Prediction of Dengue Infected Areas using A Novel Blockchain based Crowdsourcing Framework

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***Abstract*—The impact of global transformation due to mosquito-borne diseases like dengue is noticeable and according to the World Health Organization, approximately 96 million people are infected by dengue per year. Moreover, the climate of tropical countries, e.g., Bangladesh is highly in favor of dengue. The initiatives taken by different organizations every year are not enough to face the challenges of dengue. To mitigate the effect of dengue, we propose a distributed crowdsourcing framework, the *Dengue Tracker System* in which the infected patients and the conscious citizen can submit the possible infectious locations. With the submitted data, two separate heatmaps can be generated so that the people and the concerned authority can get ready to face the challenges of dengue. Moreover, the system is deployed on the Ethereum-blockchain to enhance the security of the system. To prevent fake location data, different token generation methods are implemented.**

***Index Terms*—crowdsourcing, dengue, distributed, blockchain, ethereum, token generation.**

I. Introduction

The global incidence of dengue caused by Aedes Aegypti (yellow fever mosquito) has grown dramatically in recent decades. Tropical and sub-tropical countries, like Bangladesh, are the victims of the dengue virus. The yellow fever mosquito can spread the virus of dengue fever, chikungunya, and zika fever, all of which can significantly damage the overall health condition of an individual.

Dengue fever is said to be the most influential disease of individuals with almost moiety of the world's inhabitants being in regions of danger. According to the report of the World Health Organization (WHO), 67 to 136 million people are infected every year by the dengue virus (DENV). It is not possible to solve the problem but possible to minimize. Many healthcare systems, medical data evolution systems, life insurance companies solve large problems with the help of crowdsourcing as it offers easier and less complex solutions. In this paper, we present an etherum blockchain-based crowdsourcing framework to mitigate the effect of dengue with some prevention criteria. If we think about the dengue virus, the reproduction of the Ades cannot be stopped since the monsoon comes every year. There are three ways to transmit the dengue virus [1] which are as follows:

- Mosquito-to-human transmission: When a female infected mosquito bites the human body, the virus is transmitted.
- Human-to-mosquito transmission: Even the mosquito can be infected from an infected person.
- Other modes of transmission: From a mother to her baby.

The dengue virus is said to be the world's fastest-growing vector-borne disease. However, most of the countries failed to minimize their impacts, especially the developing or poor countries.

There has been no significant study found in the literature that aims to prevent the growth of dengue with the help of mobile devices. Several works [2]–[10] have been implemented using various crowdsourcing methodologies. All these works claimed that they have found out the optimal solutions. However, these works have pros and cons and there is no such work to prevent vector-borne diseases.

The *objectives* of this work is to propose a distributed system that is based on ethereum-blockchain to identify the dengue infected places accurately and in a faster manner. The main *contributions* of this research are the followings:

- We have developed crowdsourcing strategies using public blockchain where the users do not need any knowledge of blockchain technology to use the system.
- We have used cryptographic schemes to ensure the proper identities of legitimate users, thereby protecting the system from falsified data.
- We have generated two different heatmaps based on the input given by the patients and the conscious citizen, respectively.

The rest of the paper is organized as follows. Related terminologies and existing works are discussed in the Section II. Then we describe ins and outs of our system in proposed solution, *Dengue Tracker System* in the Proposed Solution Section III. In section IV, it is discussed the methods and technologies that used to make the proposed system work perfectly. In Section V, we show experimental results and screenshots of the *Dengue Tracker System*. Finally, we conclude in the section VI.

II. Background and Related Words

Arthropod vectors, i.e., mosquitos are major patrons of the infectious disease which is one of the most obvious reasons

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for the burden of human beings around the world [12]. It cannot be solved for good. But, we can minimize the effect of this problem. To minimize the effect of mosquito-borne diseases like dengue, we have built a novel crowdsourcing system based on ethereum-blockchain. Researches based on different crowdsourcing frameworks are becoming a new drift with the availability and excessive growth of the internet. And the blockchain technology has added a new dimension to these crowdsourcing frameworks. In the following subsections, we describe the terminologies, dengue virus-related works, crowdsourcing related works, on-chain, and off-chain related works respectively.

