

# Software Architecture Design on National Level for Vaccination Planning and Dispensing System

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## Abstract

This paper describes the software architecture design for vaccination planning and dispensing system to be used nationwide in public health-care departments and hospitals in response to the immunization improvement program in underdeveloped and poor countries. The system will help in managing all activities of child vaccination right from their birth by sending alerts to their parents via SMS or voice call in their local language. This automation will help keeping track of particular vaccination against which majority of children are not getting proper vaccination in time and analyze how many chances will be there that the particular disease will spread in that area based on different trends listed in Knowledge base of the health-care system.

**Keywords:** child vaccination; software architecture; electronic birth registration, electronic medical record, electronic health record system.

## 1. Introduction

One of the major goals of public health is to prevent disease. It's more cost-effective and easier to prevent a disease than to treat it as because of immunizations many diseases, such as polio and smallpox have been nearly eradicated. It is sometimes prerequisite to show proof of immunization when parents get their kids enrolled in day care or school or travelling abroad. Keeping child's immunization up to schedule is very important but what if any child's scheduled dose is missed, can he or she "catch up" later. The answer is "YES" and "NO". As in many under developed and poor countries, parents are illiterate they even don't know the importance of vaccinations and that's the basic first reason they don't get their kids vaccinated.

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In this busy era of life, even the educated and concerned parents still most of the times miss their kids' vaccinations due to their busy routines. In this situation there has been an intense need of introducing an appropriate solution to deal with this problem hence resulting in clean sweep of infectious diseases and making countries like Pakistan free from polio and other diseases as according to a research of WHO 2-3 million new born babies die due to lack of vaccination and non-immunity of diseases in Pakistan.

### ***1.1. Software Architecture***

The software architecture of a system is an illustration of the system defining both technical and operational requirements that helps in understanding system's behavior [1].

### ***1.2. Immunization Information Systems***

Immunization Information Systems (IIS) are population based centralized repositories [2] that receive and share immunization data on individual clients/patients with a number of systems including Electronic Health Record systems (EHR-S).

### ***1.3. Information Gathering***

Gathering information has been the first step for proposing architecture design for Vaccination Planning and Dispensing System. For this purpose, many formal/informal meetings and interviews have been conducted with the experts at National EOC Pakistan regarding current system being followed nationwide. Requirements have been also gathered by conducting survey based on Questioners for both parents as well as health workers/hospital staff which helped us in leading to the problem, the people who wanted the solution for proper vaccination of children and also helped to determine the nature of the system.

## **2. The Problem**

Timely and high quality vaccination is not being provided to new born babies and children in many counties. Initially the analysis has been carried out on the current vaccination system being followed in Pakistan. As a result of requirement gathering, many problems has been reported regarding spread of various diseases specially Polio in Pakistan due to lack of proper system for the conduct of timely vaccination. There needs to be arranged proper sessions for awareness program about importance of immunization among parents. For example, in many rural areas parents have no information about importance of vaccination and they even have no access to health-care centers and hospitals. Similarly, many parents have insecurities about a particular vaccine that it may cause infertility in their child.

There is no centralized system for maintaining record of performed vaccinations. The frontline health workers use notebooks called "Registers" for recording vaccine delivery information. When these workers are outside clinic there is a possibility that they may not have those registers with them and they may write notes on some paper or even when the register is full there are chances of transfer of inaccurate information or missing records.

Currently there is no system for tracing health workers to have a check on them as According to National EOC Pakistan research one of the major cause of missed vaccinations is untrained team members. Once proper training sessions would be conducted and those health workers visiting door to door would be monitored through GIS hence resulting in overcome of missed vaccinations. Keeping in view all the problems currently being faced, there has been intense need of centralized system for vaccination. Based on emerging technology there has been proposed an automated solution (introduce a Handheld device with installed app as well as web based) system on national level for managing all activities of child vaccination right from their birth.

### 3. Proposed Framework

The proposed solution will help in sweeping the problems currently being faced. The vaccination planning and dispensing system will maintain records of vaccination against each child in its National Repository. The proposed framework consists of many modules including Electronic Birth Registry System (EBRS) that would be accessed by any authorized user/health-worker to register new born baby record into system and hence issue an RFID Card of the child. The system will be fraud free as biometrics of parents to be stored in its National repository by firstly matching the fingerprints of parents with NADRA (The National Database and Registration Authority, Pakistan) database at the time of child's registration and later matching with the system database at the time of child getting vaccinated by its parents. Another module that will cross reference child's age and particular vaccination schedule and then generate alerts (reminders) by sending SMS or making voice call to child's parents so that the child gets proper vaccination on time and hence help to overcome various diseases like Polio, Tuberculosis etc. among large group of children. The figure below shows an overview of proposed vaccination planning and dispensing system.

