Institute Vaccine Management Solution

Karthik Viswanathan
International Institute of Information Technology, Hyderabad, India
karthik.viswanathan@research.iiit.ac.in

Abstract

COVID-19 has been the biggest pandemic the world has ever faced. Various organisations have been racing amongst each other in order to provide the public with a safe and trust worthy vaccine. The governments have been working out to provide an efficient vaccination program in order to ensure the safe administration of these vaccines. We propose a software system which automates the vaccine administration process with a smooth follow-up process. By introducing this software system, we aim to provide a centralised vaccine management system in order to tackle effective mass management, reduction in vaccine wastage, prioritising groups which are more vulnerable to COVID-19, etc.

1. Introduction

The COVID-19 pandemic is the longest lasting pandemic with the highest infection count. There has been a rampant rise in the funding of vaccine studies. Various vaccines have been tested in phases and have been approved and shipped by governmental bodies in order to vaccinate their populations. One can expect that given the vaccine production rates, every vaccine produced around the world is being decentralised by the governmental bodies and is being administered to the population efficiently. Unfortunately, even with an abundance of vaccine doses, the inefficiency in administering the vaccine have not only caused vaccine wastage, but has also caused unrest among the citizens of India. Almost 3.54 % doses of vaccine could not be administered to people [7]. A huge proportion of this can be attributed to the inefficiency of the vaccine administration process. A prime example of this is the CoWin vaccine registration portal requests the citizens to register twice for two different slots. Due to this, there is cut being created between the citizen and the administrative staff. Moreover, we do not have a verification system in place which takes into consideration which individuals can safely take the vaccine. The Pfizer-BioNtech vaccine guidelines suggest that individuals who developed severe allergies after the first dose are not advised to take the second dose of vaccine [5]. Hence, it is beneficial if the administration can follow up after first dose. Furthermore, the public is not aware of which symptoms are undesirable after vaccine administration due to negligence. In some cases, a third dose of vaccine may also have to be administered if antibody count is lesser than the expected count [10]. Hence, there must be a constant and timely communication between the administrative staff and the vaccine taker. The prime goal of this paper is to ensure there is constant mode of communication and follow-up between the admins and the managee in order to ensure that we provide a smooth transition. The vaccine administration process has been divided into four stages as described in the subsections below

1.1. Registration and Verification

Since the number of people who must be vaccinated is 400, we assume that they are delivered one-shot to the campus. We will deal with the worst case scenario as we deep dive into this paper. The vaccine registration phase involves gathering details and the medical history of the people who are about to get vaccinated. Once we get the detailed analysis, we assign a vulnerability index on if the vaccine can be administered to these. We advice the people with a high vulnerability index to provide a doctor's statement (especially people who have severe allergic reaction to the ingredients in the vaccine).

1.2. Scheduling

Once the registration process is over, we segregate the population into tiers based on their risks of getting COVID and utilitarian and egalitarian principles. For example, health staff make up Tier-1 and community workers belong to Tier-2 [13] as shown in the figure below. People belonging to the same tier will be scheduled on first come first serve. A QR code will be provided (on the app) to the vaccine taker and he/she must show the ticket along with the identification proof at the location of vaccine administration.

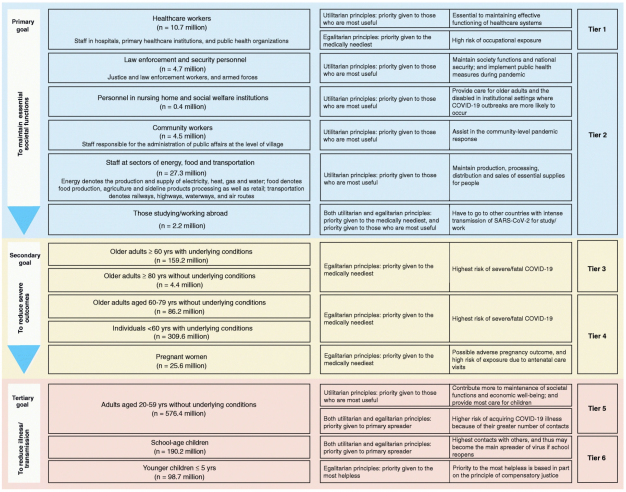

Figure 1. Tier

1.3. First Dose and Follow up

The first dose is given and the second dose is scheduled right away and is updated in the system by the scheduler. At some point after the first dose, we propose a follow-up survey in order to understand the side effects of the vaccine. This way, we can ensure that the vaccine is in Phase-3 of it's trials, but at the same time is being administered to people and the results are being forwarded to the research department for further scope of improvements. We now assign a vulnerability index based on the follow up surveys. If the vulnerability score is high, we recommend visits to the doctor and a statement from the doctor before the second dose.

