A Framework to Maintain Child Immunization Records in Secure Ethereum Blockchain-Enabled Platform

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Abstract:
As the number and type of diseases are growing throughout the world it is important to provide the vaccination to the child to immune them against the different types of disease, Specially, after the corona pandemic the importance of healthcare has increased and it is well understood that some secured and robust framework is required to store the vaccination information. In many countries around the world different vaccination are provided to the newborn baby but often these are maintained on paper or in a system that lacks in providing ease of audit transparency, immutability, , traceability and trust features. Due to the centralized nature of data maintenance, they are vulnerable to the single point of failure problem and also 24x7 availability of child immunization records cannot be guaranteed due to policies. These limitations tend to hinder the transparent, safe, trustworthy, secure and reliable maintenance of child immunization records. In this paper, we propose an Ethereum blockchain-based solution for managing data related to the child vaccination programme. We propose smart contracts to automate the traceability of records of child immunization programmes and vaccination along with ensuring data provenance, transparency, security, and accountability.

Keywords: Blockchain, Ethereum, Solidity, tamper-proof record, child immunization

I. INTRODUCTION

To protect a child from various diseases, an immunization programme is one of the key interventions for life-threatening conditions, which are preventable. In India, the immunization programme was introduced in 1978. In 1985 it was expanded as Universal Immunization Programme (UIP) [1] as the programme gained momentum and was planned to be implemented in a phased manner covering all districts in the country by 1989-90. UIP has now become a part of the Child Survival and Safe Motherhood Programme in 1992. Since 1997 immunization activities have been an important component of the National Reproductive and Child Health Programme and are currently one of the key areas under the National Rural Health Mission (NRHM) [2]. To prevent seven vaccine-preventable diseases under the Universal Immunization Programme, the Government of India provides vaccination for Diphtheria, Pertussis, Tetanus, Polio, Measles, severe form of Childhood Tuberculosis and Hepatitis B, Haemophilus influenza type b (Hib) and Diarrhoea. Today many private hospitals, practitioners, doctors, and agencies provide immunization at varied costs. However, these records are not stored in a database that can be accessed from anywhere. Only the guardians of the children maintain the immunization record on paper or maybe the hospital keeps the record of an individual vaccine. If the guardian losses the immunization record document it may be fatal for the child as there is a high chance of skipping the immunization or may be administered twice due to lack of information availability. This fatal situation may be avoided if the immunization record is maintained in a distributed manner without any tampering and third-party interference such that secured data availability can be provided. Also, it would be possible for government agencies to monitor immunization costs collected by different healthcare agencies. Even if the immunization card is lost the data available in distributed manner would help families to do the immunization safely such that double immunization or missing immunization can be avoided. Moreover, Government and Healthcare agencies can be well equipped with the stock of different vaccines if a record of a child vaccinated is available with them. Also, the vaccine production industry can benefit from this information. They can produce vaccines by estimating the population of a child due to a particular set of the vaccine.

Apart from this as parents are normally reluctant to share the health status of the child, such as allergic information, acute immune diseases information, critical condition of a child in some circumstances etc. However, if all such information is available that can help Healthcare agencies to better plan their activities in case of a pandemic and can prevent child mortality. In some cases, certain demographic areas are more prone to some kind of pandemic outbreaks. Such information can be broadcasted to critical child families to better help them. Also, it can help government agencies to better plan their free-of-cost services to special children, which may get missed by parents if it's only broadcasted through advertisements. Now as the child's family record is available, individuals can be informed about the government-free plan offered directly through phone calls or SMS services.

Maintaining a centralized record would not suffice our requirement as the data would be in the control of some registered agencies and is susceptible to being tampered with. Secondly, if the centralized server goes down data availability is hampered. Major requirements of 24x7 data availability and immutability can be provided by Blockchain technology.

In this paper, we propose a novel way of maintaining data using the Ethereum-enabled Smart Contract [3] mechanism to maintain the immunization record of the child on the blockchain. As the data gets recorded on the blockchain it becomes immutable, secure and robust. We propose to maintain the data on blockchain and access to this data can be provided to Healthcare Agencies, doctors, and families of children. As the data is available in a distributed manner all stakeholders will be benefitted. The vaccination generation industry can take advantage by getting information about the current immunized batch of children with different vaccines. They can plan their production for the next set of vaccines.

Smart Contracts can be triggered to generate messages to parents for their child's next vaccine. Critical condition children can be prevented during the time of pandemic as Smart contracts can be designed that monitor the outbreak of diseases and raises an alarm for critically ill children.