A. Preliminaries

1) Blockchain: Blockchain is said to be a sequence of blocks where digital information is contained. It also refers to a distributed ledger technology. In the early 1990s, a bunch of researchers described the basic idea of blockchain a long time before the creation of bitcoin. After a long period in 2009, Satoshi Nakamoto adopted the technology of blockchain and created bitcoin [11] which is one of the most used digital cryptocurrencies. If we store some erudition inside a blockchain, it becomes very tough to modify. Each block of a blockchain contains three things such as some data (i.e., transaction data for bitcoin), the hash of the block, and the hash of the previous block. The application of blockchain is not limited to cryptocurrency. Now, blockchain can be used for banking, crowdsourcing, medical records, life insurance, taxations, ride-sharing services, home delivery services, e-voting, IoT and so on [13].

2) Ethereum: According to the ethereum.org that ethereum is the world's programmable blockchain. And it was launched in 2015. Ethereum blockchain is a platform that offers any developers to develop next-generation distributed applications, also known as dApps.

3) Smart Contract: A smart contract is a tiny computer program code stored within a blockchain. Smart contracts are just like real-life contracts. The only exception is that they are entirely digital. we can define the smart contract in a way that a smart contract is a set of tiny computer program-code between more than one party that runs on the top of a blockchain and composes a set of edicts which are accepted by the associated parties.

4) Crowdsourcing: The term *crowdsourcing* is the combination of two different words *crowd* and *outsourcing*. As the name implies, we can define crowdsourcing as a particular process where a person or an organization accomplishes to enhance their expertise with the help of a group of people on the internet by using their services, knowledge, or goods.

5) Key-pair Infrastructure: The process of encoding information is known as encryption in cryptography. In this process, the information is also known as plaintext, is converted to another format that is known as ciphertext by using some cryptographic algorithms. So, generally, we can say that encryption is a process of making a plain text into an unreadable format. Key-pair is one of the most popular cryptographic algorithms. Here, key-pair refers to the public and private keys. These public and private keys are a part of the encryption process.

B. Dengue Virus Related Arts

More than 80% of the entire population on the earth is in danger due to vector-borne diseases [14]. Among these vector-borne diseases, mosquito-borne diseases being the most substantial contributor. Dengue virus is one of the most popular mosquito-borne viruses. Ades Aegypti is the carrier of the dengue virus. About 2.5 billion people are at risk of dengue virus (DENV) infection and about 25000 deaths are reported annually [15]. According to the world health organization, about 100 million (ranging from 67 - 136 million) people are infected every year [16]. There two types of tests to identify the presence of dengue viruses in the human body. They are Immunoglobulin M (IgM) enzyme-linked immunosorbent assay (ELISA) and/or immunoglobulin G (IgG) ELISA. Generally, the test is performed after five days of fever. Since 2020, Bangladesh has to experience the dengue virus effect every year. Four major serotypes [17] DENV - 1, DENV - 2, DENV - 3, and DENV - 4 are the reasons for the dengue virus . The infection rate through the dengue virus is drastically increasing every year. In 2019, more than a hundred thousand dengue virus cases are reported. So, we need to draw a border for the dengue virus so that we can prevent it's spread.

C. Crowdsourcing Related Arts

We can think of crowdsourcing as a form of solving large problems with the help of many people. The number of people is not limited most in case. But, generally, the higher number of participants, the better the solution is.

1) Forms of Crowdsourcing: Basically, crowdsourcing comes in two different forms such as *crowd labor* and *co-creation*. When companies work in collaboration with the populace to create new ideas, polish existing ideas, ask for suggestions/feedback through groups and polls then we call the criterion *co-creation*. In contrast, *crowd labor* is when organizations outsource their jobs that are usually performed by the employees or third-party organizations. Algorithm creation, website designing, etc. can be done through crowd labor.

2) Categories of Crowdsourcing: We can categorize crowdsourcing into four cores. Such as -

1) Crowdsourcing itself
2) Open innovation
3) Crowdfunding
4) Shared knowledge

Open innovation is a democratic path to solve problems and polish existing ideas. When we want to gather information on a particular topic, we use the idea of shared knowledge. Crowdfunding is an effective way to raise funds for an individual or organization. Though open innovation type crowdsourcing often leads to bad ideas as the participants are common people mostly and they can lead the result to an unacceptable state, if it is possible to manage the data and avoid the fake data,

then crowdsourcing is an excellent idea for solving complex problems.