1.4. Second Dose and Antibody testing

The same QR code which was shown in the first dose administration also may be shown in the second dose administration as we update the details right away. In this phase, we administer the second dose, and enforce a compulsory antibody testing after two weeks in order to look into how the body has responded to the vaccine. If the response is not satisfactory, we schedule an in-house doctor consultation. In some cases, like in the United Arab Emirates, a third dose of vaccine is being administered if antibodies have not developed [10]. Depending on the in-house doctor's statement, we provide a third dose. We record this into our database.

1.5. Post Vaccination

Post the vaccine administration, we provide proper certification and documentation to the vaccine takers in order to ensure free movement of people who have been administered with the vaccine.

1.6. Demand

In order to predict shortage, we must understand the demand. Hence, we do so by providing a dashboard to the administrative staff with the variability of demand over the administration timeline. This will help effective streamlining of the vaccine doses and hence reduce shortage. we can also predict the demand for the vaccine using NN-based Auto-regressive integrated moving average [2].

The system we choose is the campus, where we need to administer vaccine to approximately 400 people. We develop a software system which takes into account each of these stages and automates and increase the efficiency of the vaccine administration process. The above processes need to enforced for each of the 400 people in the campus and hence, we decide to develop a software system which takes into account each of these stages and automates and increases the efficiency of the vaccine administration process.

2. Literature Review

In this section, we discuss about previous works which have taken place in this field and provide a survey on these papers. Several proprietary vaccine administrative software exist in the market. Some of them have been surveyed in the upcoming blocks.

Salesforce [11] has developed a vaccine administering software especially for healthcare employees. Some of the features of this software includes accurate forecasting for rapid mass vaccination, securely scaling vaccination registration, accurately capturing the vaccine delivery information, etcetra.

Deloitte [4] has developed a vaccine administering software which is designed to provide real-time access to vaccine administration data. Some key features include appointment scheduling, administration monitoring and coverage across a jurisdiction, data exchange, inventory management, resource need tableau, etcetra.

Accenture [1] has developed a vaccine administering software which is designed to provide a smooth collaboration between health boards, commercial partners and providers. Furthermore, the app is scalable and handles more users. It also has a contact management application built over salesforce's platform.

Cowin [3] has developed a vaccine administering software which is designed to register the citizens of the country and provide them slots for vaccine administration. But, the citizen has to register for both the first slot and the sec-

ond slot. This can be a problem as the second slot must be provided within a minimal time difference and hence the portal must account for citizens who have already been administered with the first dose.

The above softwares focus on delivery to a large extent. They focus on vaccine delivery and handling over administration. In developing African countries, the database for vaccine administration [8] are being recorded on paper and hence, such records are prone to human errors. Hence, we need to enforce more open source softwares which are available freely to the public. The pre-condition of the problem is that the by the time software is ready, vaccines will have already reached the premise. The following paper [9] discusses about creating a web based vaccine administration portal using PHP, PostgresSQL and Apache web sever under a GNU/Linux platform. The work is mainly focused towards the Brazilian health care system. Some of the key features of the web app includes statistical reports, patient's vaccination history, reduction of vaccine loss, transparency and more savings.

One of the reasons why we ensure a constant mode of communication between the admin and the managee is that the after the first dose, it has been observed that the adherence rate to the vaccination schedules sharply reduces. For example, in Cyprus, while the adherence to the schedule for the first dose of diphtheria was 81 %, only 66 % adhered to the schedule for the second dose of the vaccine **attach reference**.