Properties like immutability, security and openness can be provided by Ethereum Blockchain in a robust platform to build applications. Ethereum-based Blockchain platform provides Smart Contracts and EVM. Smart Contracts are programs that are deployed on the blockchain and are programmed in a manner such that they are executed when a certain condition is met. Once the Smart contract is deployed on the blockchain it cannot be altered or tampered with by anyone. This is supported by the immutability property of the Blockchain. Smart Contract code is written in a higher language currently the language used to write Smart Contracts for Ethereum is Solidity [4]

The Smart Contract code is compiled into Opcode and Opcode is then converted to bytecode which acts as an input to the Ethereum Virtual Machine (EVM) that resides on all the nodes that are part of the blockchain.

In this paper, we have proposed a Smart contract that has been tested in a test Network provided for the Ethereum blockchain through a web browser known as Metamask [5]. Metamask provides four different test networks: Goerli, Sepolia and can be connected to the local blockchain using Ganache [6]

II. RELATED WORK

In this section, we discuss the different methods used to maintain Electronic Health Records (EHRs). Current EHRs are maintained by healthcare agencies and are in total control of them and patients do not have any access to their records. To use medical information patients are required to get these through health care agencies. An Attribute-Based Signature (ABS) [7] system using blockchain has been proposed to add the records to the blockchain platform and be endorsed by the patient using ABS. The patients can access their records which they have endorsed without any fee being charged. Different agencies are available which would provide the public/private keys to the patients. This paper uses the computational bilinear Diffie-Hellman. In another work, authors proposed a conceptual design [8] which is based on sharing personal continuous dynamic health data supplemented by cloud storage using blockchain technology to share health-related information in a secure and transparent manner. They have also employed machine learning techniques to introduce a data quality inspection module in order to have control over data quality. With an aim to enable users to have ownership, full control and sharing property of their personal health data in a secure manner, in form of a General Data Protection Regulation (GDPR) compliant. It also helps researchers and commercial data consumers effectively to collect high-quality personal health data for research and commercial purposes. Privacy of medical data is a big concern for many people and this is as explained and discussed in [9] how blockchain can be used to protect the privacy of personal data. The authors have also implemented a protocol explaining how a blockchain can be turned into an automated access-control manager without the need for a trusted third party which ensures users own and control their data. For the last few years, many research studies have started focussing on using Blockchain technology applications to store and manage healthcare data. Healthcare Data Gateway (HGD)[10] has been introduced as an application framework, which is based on blockchain and enables a patient to manage their own data in a secure manner with privacy. Healthcare systems intelligence was improved along with maintaining the privacy of user data. MedRec [11] has been developed based on blockchain that supports a decentralized health record management system that handles Electronic Health Records (EHRs). Patients can access their records in a distributed fashion from several treatment sites. All these systems mentioned maintaining a static record related to the health of a patient. As this data which is static requires less space and can be maintained easily on the blockchain.

The concept of an interplanetary file system (IPFS) [12] is a novel form of Electronic Health Records sharing architecture based on decentralized storage of blockchain and also is an e-health-based system on a mobile cloud platform. The smart contract concept of Ethereum blockchain technology increases the security of EHR. Access is granted to the user through a data-sharing protocol. The proposed model is tested on applications such as a mobile Android application and cloud computing which is provided by Amazon Web Services (AWS). Security analysis is also provided.

With an aim to provide reliable HER's accessibility to medical users[13], the technology of blockchain-based on Smart contracts is being used by doctors. This was a theoretical approach and misses many practical features such as flexibility, availability and identity management.

Blockchain technology in health can be assisted with four principles for policymakers [14]

1. Purpose where it can be applied and needs to be evaluated and fitted accordingly, after comparing it to alternative solutions.
2. Data Governance framework with regulatory alignment for Blockchain-based solutions must be evaluated for compliance with the solution.
3. All additions and implementations should not be applied as a whole but should be incremental.
4. All features like data privacy, usage, access and rules associated with ownership must be properly educated and delivered to the patients and stakeholders..

III. PROPOSED SYSTEM MODEL

In this work, we propose Ethereum Blockchain technology that uses solidity to deploy the child immunization smart contract by connecting to Metamask and ganache. The overall system works as follows:

The authorized health care agencies keep a record of child details as well as immunization details. Healthcare agencies, doctors, and practitioners may also register with these agencies. Agencies can be government agencies or government-authorized private agencies.

Child details are recorded in the system either by the doctors or by the agencies. Immunization records are provided to these agencies by the doctors. Once the immunization is given to the child, the same is verified and then after verification record is added about the immunization. Any family can then register in the system to check for the immunization record of their child. The flow of the proposed system is shown in Fig. 1.