3) Crowdsourcing Platforms: As we have mentioned earlier that any type of crowdsourcing solution is based on either a centralized platform or a decentralized platform.

Centralized Crowdsourcing Platforms: One of the major challenges for a centralized crowdsourcing platform is to avoid the Single Point of Failure (SPOF). In this era of Internet, computer security related security threats [18] have increased a lot where cybercriminals use botnets [19] that are controlled by hackers in remote locations. Historically, centralized crowdsourcing systems have experienced several cyber-attacks in the last couple of years [2], [3].

Decentralized Crowdsourcing Platforms: Information tampering is a major fatal problem for decentralized crowdsourcing platform. The number of researches on designing distributed crowdsourcing systems is not absolutely less. To reduce the problem space across a set of cloud servers for constructing independent bipartite graphs and to solve the assessment in parallel Alfarrarjeh et al. [4] proposed a class of approaches that utilizes online partitioning method. Cheung et al. [5] proposed an asynchronous and distributed task selection algorithm for mobile crowdsourcing platform to help the users plan their task selection on their own. To achieve a minimum makespan, Zhan et al. [6] developed a dissemination protocol D2 in the Delay Tolerant Network (DTN). They aimed to complete the computational task collaboratively. All [4]–[6] claimed they have done it in a distributed way. But they had provided the service in a centralized manner. Apart from these distributed systems, we want our system to be more independent and more immutable. To handle task offloading and prevent information tampering, Xiaolong et al. [7] have designed a blockchain-based mobile crowdsourcing platform to salt down the privacy of the participants and kept the integrity of the service request and resources. But they didn't introduce the smart contract in their system. J. Park et al. [8] developed a data evolution system for the efficacy test of healthcare remedies. To participate in the evolution test, any participant needs to go to a specific set of questions to achieve bounty. But, to test healthcare remedies clinical trials offer more accurate results.

To address such problems, challenges, system boundaries, we have built our system in a way that the data is collected from common people through a very handy process. Moreover, a participant needs less than one minute to input his/her desirable location. And, this system is free for the patients.

III. Proposed Solution

A. Proposed Subsystems

The mosquito-borne disease dengue has created an alarming situation for the entire globe. No region can destroy the dengue virus for good as the monsoon comes every year which is breeding season for mosquitoes. But it can be minimized by creating awareness among people and, destroying the lying-in room of the Ades. To mitigate the effect of dengue, we have designed our system considering two different subsystems. They are:

1) For dengue infected patient ← We have used a key-pair infrastructure to generate login credentials for the dengue infected patients to enter into the system.
2) For non-infected / conscious citizen ← We have used an API server to verify the user's email address.

These two subsystems state how the system looks like from the users' point of view. These can be referred to as the top view of the system. The two subsystems work altogether to minimize the effect of dengue. In our system, the involvement of people is a must. To identify infectious places, we can't do anything without the people and they have no liability on what actions they would take. But, to prevent inputting fake location data, we are proposing an incentivized system which will be providing the followings-

- Token / Login credentials for the patient/conscious citizen to enter into the system to input location data.
- Bonus for a successful input.

1) System Model for Dengue Infected Patients: The methodology of this mass data collection system (based on key-pair infrastructure) will comprise the steps as follows:

- Designing smart contracts
- Deployment of smart contracts
- Mass data collection
- Filter and export data
- Generating heatmap

The above mentioned five steps can be depicted in Fig. 1. To elaborate, Fig. 1 states the following things.

- Admin will deploy the contract into the ethereum blockchain and call the function *addDiagnosticeCenter()* to add a specific diagnostic center. The main advantages of smart contacts are that they are open and irreversible. These are the main limitations too.
- The diagnostic center authority will add their doctors and employees through key pair method criteria.
- To serve the patients the doctors/employees will generate tokens which can be used as login credentials to access our system through our designed mobile app.
- The public address is stored in the contract and the private key is given to the patient through a QR viewer.
- The patient can scan the code and after scanning it, he/she can input the dengue infected location.
- After completion of the input, the geolocation data will be validated and then stored in the contract.