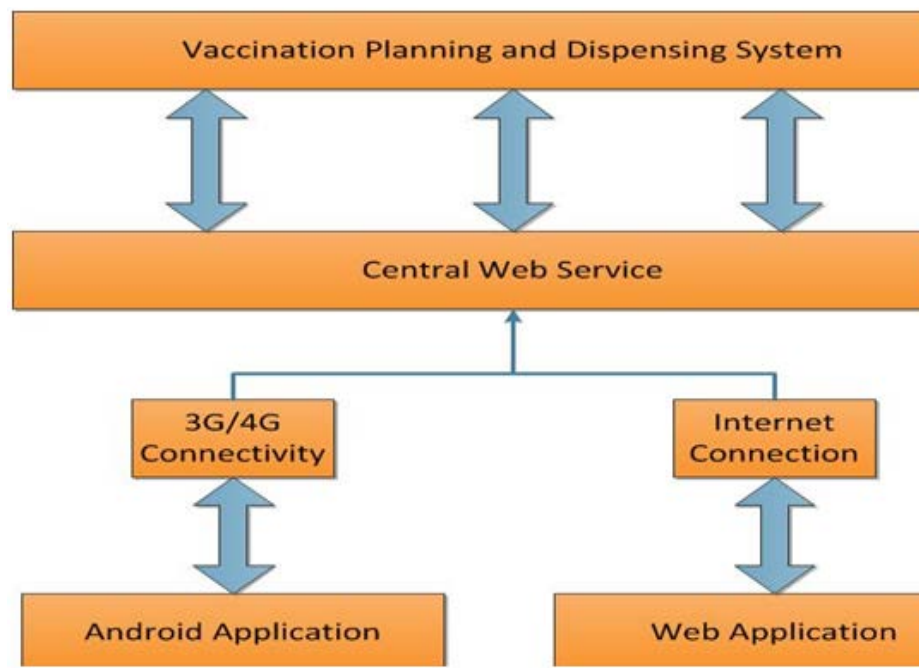
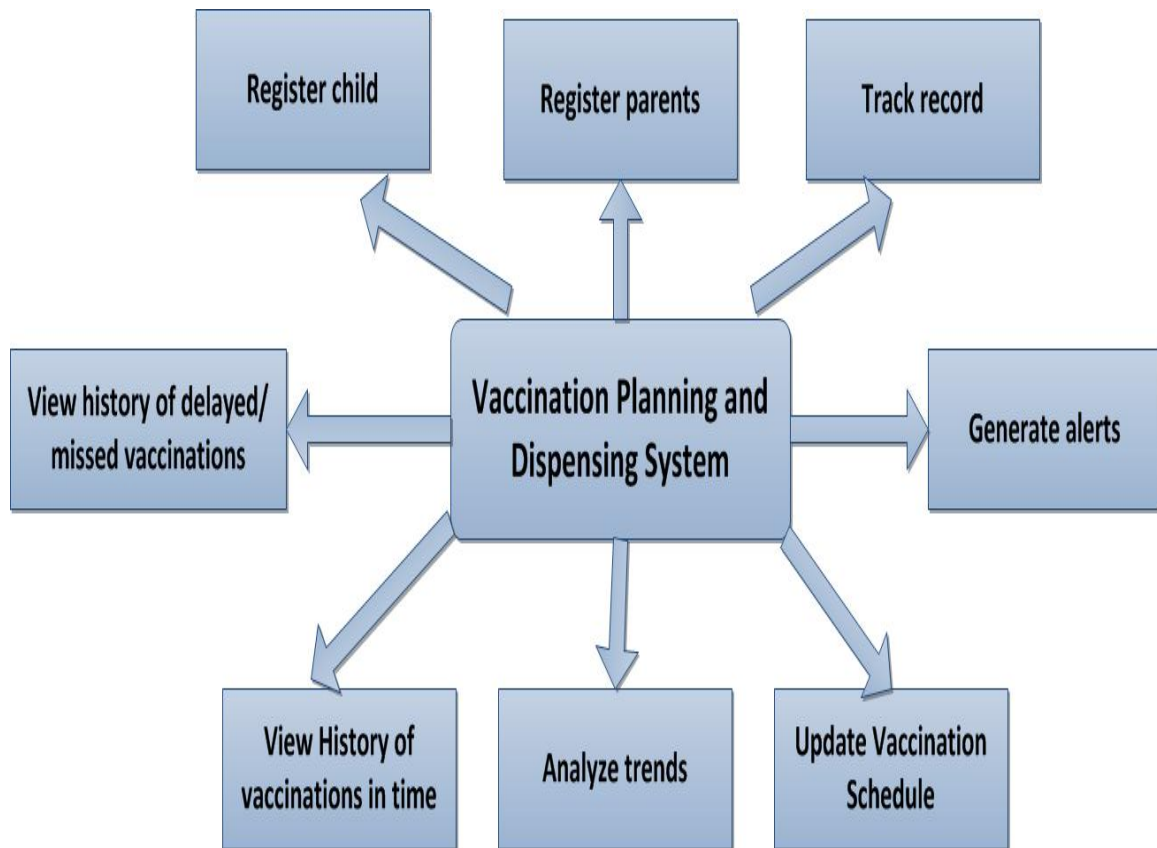


Figure 1: Pictorial Representation of Proposed Framework

#### 4. System Features

The figure below gives pictorial representation of system features.



