ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

FACULTY OF INFORMATICS

DEPARTMENT OF COMPUTER SCIENCE

Mobile based Voluntary Counseling and Testing Data Collection System

By

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A Project report submitted to the School of Graduate Studies of Addis Ababa University in partial fulfillment for the Degree of Masters of Science in Computer Science

June, 2010

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ACKNOWLEDGMENT

First and foremost I would like to thank Dr. Solomon Atnafu for his advice and support in completing this project successfully. Next I would like to thank Ato Nassir Kelil from Federal Ministry of Health for providing me all necessary information. My deepest gratitude goes to beloved wife Ameturahman Nassir who was beside me providing moral support. I would also like to thank my friends Abebe Abeshu and Zenebe Nigussie and other colleagues for providing me with ideas with the project paper and implementation of the project and unforgettable sleepovers.

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List of Acronyms

AIDS	Acquired Immune Deficiency Syndrome
API	Application Programming Interface
ART	Antiretroviral Treatment
ETB	Ethiopian Birr
FK	Foreign Key
GPRS	General Packet Radio Service
HIV	Human Immunodeficiency Virus
MIT	Massachusetts Institute of Technology
MMS	Multimedia Messaging Service
ODK	Open Data Kit
PK	Primary Key
SMS	Short Message Service
TB	Tuberculosis
UI	User Interface
VCT	Voluntary Counseling and Testing
W3C	World Wide Web Consortium

ABSTRACT

Access to up-to-date health data plays a crucial role for the improvement of health service delivery. In Ethiopia, one of the sub-Saharan countries highly affected with HIV/AIDS, there are a number of governmental and non-governmental organizations providing health service related to HIV/AIDS. Voluntary Counseling and Testing (VCT) is one of such services. Monthly reports on VCT are collected from all over the nation using paper forms. This paper forms have to pass through various administrative hierarchies and are recompiled at each level. Due to these the reports are delayed and up-to-date data on VCT is not available.

VctCollect is a mobile VCT data collection system developed to avoid the delays involved in collecting VCT data. The system allows health workers at VCT centers to fill forms for each VCT client using android mobile phones and send the filled data to a central VCT resource center. The mobile application of the system has a bilingual user interface, Amharic and English, which makes it easier to use. The data is sent from the mobile phone through the GPRS mobile internet network. The server side web application of the system allows users to have access to the latest data collected from VCT centers. Users can have access to up-to-date VCT data all over the nation in various formats. The system was developed using the open source Open Data Kit as an underlying framework.

Keywords: Mobile VCT, VCT data collection, HIV data collection, VCTCollect, mobile health data collection

1. INTRODUCTION

1.1 BACKGROUND

As education, agriculture, business or any other industry, health service delivery needs to make use of information. What makes it different from the others may be the type of information to be handled. Information to be handled in health could be patient record, drug record, prevalence of epidemic diseases and the like. Prevention and treatment are the major health services to be delivered by the health sector. Decisions to be made for the purpose of prevention or treatment need to be based on up-to-date information regarding the disease at hand. Failure to have up to date information at hand for decision making might have adverse consequences. For instance, less effort could be spent for the prevention of a particular disease, due to the lack of information about its spread.

In the developed world, where there is adequate communication infrastructure, having access to up-to-date information for decision making is relatively easy. But in a developing country, like Ethiopia, the lack of reliable infrastructure, ubiquitous connectivity, and adequate expertise makes this more difficult. When it comes to collecting information from rural areas, the problem becomes even worse. Currently, most organizations collect data on paper forms despite inefficiencies such as the physical collection of completed forms, data transcription errors, and long delays before the data is available.

Unfortunately this is also the case of the health sector in Ethiopia. Information regarding even one of the most fatal diseases, HIV/AIDS, is collected on paper forms. A lot of governmental organization and non-governmental organizations are currently working in Ethiopia to prevent the spread of HIV/AIDS and treat HIV patients. VCT and ART are two of the major health services provided in relation to HIV/AIDS. VCT refers to voluntary counseling and testing service which is carried out by VCT centers around the nation. ART refers to anti retroviral treatment which is carried out by ART centers around the nation. All the governmental and non-governmental bodies working on this two basic services use reports collected by ministry of health as their source of information. As these reports are collected using papers they are delayed and error prone.