Depending on the age group and the occupation, we provide tiers to the individuals as shown from the paper. The tiers have been calculated after extracting the vulnerability index in terms of contracting COVID-19. Another resource through which the slots can be fixed is by mathematically modelling the vulnerability of the CoVID-19 on an individual.

3. System Architecture

In this section, we will provide a fine blueprint of the system by defining classes, establishing relationships between the classes and provide details on the updates taking place in the database.

3.1. Classes

We will now define the classes as follows.

3.1.1 Individual

The individual class stores information about the individual who is about to be vaccinated. The individual is registered in the database with personal details like name, age, phone number, Aadhaar identification. If an individual entity exists in the database, it means that at least one details which uniquely identifies the individual. In this scenario, we send a one time password (OTP) to the registered college email ID and include the individual in the database. If the individual is a part of the administrative staff, we verify their identity with the partner organization accordingly. The individual class has details on the vaccine doses, the priority tier the individual belongs to, the assigned slots, the medical history ID, the follow-up surveys of the individual, doctor's statement, the communications between the individual and the vaccine administrative staff, antibody test ID, in house doctor appointments (if any) between the vaccination periods, the Vaccine batch numbers for each of the doses, vulnerability index and eligibility (Boolean).

3.1.2 Administrative staff

The administrative staff class stores about the details of the administrative staff, their work schedules, their category (doctor/ nurse/ clerk/ admin). For the nurses and doctors, we will have a list of individual ID's they administered. For the admins, we will have a list of ID's of doctor, nurses and clerks managed by them. This is for better accountability in case of an unfortunate event. Furthermore, the ID's of the requests made by the administrative staff and their status location ID's.

3.1.3 Reports

For each of the individuals, the antibody tests and the vitals after each of the vaccine doses, ID proofs are stored in the Reports class. The vitals is a dictionary of the blood pressure and the pulse rate. Furthermore, depending on the follow up survey, if the patient visited a doctor, the medical test reports of those are queried from the individuals and are stored over here. For each of the administrative staff, their detailed RT-PCR test reports are stored over here. Vaccine certificated for individuals can also be viewed from here.

3.1.4 Batch

Since the vaccines delivered may have various production dates and the vials may have varying expiry dates, we need to record the production date, the vial expiry date, the batch number and the number of doses in the batch and the ID of the nurse who will be administering the vaccine.

3.1.5 Location

Assuming that the vaccine administration will take place in different locations, we store the address of the location in this class and assign it with a unique ID.

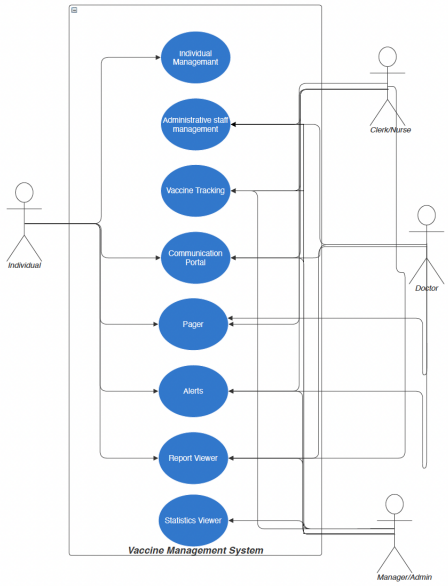

Figure 2. Use case diagram

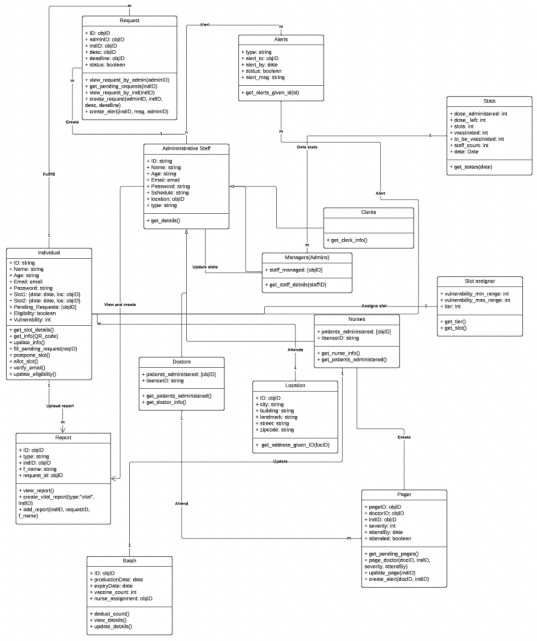

Figure 3. Class Diagram

3.1.6 Pager

Paging requests include an ID, the doctor attending the page and the severity of the page.