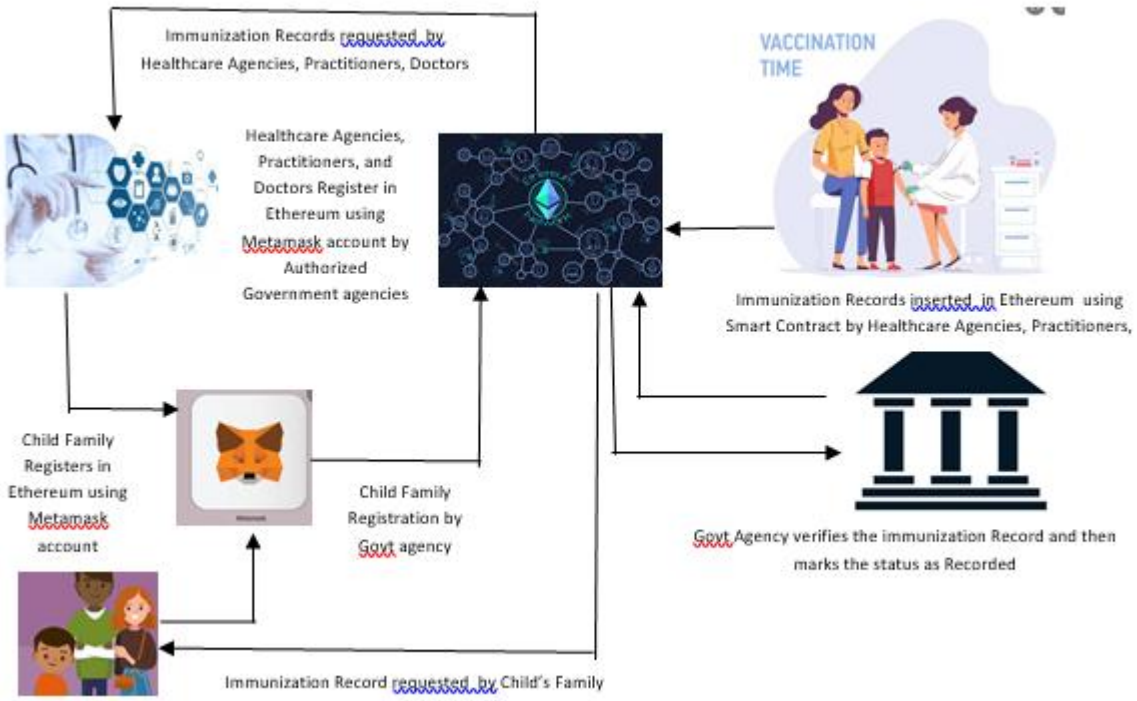

Fig. 1. Overall System Flow

The steps of the execution are depicted below:

- Step 1: Authorized healthcare agency deploys the smart contract. This agency is a government agency or a reputed agency which is authorized to register healthcare agencies, practitioners, doctors and families of the child to be immunized.
- Step 2: After registration healthcare agencies, practitioners, doctors and the family of the child are allotted a unique ID.
- Step 3: Once the immunization is given healthcare agencies, practitioners, and doctors then enter the child's details into the system and the status is set to "Given" and added to the blockchain.
- Step 4: Authorized government agency checks the immunization details and marks it as “Verified”.
- Step 5. The verified record then waits for more confirmations from peer records and then is provided with the status “Recorded”.

Step 6. Healthcare Agencies, Practitioners, Doctors and families of Children can retrieve immunization records.

IV. PROPOSED SYSTEM CONTRACT

The proposed smart contract is given below:

contract VaccinationRecord

Smart Contract in solidity has been designed with the following functions.

1. function AddChildDetails(

bytes32 _Remarks,

bytes32 _ChildName,

uint _ChildAge,

bytes32 _ChildMedicalDetails,

uint _ChildContactNo

)

public. This function adds Child Details

2. function AddImmunizationDetails(

bytes32 _Remarks,

bytes32 _DoctorName,

uint _DoctorContactNo,

bytes32 _DateImmunized,

uint _childId,

bytes32 _DateUpdated)

public { This function adds Immunization Details

3. function verifyImmunization(uint _ImmunizationId) public This function verifies Vaccination/Immunization Details.

4. function RecordImmunizationDetails(uint _ImmunizationId) public { This function records immunization/Vaccine details in the system.

5. function addHealthCareAgency(string memory _agencyType,string memory _agencyName,

address _addressID,string memory _contactPerson,

uint _contactNo,string memory _agencyAddress,uint _pincode) public: This function adds agency data by accepting HealthAgency address ID

6. function getHealthCareAgencyData(address _addressID) public view returns(Agency memory agency): this function returns the Health care agency data administering immunization. In the case of doctors, it would return Doctor's Details

7. function getImmunizationStatus(uint id)public view returns(uint)- This function retrieves the status of immunization i.e "Given", "Verified" "Recorded"

8. function VaccinationList(uint start)public view returns(vaccinationDetails[10] memory temp)- This function would retrieve the status of 10 records at a time to enable the authorized agency to verify and record the immunization status.

The Smart Contract code has been added to github repository at: https://github.com/rashminielitkol/Child-Immunization/tree/main.