The fifth step of this methodology will be executed after the successful submission(s) of location data by the patients.

2) System Model for Conscious Citizen: The steps of this model are depicted in Fig. 2. In this criterion, we will let the people input the possible infectious places where Ades thrives. The steps of the model for the conscious citizen are as the followings:

- Log in to the mobile app that we have developed by choosing the option *continue as a conscious citizen*.

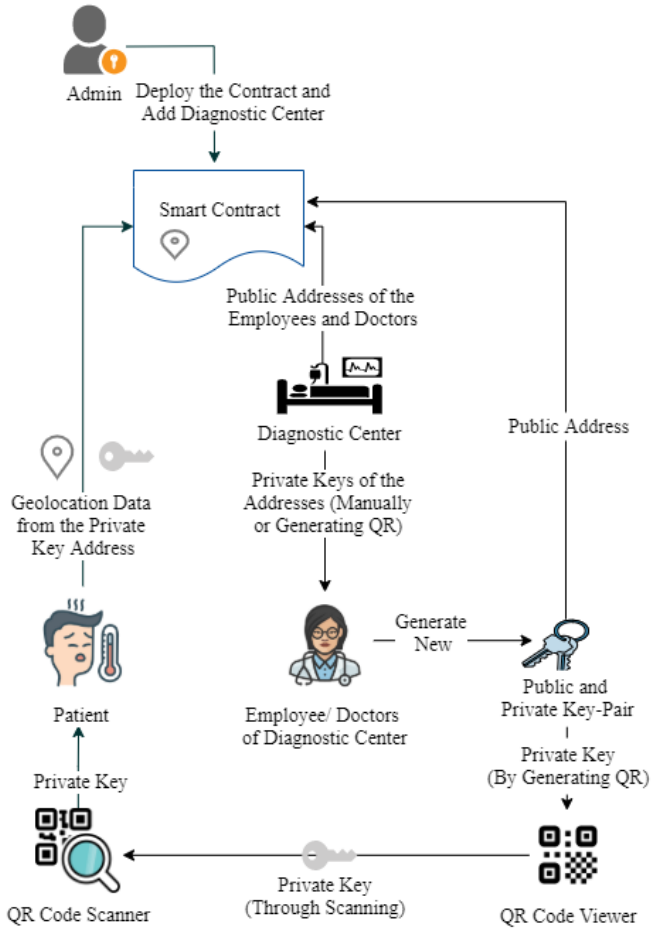

Fig. 1. System model using Key Pair

- Input an email address to get the verification credentials.
- The email is sent to the API server to check the validity of the email id and to check whether it is used before or not.
- If the email id is invalid then the system returns an error requesting to input a valid email address.
- If the email address is used before then it returns an error specifying that this email address is already been used with the system.
- If everything is checked out, the system sends a verification code to the user's email address.
- He/she can input possible infectious places of the dengue virus using the verification code. In this regard, they can read the guideline of WHO to choose the lying-in-bed of Ades.
- The given locations are stored in the contract.
- The system generates a heatmap with those coordinates fetched from the contract.
- The system can also make an alert if more than a threshold amount of persons complain about the same place. This is how the system gets more legitimate places.

Moreover, in both of the above mention system models, if the submitter mistakenly submits the wrong location, the contract allows the submitter to update the submitted location within a time period.