3.1.7 Request

Requests are between an individual and an administrative staff. The attributes include the request, the individual's ID, the staff's ID, the request along with the report associated with the request (if any).

3.1.8 Alerts

Alerts can be to either an individual or an administrative staff. Hence, we store the ID, the concerned type and the the description of the alert.

3.1.9 Slot assigner

Depending on the vulnerability index range which have been decided based on egalitarian and utilitarian principles, as discussed previously in the literature review.

3.1.10 Stat

The statistics are only accessible by admins.

Let us now define the relationships between these classes. On any one physical visit to the administrative staff (nurse/doctor), the individual's ID is added to the list of individual's administered by the doctor/nurse. Furthermore, if the individual visits the doctor, the statements are updated in the individual's database. The doctor can update the individual's vulnerability index and the eligibility. The doctors and the nurses can view and add individual's reports to the database. An individual can upload his/her own report to the database if any administrative staff requested for the same. An administrative staff member can search through various instances in the Reports. If a report is missing, they can request a patient to submit the report and once the patient submits the report, the request is removed from the pending requests list and the administrative staff is notified about the same. The clerks and the admins (admins) can update and view all the fields in the vaccine database. The clerks can update the vaccine slots of an individual. Let us discuss the main workflow of the system.

3.2. Main Workflow

1. Initially, before the registration of the users are done, we register the administrative staff and the vaccines.
2. The individual registers himself/herself and performs a health survey in order to know if there are any statements from the doctors required. If any allergies are present, the in-house doctor can schedule an appointment/ open a request.
3. Once eligible, depending on the tier, slots are scheduled for the individual. The individual may request for

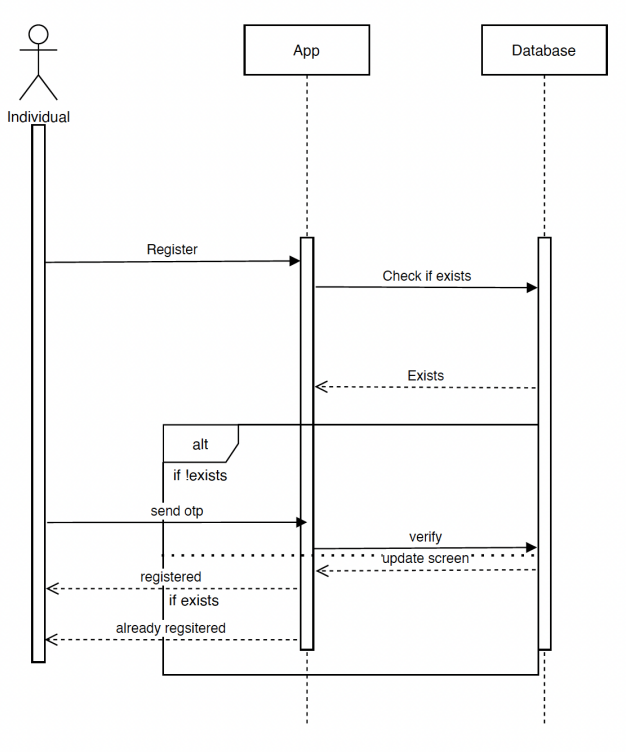

Figure 4. Seq-1

a slot postponing for the first dose of the vaccine.

4. Once the slots are fixed, the individual must display the QR code before vaccination along with the ID proof.

5. Upon the administration of the first dose, it is mandatory for the individual to fill a survey form one week after the vaccination. Once the individual fills the survey, the app provides the individual with the second slot. Vitals are recorded.

6. Upon administration of the second dose, the antibody test slot is updated on the app right away. Vitals are recorded. After the antibody test, if the antibody count is higher or equal to the expected the count, the app provides the certification in a password protected PDF.