**Figure 2:** System Features of Vaccination Planning and Dispensing System

The proposed system will consist of following features give below;

##### **4.1. Registration of Health Workers**

The system will allow health workers to get registered into the system through Web based front end.

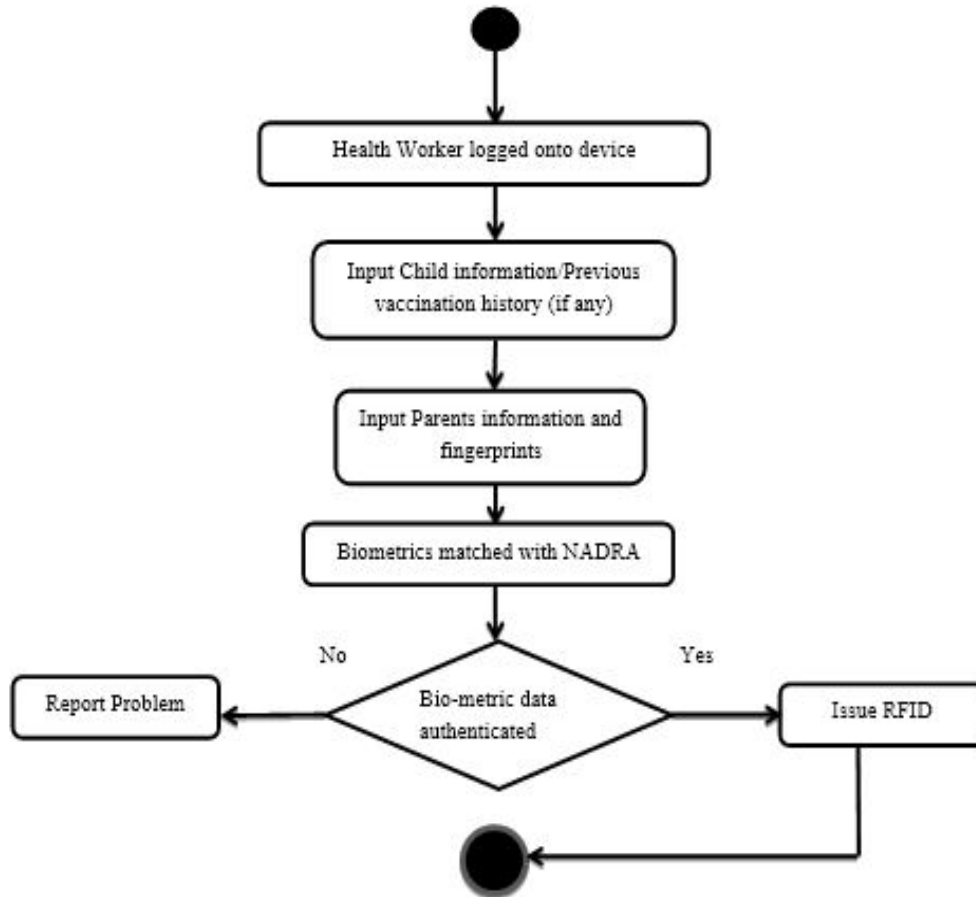
##### **4.2. Login to system**

The system will allow only authorized users to login the app to use functionalities provided within its different modules. Similarly, on admin side, different authorized admin users with pre-defined set of responsibilities in specific domain can view all on going activities. There will be different levels of users with privileged rights into the system.

##### **4.3. Registration of child record through EBRS**

The children are registered into the database of the system through electronic birth registration system. The health workers will be authorized users to register new child record into the system by inputting child's and its

parents' particulars and match parents' fingerprints with the NADRA database system. As a result of registration, an RFID Card will be issued for future reference. The flowchart below lists all the activities for issuance of RFID card.



**Figure 3:** Flowchart for entering birth record

#### 4.4. Adding/Updating Vaccination Schedule

The system will add/update the vaccination schedule for children. The figure below shows the vaccination schedule to be followed for Pakistan. The schedule can be updated and set according to every country's requirement keeping in view its vaccination schedule and criticality against each disease.

#### 4.5. Vaccinating a child

The health worker will update the vaccination record against each child after vaccinating the child by either visiting its doorstep or when the parents bring their child to the hospital. The figure below shows the flow of steps to be followed while vaccinating a child.