Sample Data Entry Record and simulation of the contract in remix ide:

Step 1. Deploy the contract

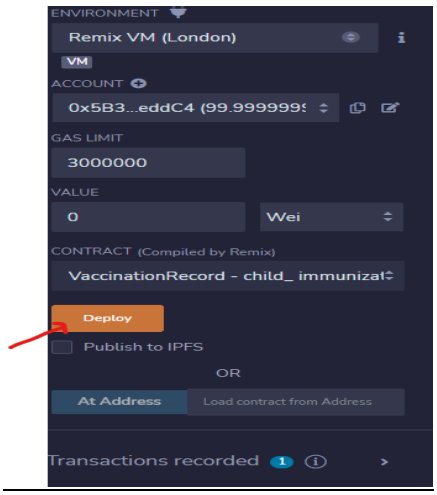

Fig. 2. Deploy the Contract

After Deployment following screen will appear:

Fig. 3. Screen after contract is deployed

Step 2: Register healthcare agencies

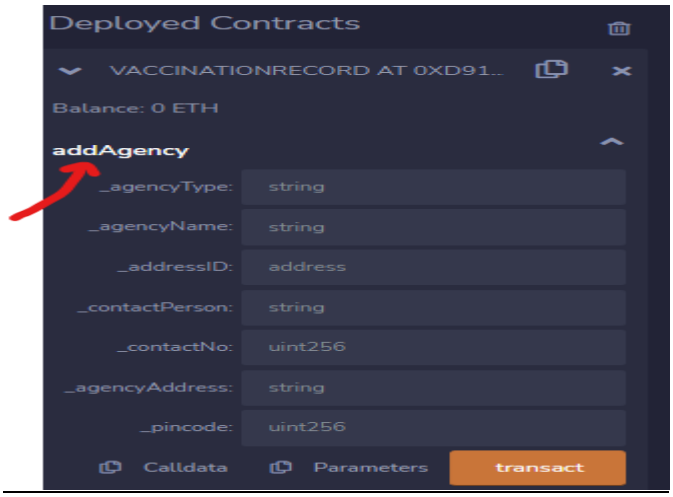

Fig. 4. Screen for adding Agency

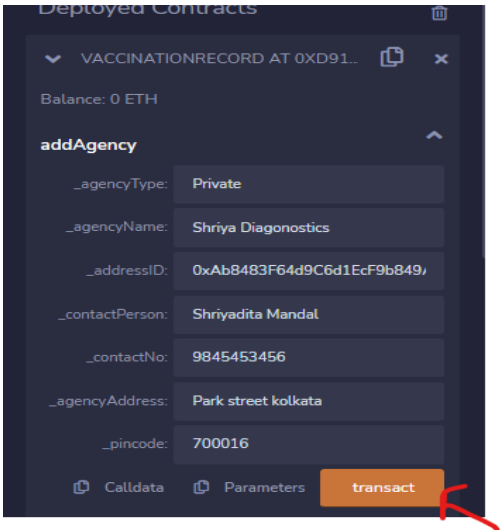

Fig. 5. Screen for transacting addAgency tab

Check the log for successful transaction:

Fig. 6. Screen after contract is deployed

Step 3: Add one more agency of Type Government

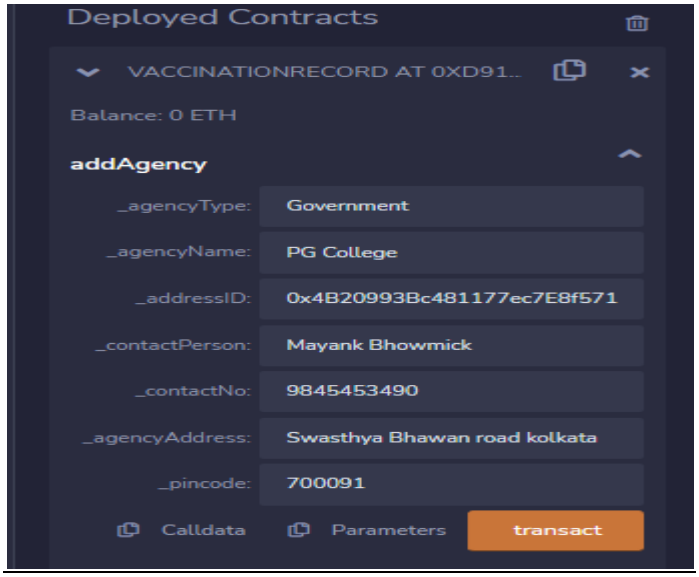

Fig. 7. Screen for adding one more agency

Step 4: Now move to account two which is the account address for first agency registered:

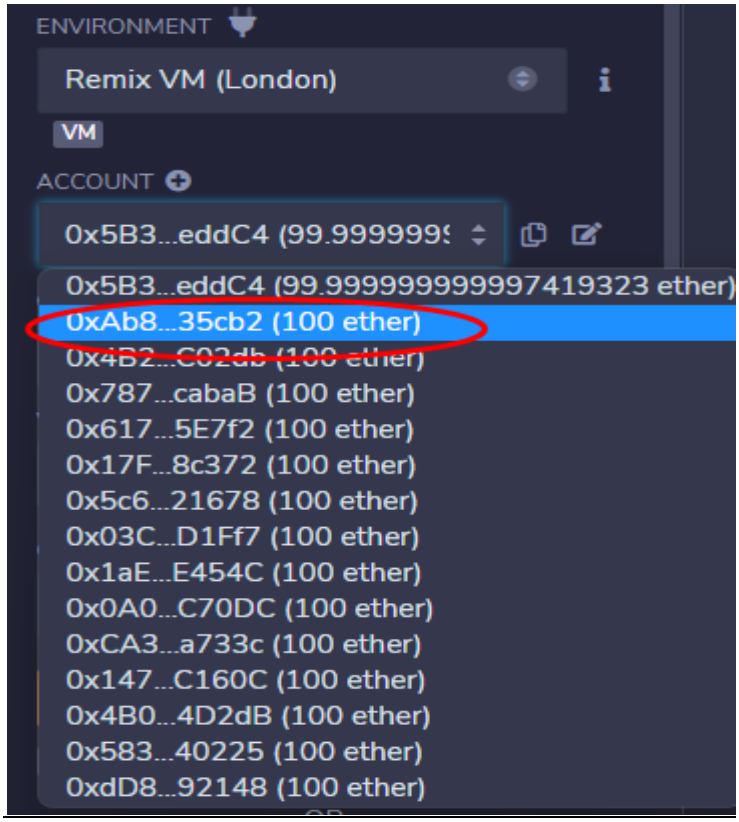

Fig. 8. Screen selecting second account

Step 5: Now add childs details:

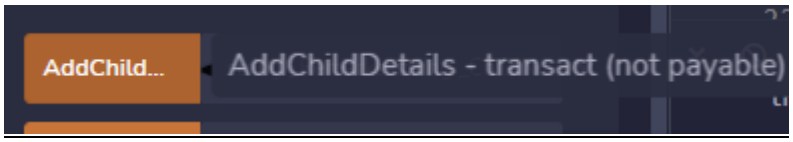

Fig. 9. Screen for AddChild function

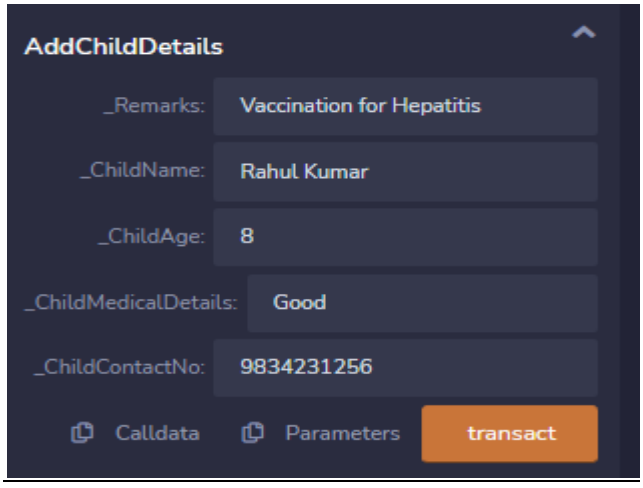

Fig. 10. Screen for adding child details

Check the log details . Child ID created is 1

Fig. 11. Screen for checking the log details

Step 6 : Move on to add more child details with second account:

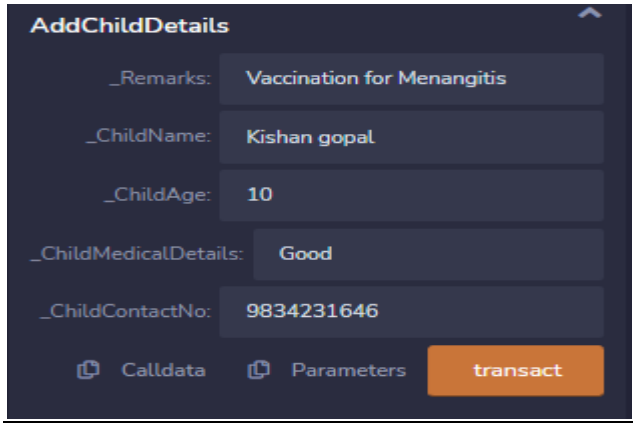

Fig. 12. Screen for adding child details

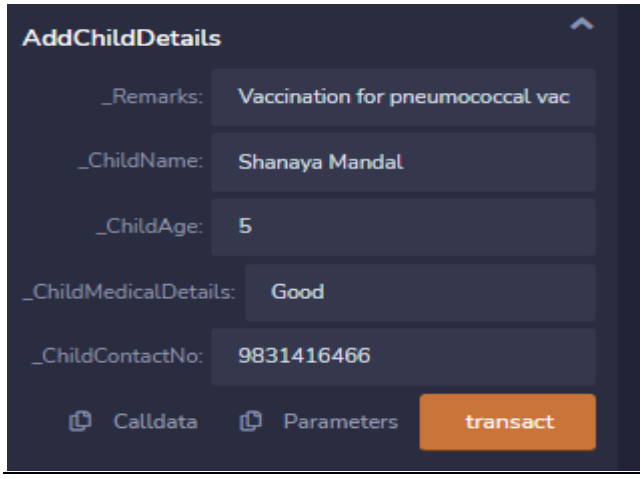

Fig. 13. Screen for adding another child details

Fig. 14. Screen for log details for added child information

Step 7: Now switch to third account. Then add one more child detail

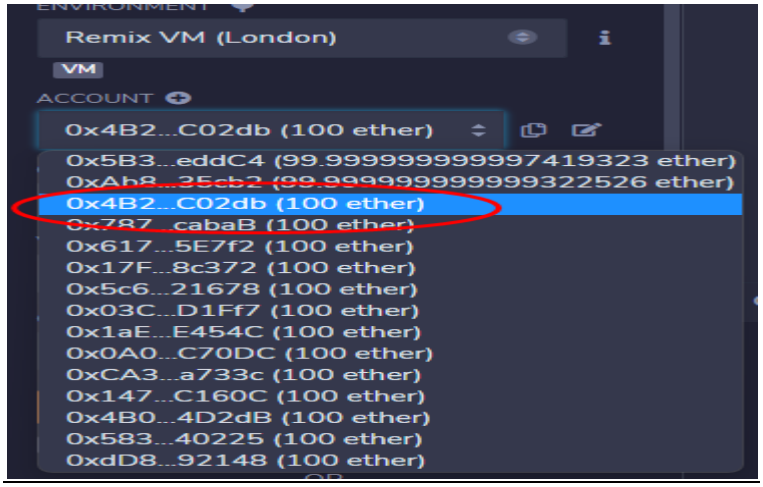

Fig. 15. Screen for switching to third account

Step 8: Add one more child detail with third account

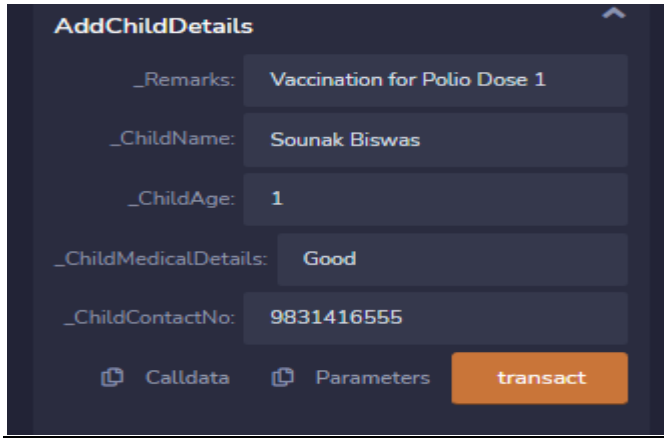

Fig. 16. Screen for adding child details

Check Log:

Fig. 17. Screen for log details

Step 8: Check total children added to the system:

Fig. 18. Screen for checking the function for total children added

Step 9: From owners account you can also check the agencies details:

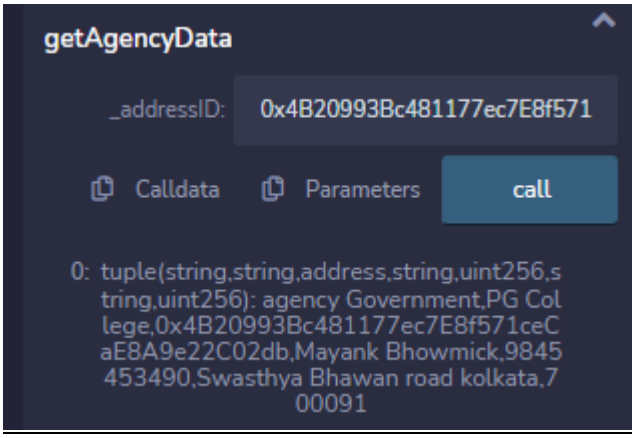

Fig. 19. Screen for get agency Data

Also total number of agencies registered:

Fig. 20. Screen for Total number of agencies registerd function

Step 10: Now let us add the vaccination details:Select the details for Child with id 1.