With the continued expansion of mobile technology around the globe, and the persistent lack of universal Internet connectivity, the use of mobile phones in public health presents a new opportunity to improve health services delivery. In addition to the variety of data (text, photos, location, audio, video, barcode scans) that can be gathered, mobile devices have proven to be dramatically faster at both collecting the data and making it available to decision makers. Moreover, deploying mobile devices can be less expensive and less error prone than using pen and paper [1, 2].

More and more people are using mobile phones in Ethiopia. The reduction in the price of mobile devices and expansion of mobile network coverage has contributed too much for the widespread use of mobile devices in the country. Currently there are about 4.1 million mobile phone subscribers and the mobile network coverage is expanding even in rural areas [3].

The use of mobile phones in Ethiopia is still mostly limited to telephone calls and short messages. But they can be used for various applications including data collection. The fact that mobile phones are also being used in rural areas in addition to urban areas provides a good opportunity to use mobile phones for health data collection.

Reports on VCT and ART, which are currently being collected on paper forms, could easily be collected using these mobile phones. This reduces the cost and delay of the reports, increases the accuracy of the data and allows access to up-to-date information which can be of great input for the prevention and treatment of the chronic diseases like HIV/AIDS.

The system to be developed is a mobile VCT data collection for Ethiopia. Health workers in VCT centers will use a mobile device to upload data to a central server. On the server side the system will allow generation of different kinds of reports on VCT. This will allow access to a more accurate and up-to-date data on VCT for governmental and non-governmental organizations currently working on HIV/AIDS ,researchers, students or any other interested party.

1.2 PROBLEM STATEMENT

It has been stated that access to up-to-date health information improves health service delivery. Currently in Ethiopia health data is being collected on paper forms. Other alternate means of data collections are not being utilized. Paper based data collection is error prone, slow and more expensive.

In particular Ethiopian ministry of health collects monthly HIV VCT reports from all over the nation using paper forms. The existing reporting mechanism has obviously some shortcomings. First and for most the reports should be recompiled at the zone level and region level .This recompilation at each level is error prone. Another problem is the time taken for a report from a VCT centre to reach the Ministry of Health. Much time and resource is wasted to take a report from each VCT centre to zonal health bureau, zonal health bureau to regional health bureau and from regional health bureau to Ministry of Health. Due to this the national reports of the ministry lag behind [4].

1.3 OBJECTIVE

1.3.1 General objective

The main objective of this project is to design and develop a mobile system for collecting VCT data using the open source ODK technology.

1.3.2 Specific objective

The specific objectives of the project are to

- Analyze the current situation to propose a better and a working system.
- Design a system that considers the current situation and the available technologies.
- Identify appropriate devices and technologies to implement the designed system.
- Implement the system based on the current requirements.
- Test and evaluate the developed system.

1.4 SCOPE

The scope of the project work is limited to the following:

- The mobile application to be developed for the client will only work for android mobile phones.
- Due to time limitation, the project to be developed will be limited to VCT and does not include ART or any other types of services offered in relation to HIV/AIDS.
- For the purpose of accepting reports or data from mobile devices, SMS and MMS will not be used; the system will only use GPRS network as a means of accepting data from mobile devices.

1.5 METHODOLOGY

In order to design and develop the system,

- Literature review has been conducted to study and analyze the previous efforts in this domain.
- Existing VCT data collection system has been assessed to find out what data needs to be collected, how the collected data is analyzed and monitored in the VCT service provision.
- Requirements of a VCT data collection system have been identified.
- Based on the requirement identified, the system has been designed
- Prototype has been developed and then tested in the identified target environment. During implementation stage, programming languages, simulators and other software tools were selected and used.

For the overall system development life cycle, object-oriented software development approach is used.

1.6 OUTLINE OF THE DOCUMENT

This project report contains six Chapters including this Chapter. In the next Chapter, reviewed literatures and related works are presented. In Chapter three, the current system and its limitation are presented. In Chapter four and five, requirement analysis and design of the proposed system is presented. In the remaining Chapters, the developed prototype is shown and then conclusion and future work is given.