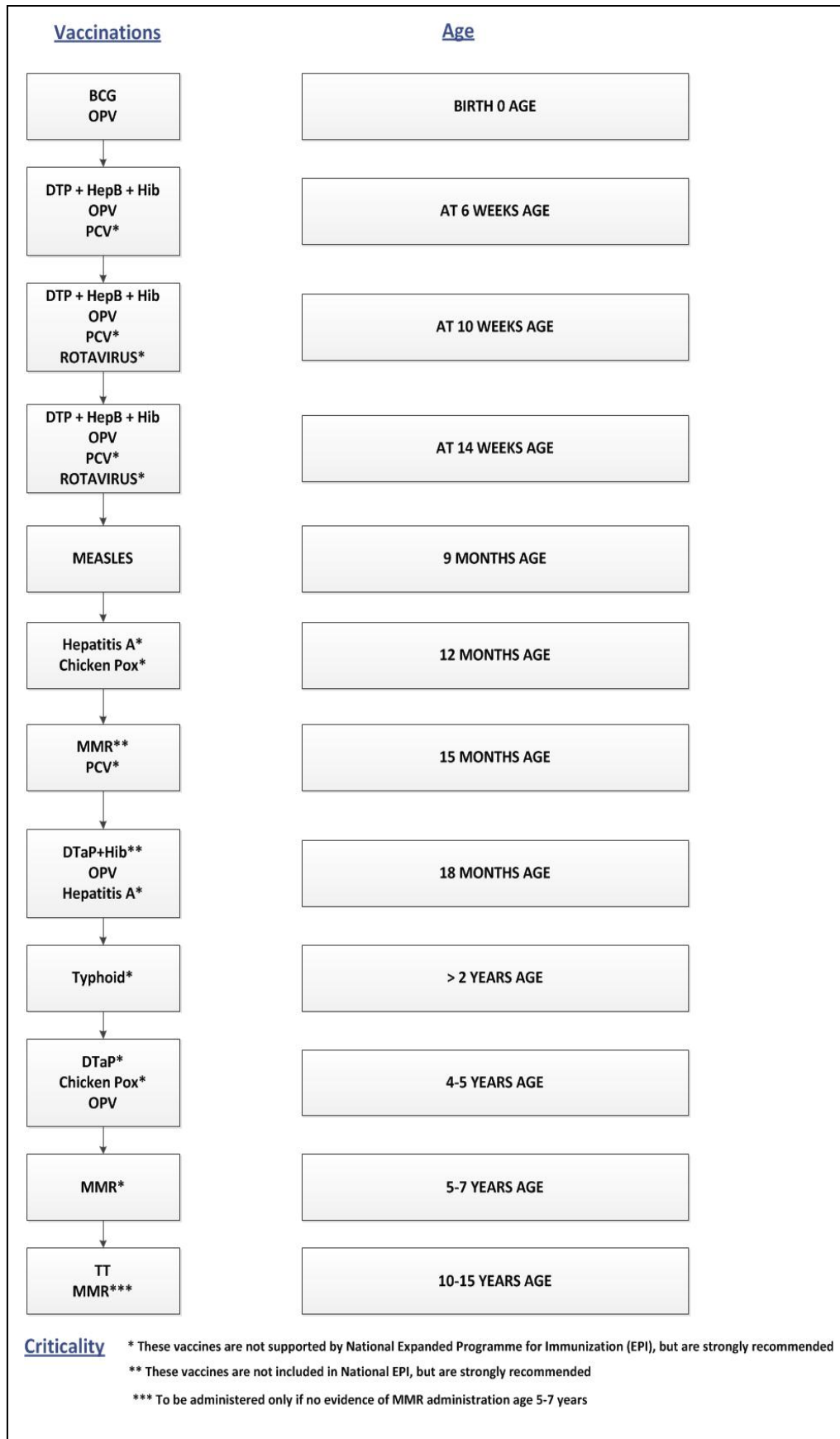


Figure 4: Vaccination schedule and criticality levels

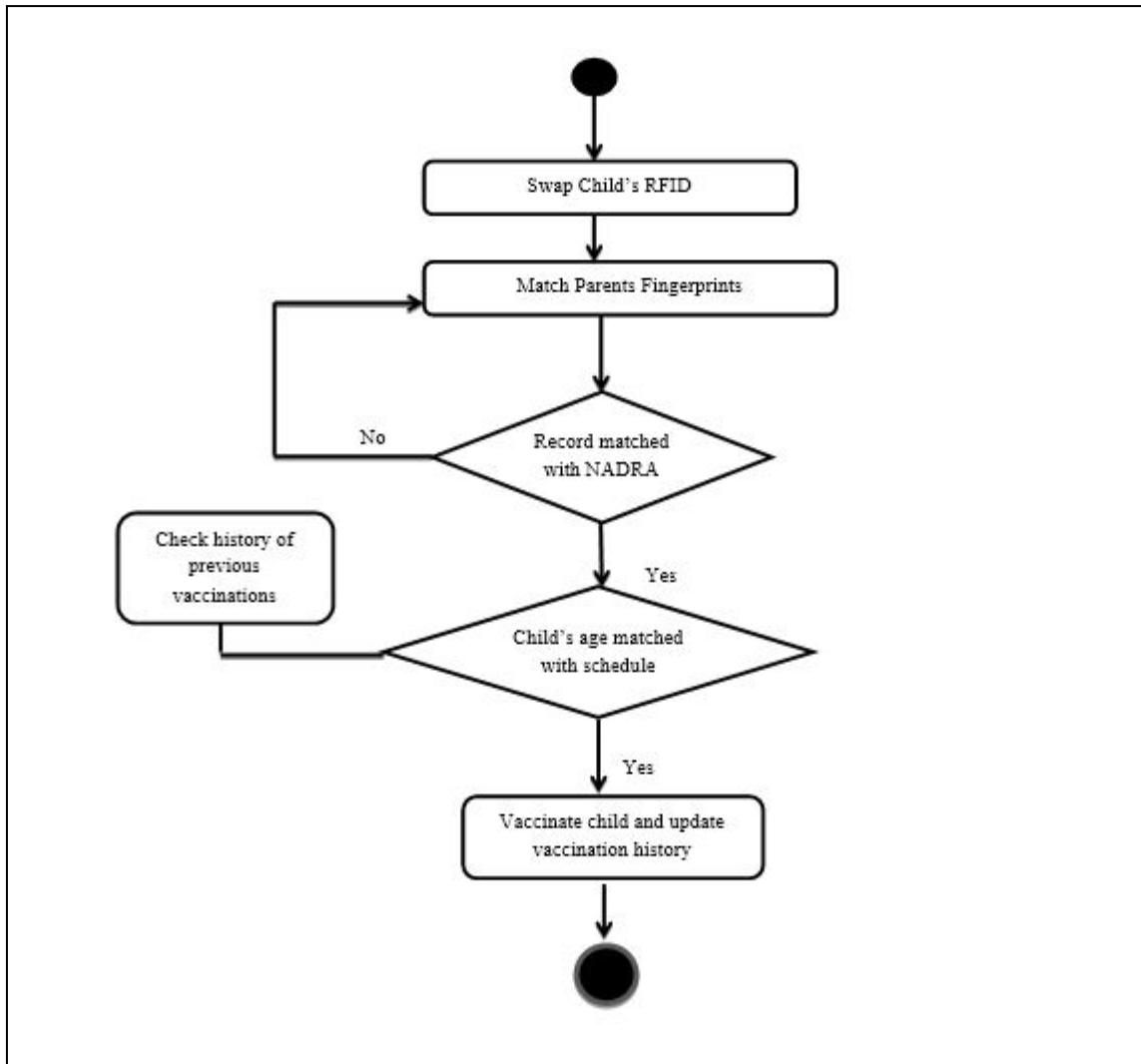


Figure 5: Flowchart for vaccinating child and updating its history

#### 4.6. Tracking Vaccination

The system will track the record of vaccinations given to child in accordance with child's age in order to make sure timely vaccinations. The health workers will be notified of upcoming vaccinations in their designated area.

#### 4.7. Viewing History of in Timely and missed/delayed Vaccinations

The system will allow viewing history of vaccinations given to children in time as well as missed and delayed vaccinations. Based on historical data of children vaccination analytics can be calculated against each vaccine having percentage of timely, delayed and missed vaccinations. The analytics can be further streamed down to province and district level and displayed to user both in tabular and graphical forms.