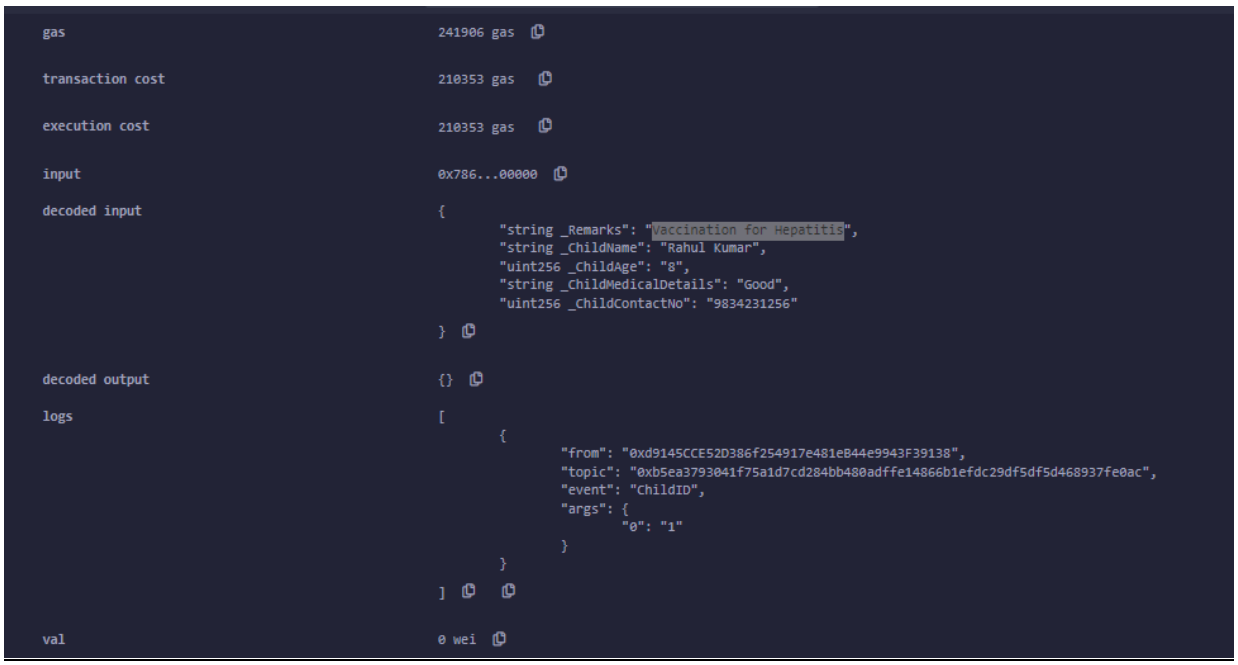

Fig. 21. Screen for selecting child details

First switch to second account:

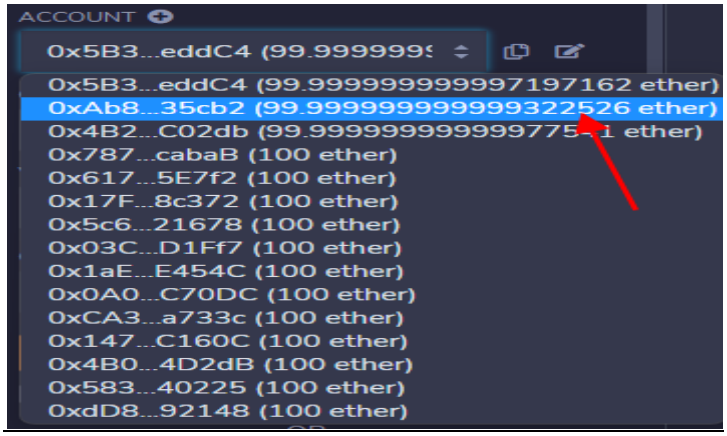

Fig. 22. Screen for switching to second account

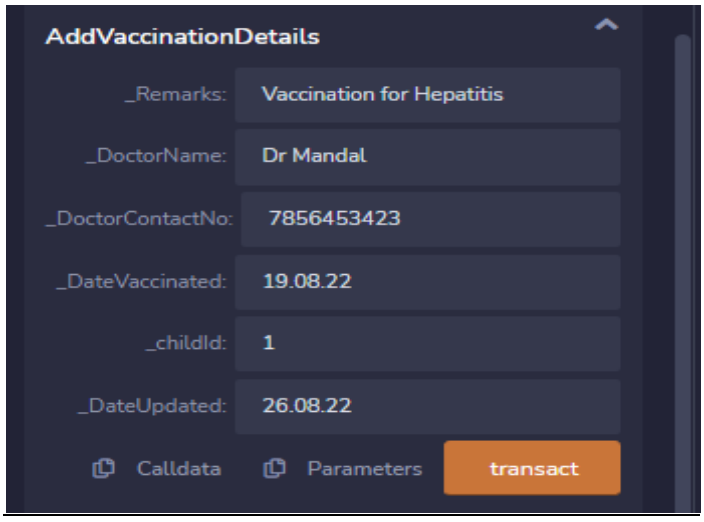

Fig. 23. Screen for adding Vaccination details

Click on Transact and check the log:

Fig. 24. Screen for checking Log

Do for second child also:

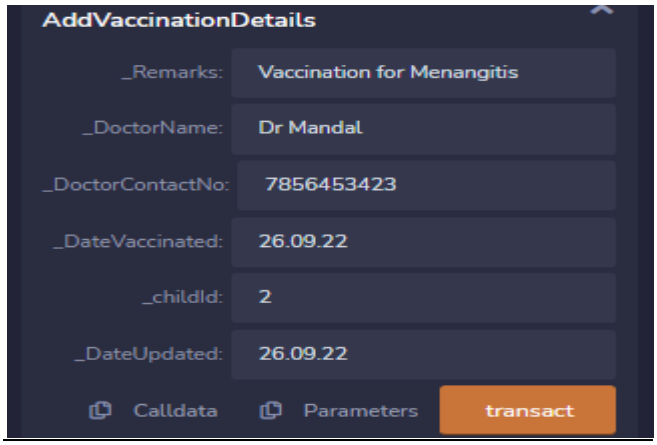

Fig. 25. Screen for adding Vaccination details

Similarly for child Id 3:

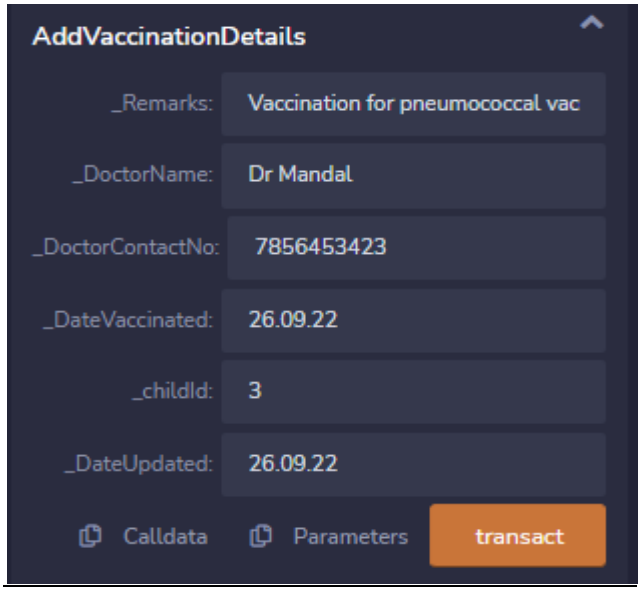

Fig. 26. Screen for adding one more Vaccination details

Step 11: Now switch to owners or Admins account :

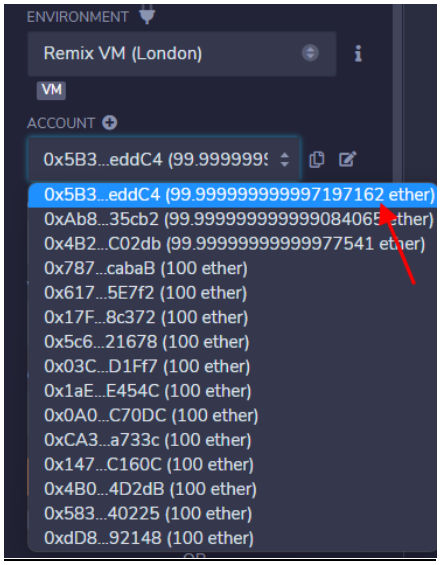

Fig. 27. Screen for switching to owners account

Step 12:Now Verify the Vaccination

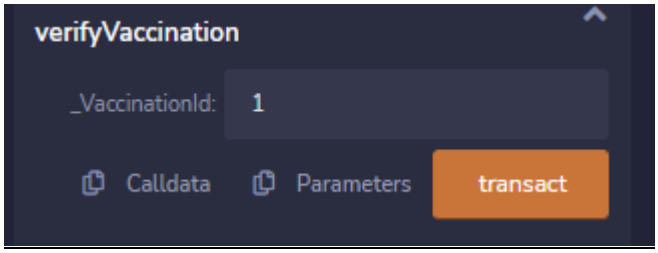

Fig. 28. Screen for verifyng the vaccination

Fig. 29. Screen for Log details

v. CONCLUSION

The proposed framework has been designed for manifold benefits. First, the child immunization record will be digitized and will be available anywhere. Henceforth the loss of the vaccination report of a child will not be a problem. Guardians also do not need to carry the vaccination report every time they are visiting the doctor. Second, the government will have a clear view of the vaccination required and also predict the outburst of some specific diseases region-wise. Third, based on the requirement of the vaccines pharmaceutical companies can prepare their manufacturing plan. Fourth, as the system is developed in blockchain the inherent benefits of blockchain will be available such as secured and tamper-proof data, 24x7 availability etc.

The proposed system can be extended in multiple dimensions. Based on the data collected from the system different predictions can be done to identify possible pandemics/outbursts of disease. Different machine learning algorithms can be applied to do this forecasting. Moreover, in order to involve the guardian in this system's front-end application, mobile applications can be developed so that the guardian can download the report anytime and also reminders can be sent to the guardian to follow the schedule of the vaccines..

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