2. LITERATURE REVIEW

2.1 ODK

Open data kit is an open source tool developed by researchers at the University of Washington and Massachusetts Institute of Technology in 2009. It serves as a framework for developing and deploying mobile based data collection systems. Data is transferred from the mobile phone to server using forms. The mobile phone client downloads a form from the server, fills the form and sends the filled form back to the server. The tool accepts forms designed according to the W3C XForm standard. It has two major components, ODK Aggregate and ODK Collect [1].

ODK Aggregate is the server side application of the tool. It is designed to run on the Google App Engine, a web server provided by Google for hosting web applications. But it can also be configured to run on a localhost or any other web server. It allows uploading new forms. Once a form is uploaded to the server, authorized clients can download the form to their mobile phone, fill it and send back the filled form to the server. This server side application logs each filled form as submissions. But it doesn't have any mechanism of presenting the data in a manner that can be understood by end users. It displays the submissions of a form in a single table, which could have many columns depending on the type of form and data submitted. Each row of this table represents a single submission. Despite this it doesn't provide any mechanism of searching, analyzing or generating reports based on the submitted data.

ODK Collect is the client side application of the tool. It is designed to run on mobile phones which are based on the android platform. It allows users to download forms from ODK Aggregate, fill, save filled forms for review, and send filled and reviewed forms. The user interface of ODK Collect is in English. Furthermore it doesn't have authentication mechanisms to restrict access to the system [1, 12].

2.2 RELATED WORKS

Mobile phones are currently being used to improve health service delivery in many countries including South Africa, Kenya, Uganda and many other sub-Saharan African countries. A range of mobile based applications were developed for this purpose. Based on the technology of implementation we can categorize these applications into two, as SMS or MMS based and ODK based. Those applications that are based on SMS or MMS use SMS or MMS for sending data from mobile phones. Those that are ODK based are built upon the ODK framework use GPRS mobile internet network for sending data from mobile phones. Such applications have been deployed in several developing countries mainly as a pilot project [5]. Some of these applications are discussed in the following sections.

2.2.1 SMS or MMS Based

Click diagnostic

Click diagnostic is a system developed to deliver health care services through mobile telemedicine. It is piloted and deployed in developing countries such as Botswana, Malawi, Egypt, Ghana, and Bangladesh. University of Pennsylvania's Global Health Program and MIT's Innovations in International Health were involved in this project. Click Diagnostic system enables health-workers to provide advanced medical consultation and gather health data by connecting to global health servers via mobile phones. It is designed to provide different services such as remote consultation and diagnosis, early diseases detection and warning and public health data-gathering. For instance, with the help of this system, health workers can take pictures of people's eyes or skin and transmit the picture to doctors for diagnosis. The system uses mobile phones with MMS capability for sending data from mobile phones to the server .The server side application of this system is not web based and the data collected cannot be accessed by researchers, students and others which do not have access to the system [7].

Cell-Preven

Cell-Preven is a system that combines mobile phone and Internet to create a real-time surveillance system of adverse events. It is tested in Peru as a pilot project. The overall goal of this application was to develop an interactive-computer system using mobile phones for real-time data collection and transmission of adverse events. By the help of this application, data can be

collected by interviewers from field and the collected data can be sent to an online database where it could be accessed immediately. In addition selected symptoms can be reported to key personnel via e-mail and SMS messages to act on it on time.

This pilot project has demonstrated that it is feasible to develop a public-health surveillance system based on mobile phones to collect data in real-time in Peru. Mobile phones are chosen in this project because they are affordable by most users and require limited infrastructure to run in remote areas where Internet connectivity and electric power supply is limited. With the help of this application, health workers can collect data and report adverse events and disease outbreaks from field and the collected data can then be analyzed on time to give immediate response. [8].