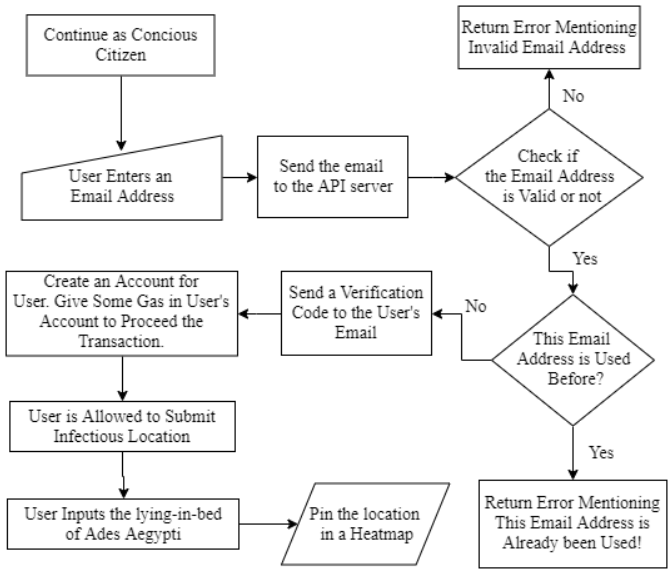

Fig. 2. System Model for Conscious Citizen

IV. Implementation

As the backbones of the whole architecture are smart contracts, we implemented the smart contracts using the Solidity language. Along with those, we also implemented these systems-

- An Android application for users
- A website for displaying the heatmaps
- A webserver to validate email addresses provided by conscious citizens

A. Patient Location Submission

The smart contract of this system contains logic for the following operations-

- Adding a diagnostic center account - can be accessed only by the contract admin
- Adding an employee account - can be accessed only by the diagnostic centers
- Adding a patient account - can be accessed only by the employees
- Submitting the location data - can be accessed only by the patient and the employees
- Retrieving location data for generating the heatmap - can be accessed by anybody

Among those operations, two of the most important ones are adding a patient account and submitting the patient's location data. We will be discussing them in detail next.

Algorithm 1 described the exact condition check as well as the process followed by the smart contract to add a patient entry initiated by the doctor or the employee of the diagnostic center.

Algorithm 1 Add a patient by an employee

Require: Exisitng $Diagnostic\ Center\ id$ and $Employee\ id$
Require: $Patient's\ Address$ that will be added
Ensure: A new $patient$ is added to the $Patient'sList$
return error if $Diagnostic\ Center$ is invalid
return error if $Employee$ is invalid
return error if $Employee's\ Address \neq Message\ Sender's\ Address$

$patient \leftarrow new\ Employee()$
$patient.address \leftarrow Patient's\ Address$
$patient.enable \leftarrow true$
$patient.createdAT \leftarrow now$
store $patient$ to the $Patient'sList$
$totalPatientCount++$

transfer $WeiToSendUser$ amount of Wei to patient's address
emit $PatientAddEvent$ event with $PatientAddress$ and $Index$ at which patient is added as data

The verification process of the patient's identity which is done when a patient submits his/her location information to the system has been described in the algorithm 2. It has the details of the store procedure.

Algorithm 2 Submit location data by a patient

Require: Exisitng $Diagnostic\ Center\ id$ and $Employee\ id$
Require: $Patient's\ Location\ Data$
Ensure: $Patient's\ Location\ Data$ will be stored
return error if $Diagnostic\ Center$ is invalid
return error if $Employee$ is invalid
return error if $Patient$ is invalid
return error if $Patient's\ Address \neq Message\ Sender's\ Address$

$patient \leftarrow getPatientFromStorage()$
$patient.location \leftarrow Submitted\ Location$
$patient.coordinate \leftarrow Submitted\ Coordinate$
$patient.submittedAT \leftarrow now$
save $patient$'s state

emit $PatientSubmittedDataEvent$ event with $PatientAddress$ and $Index$ at which patient was loaded from as data

The Android app holds the following operations of this system implementation-

- UI for easy addition of diagnostic center, employee, and patient accounts
- UI for patients from where they can submit their location data by using the GPS or searching for any specific location
- UI for the general public to view the generated heatmap of submitted location data

B. Conscious Citizen Location Submission

The smart contract of this system contains logic for the following operations-

- Adding an account for conscious citizen - can be accessed only by the contract admin
- Submitting the location data - can be accessed only by the conscious citizens
- Retrieving location data for generating the heatmap - can be accessed by anybody

The two major functions of the smart contract that stores the data and control the modification of the state are as follows.