#### 4.8. Analyzing Trends

The system will allow keeping track of particular vaccination against which majority of children are not getting

proper vaccination in time and analyze how many chances will be there that the particular disease will spread in that area based on different trends listed in Knowledge base of system.

#### 4.9. Generating alerts, sending SMS and making calls

The system will generate alerts for every vaccination and will send SMS or make call to child's parents to remind them of vaccination. Twilio web service to be used for sending SMS and making voice calls. Figure below describes the steps for sending alerts to parents.

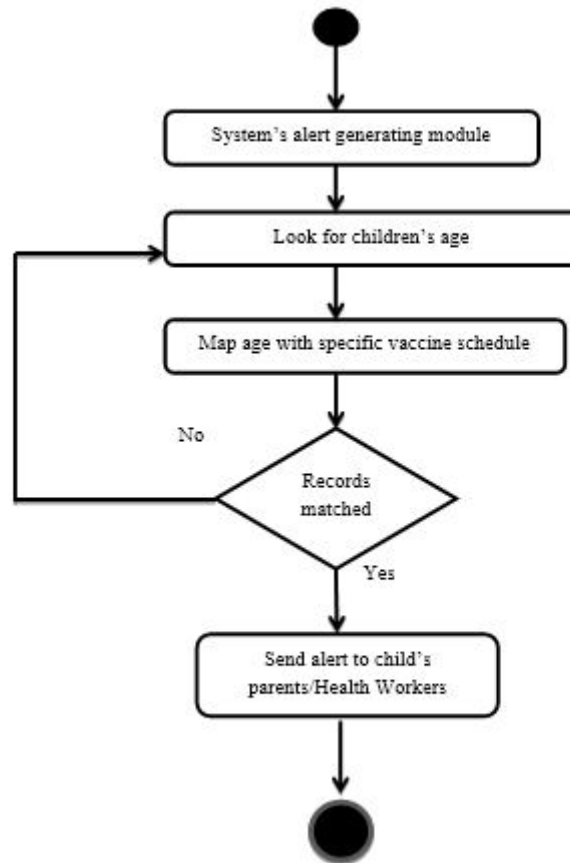


Figure 6: Flowchart for generating vaccination alerts

#### 4.10. Geo-locating health workers

The system will track health workers by geo-locating hand-held device and its active status in order to monitor them through NOC.

