long run. This proposed framework consists of trailing and tracing covid-19 vaccines by contiguously monitoring the initial registration of vaccines and beneficiaries, keeping them in storage units before leveraging distribution of vaccine in supply chain system, delivery at the MHC and the reporting of approval or disapproval by the MHC and patients by self-reporting. The tracking of voyages and its distribution among the patients is traced upon depending on the Set guidelines by the Vaccine producers. Those guidelines will comprise of the required minimum temperature and moisture in the Vaccine Units. The ethereum based blockchain solution encompasses the feasibility of the proposal with solutions having immutable entities registered and transaction data preserved in it. The UIN and VUIN along with observed temperature by IoT Sensor devices are regularly notified for monitoring the efficacy of the vaccine units to be delivered. Our proposal will a) monitor the effective efficacy of the Vaccine units, b) will maintain the transparency of the system by assuring the track ability of each units and c) provides a self-reporting

mechanism which in turn will be useful in understanding the handling of vaccine units during the voyage.

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