Add Data Submitter: To make a legitimate system, we have introduced the add data submitter option. It will help to verify actual conscious citizen who wants to help and discourage fraudulent users. As to get added by the system, every user needs to enter email id to get a login code. Without the code, no one can enter into the system. The function is used by the API server to add an account for the conscious citizen. Code segment 1 holds the function details.

```
function addSubmitter(address payable submitterAddr)
     public isAdmin {
    uint indx = submitters.length;
    submitters.push();
    submitters[indx].addr = submitterAddr;
    submitters[indx].flag = true;
    submitters[indx].createdAT = now;
    totalSubmitters++;

    submitterAddr.transfer(WeiToSend);
    emit SubmitterAddEvent(submitterAddr, indx);
}
```

Listing 1. Submitters are add by calling this function

Submit Location Data: After creating an account without any difficulty, the user opts to submit an infectious location. This function of the contract is used by the android app. The function structure is provided in code segment 2.

```
function submitSubmitterData(
    uint submitterId, uint256 lat, uint256 long,
        string memory locStr
    ) public {
    require(submitterId < submitters.length, "
        submitterId is invalid");
    Submitter storage submitter = submitters[
        submitterId];
    require(submitter.flag, "The submitter has been
        disabled");
    require(submitter.addr == msg.sender, "The
        submitted should be the submitter");

    submitter.locOrd.lat = lat;
    submitter.locOrd.long = long;
    submitter.locStr = locStr;
    submitter.submittedAT = now;

    emit SubmitterSubmittedEvent(submitter.addr,
        submitterId);
}
```

Listing 2. Conscious citizen submits the location data through this function

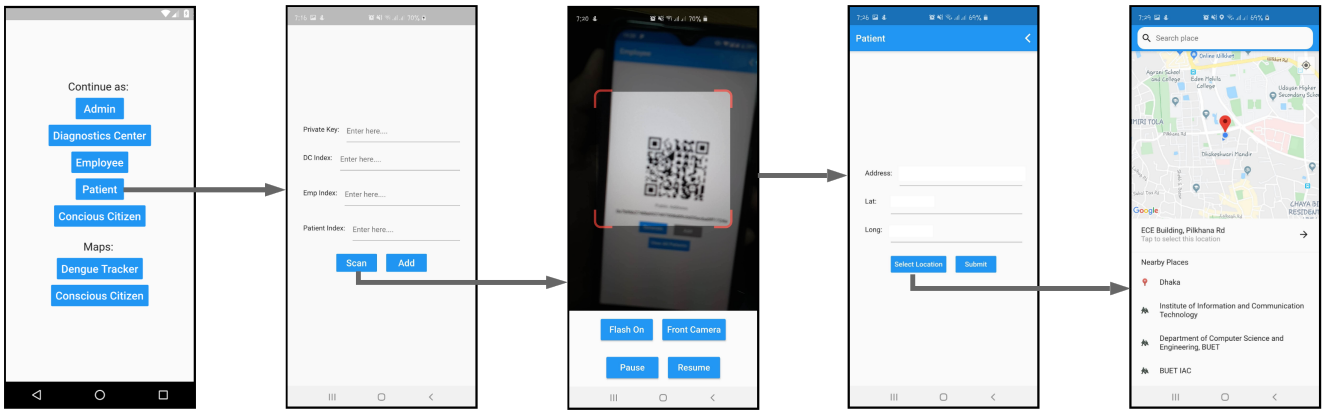

Fig. 3. Patient App Use Flow

The webserver built for this system does the following works-

- Stores the email addresses that requested for a conscious citizen account
- Checks the validity of a conscious citizen account request
- Sends an email containing the email verification code
- Invokes smart contract function to create a conscious citizen account into the contract itself and sends back the credentials to the citizen who requested for it.

C. Heatmap Generation

Both key pair method of patient's location submission and the conscious citizen's location submission need heatmaps to visualize the locations. For generating the heatmap of the location information submitted by the corresponding parties, all the location data are needed to be aggregated first. As the data are stored into the smart contract, it provides a function that aggregates all the stored locations first and returns them as an array. Then a map is built from the array. We have used the frontend framework *React* combined with *Truffle* to populate this map and show it on a website. For building the heatmap, we have used *Google Map*'s heatmap generation feature by providing it the location co-ordinates. Google sets the intensity of the heatmap color based on the counts of the particular co-ordinate.

V. Results

In this section, we present the screenshot of our developed crowdsourcing platform.