### 5. Software Architecture

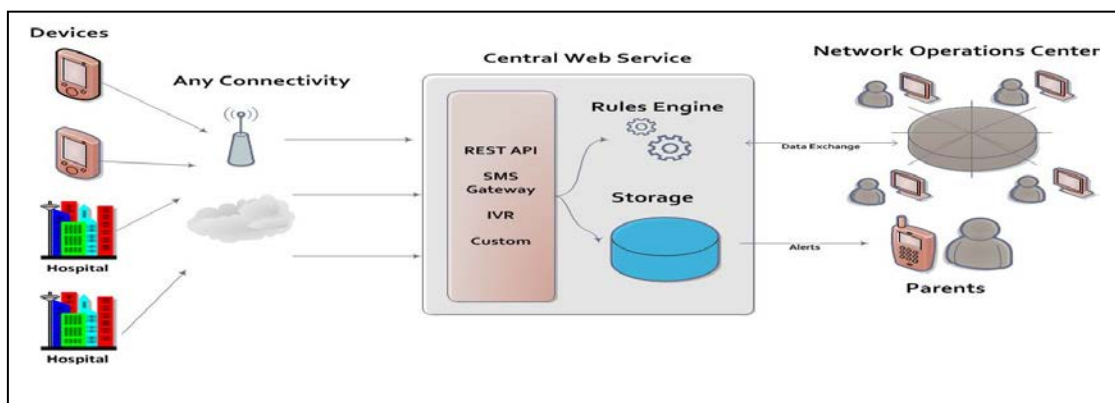
There will be thousands/ millions of active handheld devices with installed app those directly linked to Cloud servers via 3G/4G connectivity as well as web based interface accessible from anywhere to be used by hospitals, health-care departments and many more. The cloud servers will be further connected to different repositories



like NADRA repository for authentication of parents' fingerprints, national repository to retrieve/update child's vaccination history and view schedules. The national repository will be storing itself all the information of the system including analytical results. The Network operators within NOC will be able to visualize all analytical metrics ranging from tracking records of health workers to delayed/missed vaccinations within district, national and global level. The system will be continuously monitoring different analytics based on different extracted parameters and will be able to deal with trends listed in Knowledge base of our system.

**5.1. Application Architecture**

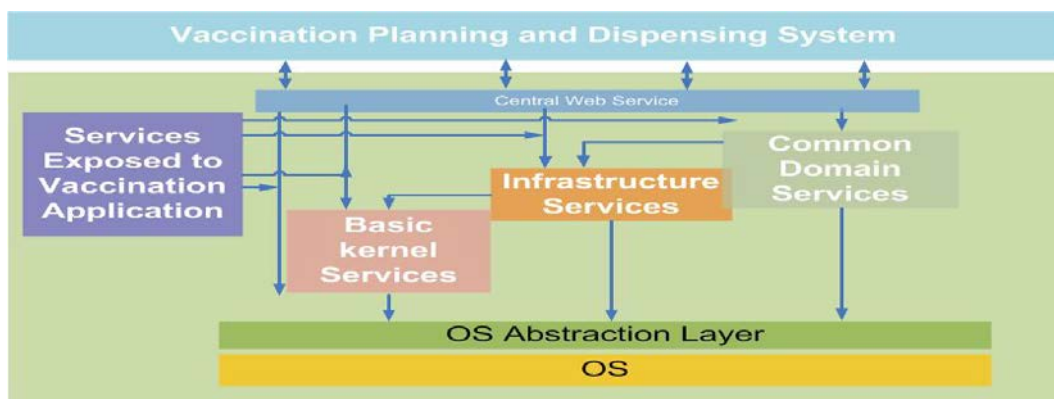
The diagram below gives general overview of application architecture. The devices are connected via 3G/4G or internet to central web service comprising rule engine, central database storage and different APIs. The data is exchanged to NOC and alerts generated to parents.



**Figure 7:** Application Architecture of Vaccination Planning and Dispensing System

**5.2. Service Oriented Architecture**

The hand-held devices as well as web application will communicate over the network providing all services ranging from basic kernel to infrastructure services. The diagram below illustrates the proposed service oriented architecture for the system.