7. If the antibody test provides the count less than the expected count, the doctor is paged. The doctor may create a request/ schedule an appointment. If a third dose is required, it is administered and the individual is certified.

8. The administrative staff must present their RT-PCR test results every week.

9. A doctor may be paged for any medical emergency happening in the location of administration.

10. Even after an alert, if an individual misses his/her slot, we provide the next free slot to the individual if the dose is a second dose or provide another slot based on tier if it is the first dose.

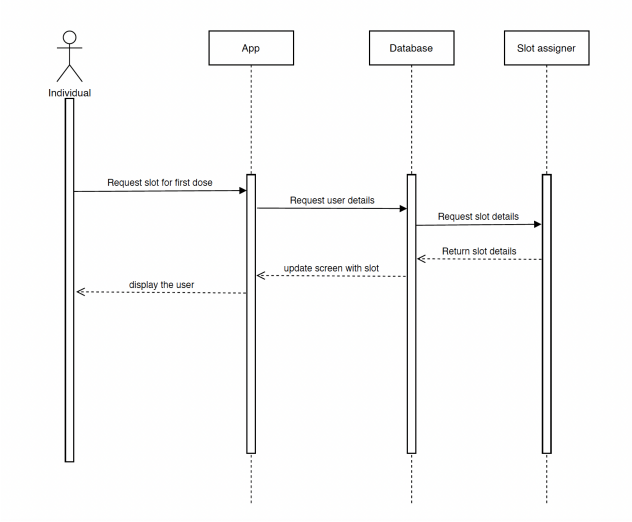

Figure 5. Seq-2

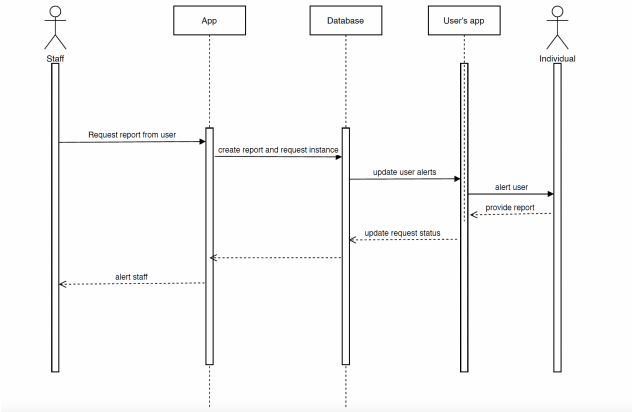

Figure 6. Seq-3

3.3. Requirements

Let us now define the requirements and build a use case diagram.

3.3.1 Functional Requirements

1. **Individual Management**: We provide a secure platform for the users to register, login, fix their slots, edit their information, postpone their slots and view QR codes.

2. **Administrative staff Management**: We provide a secure platform for the administrator to administer to the needs of the individuals and fellow work mates and upload their RT-PCR tests every week. admins can add doctors/nurses supervised by them.
3. **Vaccine Tracking**: We provide a platform where the administrative staff can track the vaccine post-delivery. Post delivery, the clerk initiates the vaccine tracking phase by inputting the attributes of the vaccine class. The nurses are then entrusted with the duty of decrementing every does administered from its corresponding batch count and assigning this batch ID to the individual's class entity along with the timestamp.
4. **Communication Portal**: Since we are handling communications as requests, we must provide a portal where the individual can submit reports (alias documents) and the administrative staff is notified about it.
5. **Pager**: We will have an automatic random paging tool which pages the in-house doctors and also sends the antibody test results. The doctors can then open requests through the communication portal.
6. **Alerts**: The alerts for individuals include reminding them before slots/document requests being late/survey not filled, etcetra. The alerts for nurses include vial expiry for an existing batch which is being administered by them. The alerts for doctors include late paging responses, and unattended responses to the requests made by them.
7. **Report Viewer**: The administrative staff and the individuals can view their reports, time stamps and requests (if any) associated with the report.
8. **Statistics**: Provisions for the admins to view statistics given a date.