A. Modules of Dengue Tracker App

The dengue tracker app consists of five modules as follows:

1) Admin
2) Diagnostic Center
3) Employee
4) Patient
5) Conscious Citizen

The above-mentioned three modules are associated with the fourth module and the last module is only associated with the first one.

B. Patient Module of Dengue Tracker App

There are four major steps to follow to use the patient module. They are –

1) Scanning the credential QR code
2) Selecting location using GPS or the map
3) Submitting the location data
4) Viewing the generated heatmap (optional)

These steps have been shown in Fig. 3.

C. Conscious Citizen Module of Dengue Tracker App

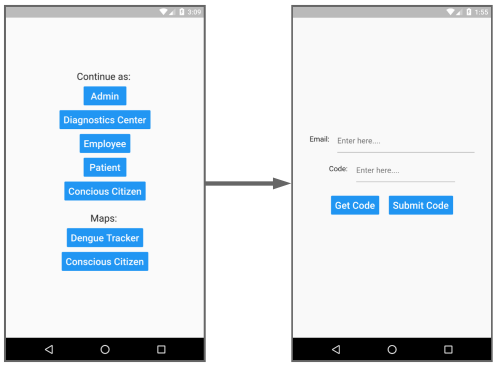

Fig. 4. A conscious citizen provide email address as login credentials

This module of the Android dengue tracker app consists of several steps. Two of the most important steps are as follows-

1) The foremost step is to continue as the "Conscious Citizen" from the dengue tracker app's home layout. Then, a new layout will appear and the user has to provide an email address to use the system (Fig. 4).
2) In this system, the user doesn't have to worry about this key and indexing as everything will happen inside the

app without any concern of the user. After submission of the verification code, a new layout (Fig. 5) will appear where the user can select the desired location.

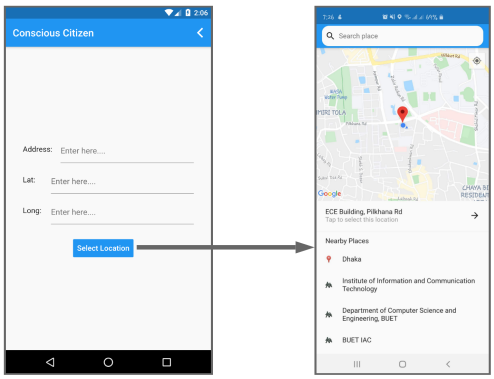

Fig. 5. Select the desired location from Map

This may seem hard for the user to enter the location (lat, long) manually. But they don't have to worry about that as they don't have to input the desired location manually. Rather, they press the select location button to choose the desired location through the map directly (Fig. 5). If the user wants to choose the current location, he/she can do that easily by pressing the current position button.

D. Heatmap

The submitted location will be collected from the smart contract state and plotted into a heatmap of most probable infected areas (Fig. 6).

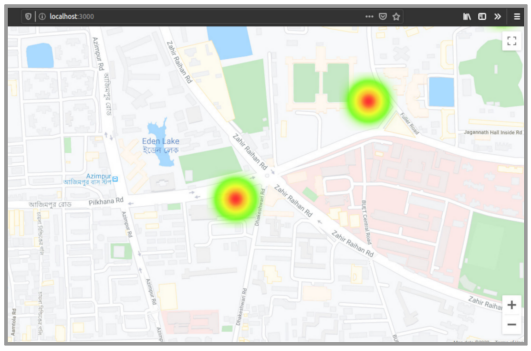

Fig. 6. Sample Heatmap based on the input of Conscious Citizens

VI. Conclusion

Since mosquito-borne diseases cannot be eliminated completely from the world, it is essential to track dengue infected areas for taking proper and timely remedial measures to mitigate the impact of the virus. We have proposed and developed a novel crowdsourcing system based on ethereum-blockchain to make a barrier between mankind and mosquito-borne diseases. And We strongly believe that the developed Dengue tracker system is a novel initiative to prevent the growth of Ades as well as other vectors and reduce the rate of unfortunate death due to mosquitoes by creating awareness and providing the location data of infectious spots to the concerned authority. As COVID - 19 and all the arthropod vector-borne diseases have a strong relation with locations, this work can be extended for these use cases.

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