**Figure 8:** Service Oriented Architecture of Vaccination Planning and Dispensing System

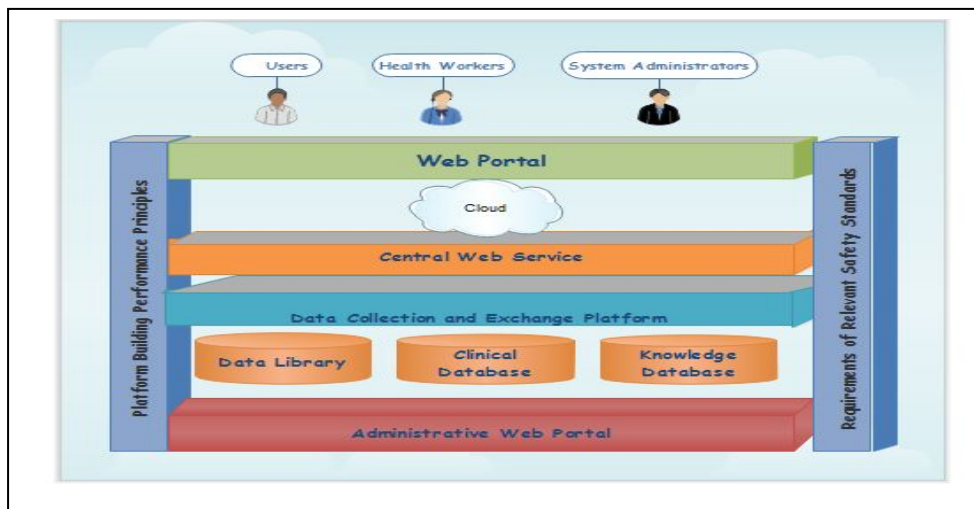
The table below lists the common, infrastructure and basic kernel services for the system.

**Table 1:** Services included in Service Oriented Architecture

| Common Domain Services                                | Infrastructure Services                        | Basic Kernel Services        |
|---|--|------------------------------|
| User Identification, Authentication and Authorization | Centralized Software installation and upgrades | Vaccination Monitoring       |
| Information exchange and editing services             | Web Services                                   | System Management            |
|   | Database Management System                     | Information Authentication   |
|   | Data storage, recovery and archiving           | Data encryption/decryption   |
|   | Database security services                     | Logging                      |
|   | SMS and Voice calls services                   | Exception Management service |

### 5.3. Web Based System Design

The diagram below gives general overview of the web based portal that has been proposed to be accessed from anywhere. This web based portal will be mostly accessed by hospital staff whenever a child will be brought to health center or hospital for vaccination or registration.



**Figure 9:** Architectural Design for Front-end Web Portal of Vaccination Planning and Dispensing System

## 6. Vaccination Information System

Vaccination Information System is a real-time android application to be used as a prototype model for implementing the proposed system on National level. This is done by incorporating a system consisting of handheld devices with this application installed onto them. This system uses a finger print scanner to authenticate the finger prints of the parents of the child. It stores all the records of the child immunization and also provide analysis on diseases and their vaccinations. At the time of vaccination, the time and location of the child is automatically stored into the database through the GPS of the application device that further helps in determining the vaccination campaign success rate. All this information to be stored in the database which is being saved and managed on windows azure. SMS alerts using Twilio Service are sent to parents to remind them of their child's vaccinations. The figures below show snapshots of the different interfaces of application.