3.3.2 Non-Functional Requirements

1. **Security**: Since we are storing very sensitive information about the individuals and the administrative staff, we must provide a very secure platform for them to operate upon.
2. **Scalability**: As a research institution, we must be able to provide this app to the public after we use it. Hence, the app must be scalable for public use.
3. **Data Integrity**: The data must be very accurate as this plays a major role in the individual's health.

The overall system architecture can is shown in figure

Based on the discussion above, we present the UML use case diagram is represented in Figure 1 and the UML class diagrams is represented in Figure 2.

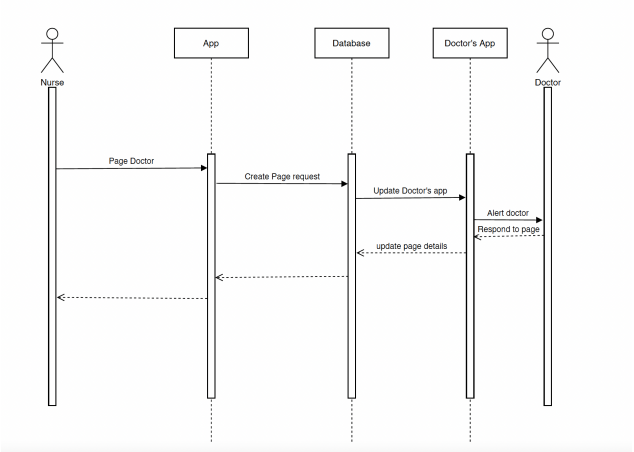

Figure 7. Seq-4

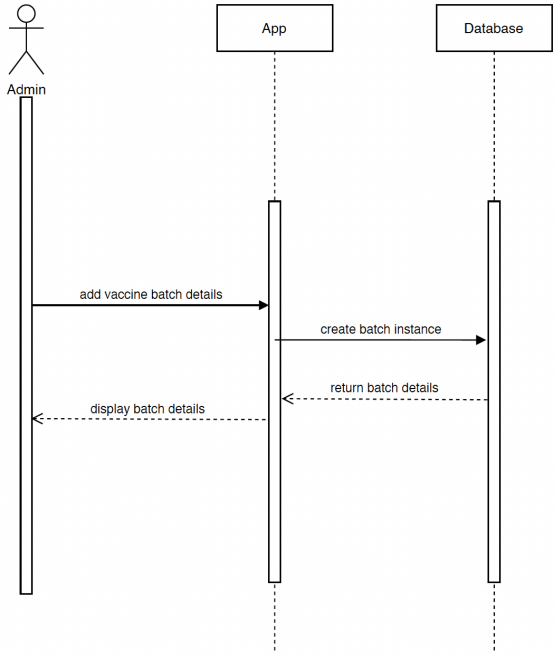

Figure 8. Seq-5

3.4. Sequence Diagrams

The sequence diagram for the individual/staff registration is shown in Figure 4. The sequence diagrams for slot requests is shown in Figure 5. The sequence diagrams for requesting a report is shown in Figure 6. The sequence diagrams for paging a doctor is shown in Figure 7. The sequence diagram for adding vaccine batch details is shown in Figure 8. Finally, we have statistics request by admins shown in Figure 9.