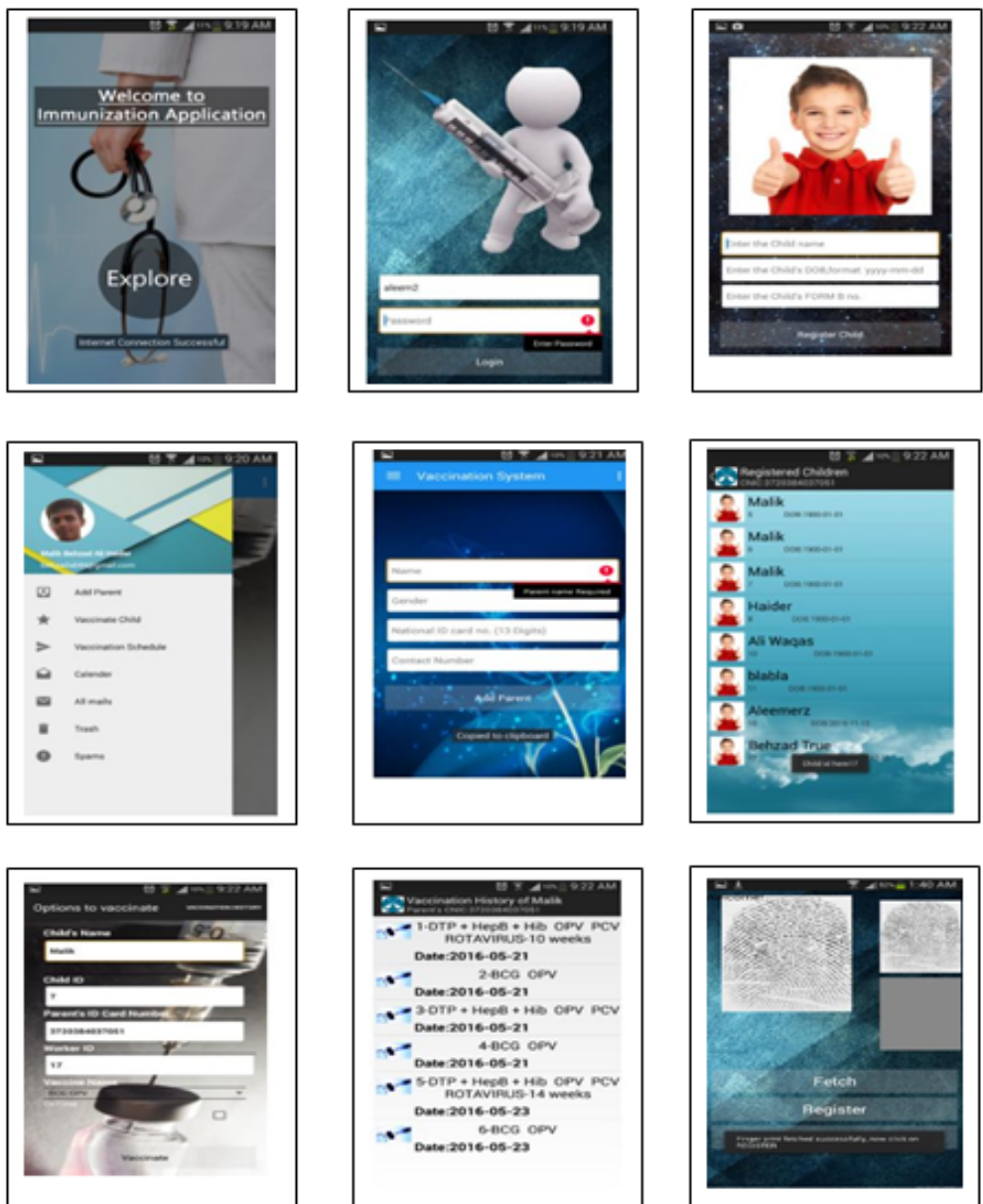


Figure 10: Vaccination Information System Interfaces

## **7. Related Work**

A middleware framework comprising HL7 and web services standards has been proposed for the Health Information System (HIS) as a project of National Taiwan University Hospital (NTUH) [3], providing an effective solution for integration of information systems on large scale. In order to overcome the health information gaps in rural Africa, a software architecture design having an application based on Mobile technology (namely MoTeCH) has been proposed to address the information needs of pregnant women, young mothers and frontline health workers in response to health development [4]. An architectural e-healthcare design along with its demonstration prototype [5] based on GSM Networks that provide well-defined interfaces for client's application. The healthcare services are provided by Clinic and Pharmacy Architecture. A speech recognition engine namely SRI's DynaSpeak has been used in this system for illiterate patients. Many parents have different risk concerns about vaccination due to which they don't get their children vaccinated properly. To overcome and reduce these parental concerns, an interactive web-based tool [6] using different quantitative and qualitative methods like individual interviews, surveys, focus groups and usability testing has been developed. An autonomic system Cloud environment [7] architectural design has been proposed to analyze ECG data that integrates Cloud as well as Mobile Computing.

## **8. Conclusion**

The proposed architecture is an initial iterative step to overcome immunization problems being faced in poor and under-developed countries. The application is addressed to needs of parents as well as health workers for timely vaccination of children. The application will make voice call to parents in their local language as well as send a reminder SMS of their kid's upcoming vaccination. The health workers will update record of child vaccination by firstly authenticating registered child from its parents' biometrics or RFID card and then providing information about the given vaccine like vaccine name, date, time and place where vaccine given. The system will help analyzing trends based on timely provided and delayed vaccinations for particular area or district or National level thus helping us to predict spread of various diseases in future. These systems' implementation requires advanced software development skills, keen attention to software requirements meeting quality standards in order to provide a configurable design to be more readily available to Public health department and hospitals so that they can make use of them.

## **9. Recommendations**

This research deals with software architecture design so the main focus is to perform requirement engineering from user perspective in order to propose an architecture for developing a user-friendly system. The constraints from developer's prospective are not yet discussed in this research. The proposed architecture is initially used to implement an android-based application model with limited features. This prototype model is used and tested for a small population only. In future we will implement a system on National level by using iterative software development model and validate the system using different testing methodologies and applying acceptance test procedures. The scope of this research can be extended to perform trend analysis of different diseases like Polio, Measles and establish inferences based on the number of timely dispatched and missed vaccinations by

analyzing historical vaccination data and predict percentage of spread of various diseases for the years to come.

### **Acknowledgements**

To present the software architecture design for vaccination planning and dispensing system would not have been possible without leadership and contribution of Dr. Shoab Ahmed Khan. An android “Vaccination Information System” application has been developed by students of Computer Engineering Department, CEME NUST based on the proposed architecture and design. The application will serve as a prototype model for building the system on National level in near future to be funded by Ministry of Science and Technology, Pakistan.

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