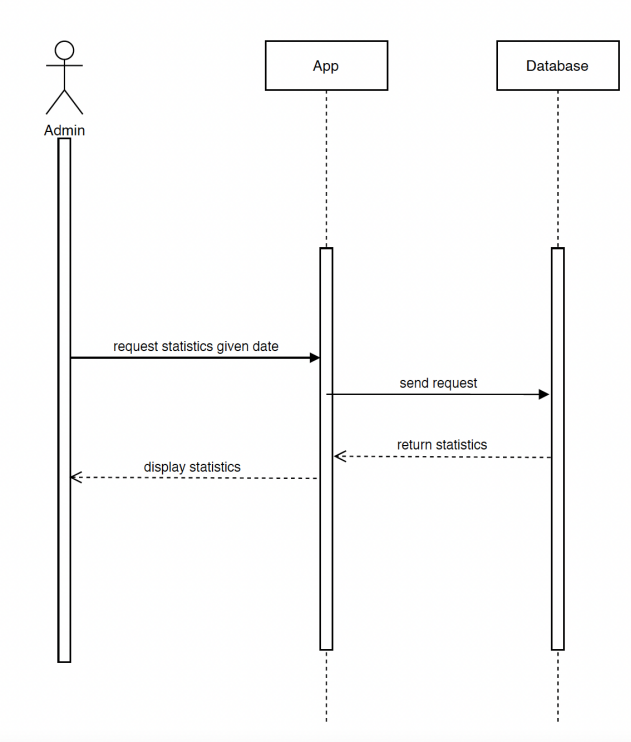

Figure 9. Seq-6

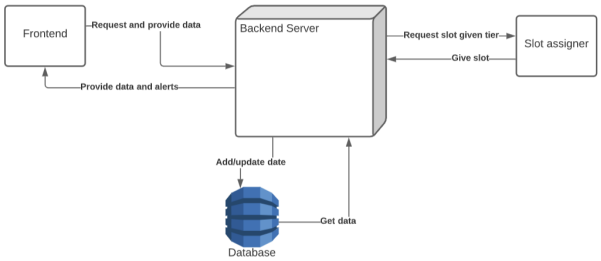

Figure 10. System Architecture

4. Conclusion and Future Work

In this paper, we discussed about developing an efficient software system which can automate the process of vaccine administration with minimal wastage and discrepancies. From vaccine slots to emergency paging requests, everything can be handled using this app. The app is designed to be secure, scalable and reliable. Future works to this app can include developing a machine learning based model to assign a vulnerability index for finding the tier using vulnerability modelling [12]. When launched for the public, instead of paging the in-house doctors, we may provide the individuals with nearby hospitals and associated doctors along with the information of the request. Moreover, if various brands of vaccines are required to be administered, depending on whether the vaccine is m-RNA based or not, we can address which individual can be administered with which vaccine depending on the whether the vaccine would produce a desirable result [6]. Furthermore, the vulnerability index can be calculated using Machine Learning techniques and depending on the immunity of the individual and if the individual is on steroids or not.

References

[1] Accenture. Vaccine management solution. Link.

[2] R.-k. Chiu, C.-M. Chang, and Y.-C. Chang. A forecasting model for deciding annual vaccine demand. In *2008 Fourth International Conference on Natural Computation*, volume 7, pages 107–111, 2008.

[3] CoWin. Vaccine appointments. Link.

[4] DeloitteUS. Vaccine management system. Link.

[5] W. W. Gibbs. This is how to vaccinate the world: We can manufacture and distribute enough doses to protect humanity from covid-19. *IEEE Spectrum*, 58(1):32–37, 2021.

[6] P. Gonzalez-Dias, E. K. Lee, S. Sorgi, D. S. de Lima, A. H. Urbanski, E. L. Silveira, and H. I. Nakaya. Methods for predicting vaccine immunogenicity and reactogenicity. 2020.

[7] T. Hindu. Shortage and wastage: On cutting vaccine wastage. Link.

[8] E. Osei, M. Ibrahim, and G. Kofi Amenuvegbe. Effective vaccine management: The case of a rural district in ghana. 2019:5287287, Oct 2019.

[9] C. T. Renck, L. Sorgetz, and F. A. M. do Nascimento. VCS: an open source web-based vaccination management information system. In J. Filipe, J. Cordeiro, B. Encarnação, and V. Pedrosa, editors, *WEBIST 2007 - Proceedings of the Third International Conference on Web Information Systems and Technologies, Volume SeBeG/eL, Barcelona, Spain, March 3-6, 2007*, pages 242–246. INSTICC Press, 2007.

[10] S. Said. Early adopter u.a.e. starts giving third dose of sinopharm vaccine amid efficacy concerns. Link.

[11] Salesforce. Vaccine cloud for health authorities. Link.

[12] A. Tiwari, A. V. Dadhania, V. A. B. Ragunathrao, and E. R. Oliveira. Using machine learning to develop a novel covid-19 vulnerability index (c19vi). Jun 2021.

[13] Z. W. S. H. e. a. Yang, J. Who should be prioritized for covid-19 vaccination in china? a descriptive study. *BMC Med 19, 45 (2021).*