The Dokoza System

The Dokoza System is SMS based mobile system designed to fast-track and improve critical services to patients. Initially it was developed for HIV/AIDS and TB patients but it was later extended to include other diseases patients. The project is implemented in South Africa mainly to solve the problem of data-sharing in health sector. The system involves the use of SMS & mobile phone technology for information management, transactional exchange & personal communication. The mobile phone makes use of an existing mobile technology and normal SMS text message. As a result it does not require special additional software for interacting. Dokoza's back-end system is extensively rule based for intelligent interaction to build the capacity of health workers with little knowledge and experience. The Dokoza system is also integrated with the existing hospital system for data sharing. The server side application of this system is not web based and the data collected cannot be accessed by researchers, students and others which do not have access to the system [5].

Mobile Phone for Tele-dermatology

Tele-dermatology is a subset of telemedicine that incorporates information technology to deliver dermatology service at a distance. In dermatology, examination is primarily based on visual inspection. For this purpose, visual information can be passed as digital image for tele-consultation and tele-diagnosis.

For such application, images can be transmitted electronically by using MMS functionality of mobile phones. Currently new generation mobile phones allow taking good quality images and transmitting them directly to other mobile phones via messaging services. Such application is very helpful in cases where there is lack of dermatologists or when the patient is in remote area where face-to-face communication or consultation is impossible. This system is mainly developed for remote diagnosis and cannot be applied for health data collection [9].

Health Information System through Mobile Telephony

This system serves both health workers and the general public. It allows health workers to obtain information about HIV patients and monitor follow-up care between visits. It uses a mobile phone-based software application that enables health workers to capture, store, and process, transmit, and access patient records. The client side application which runs on a mobile phone will allow public users log into the system and ask questions regarding HIV. The questions are sent to the server side application as SMS text. On the server side a search agent application, running on top of a database of answers to frequently asked questions, will analyze the SMS message and reply with the most relevant answer as SMS text. This system is developed and being used in Botswana. This system is primarily developed to provide support and information for the public and cannot be applied for health data collection [10].

Medical In-Field Diagnostic Assistant (MIDA)

MIDA aims to help isolated rural health workers with a free, interactive diagnostic support tool to enhance their work and also to compile health information to assist government and NGO workers. MIDA uses mobile technology to minimize system running cost and to realize mobility. With the help of this system, rural health workers can get assistance from the server by sending SMS text message from their mobile phone. Reported cases can also be accessed by health professionals in the health center through the web interface. In addition the health authorities can be alerted early about spreading epidemics by accessing data in real-time basis.

MIDA utilizes a simple user interface through which field workers can submit query as SMS text-message to the central data-hub. The central system can then interpret and process the given query automatically and provide medical diagnostic information back to the field worker.

Through the series of SMS message exchange, the field worker can get solutions to the reported problem. The system is also capable of routing the reported information to specialists via email for further consultation. This system is primarily developed for providing diagnostic assistance for health workers in remote areas and cannot be applied for health data collection [11].

2.2.2 ODK Based

AMPATH

AMPATH which stands for Academic Model for the Prevention and Treatment of HIV, is an ODK based system used for health data collection for home based HIV counseling and testing in rural areas of Kenya. Counselors use android mobile phones to record data regarding every household. This data includes the barcode ID of every test client, the GPS location of the household and other demographic details. The collected data is submitted to a medical records system (OpenMRS) for analysis and follow up. As the system is based on ODK, it uses the GPRS network for sending the data from the android mobile phones to the central medical records system. The server side application of this system is not web based and the data collected cannot be accessed by researchers, students and others which do not have access to the system [1].

2.2.3 Summary

The SMS based mobile health data collection systems can only be used to collect textual data up to 160 characters [14]. This imposes a limit on the type and amount of data that can be collected using such systems. But since SMS functionality is available in almost all mobile phones the initial cost of deploying the system is less expensive.

The MMS based health data collection systems can be used to collect different types of data including text and pictures. But unlike SMS not all mobile phones are capable of sending MMS messages. So relatively more expensive mobile phones are required. Furthermore the price charged for a single MMS message is more expensive than that of MMS.

The ODK based health data collection system can also be used to collect different types of data including text, picture and the like. But since they can only run on android mobile phones, which are relatively more expensive, the initial expense of deployment could be relatively higher than

that of SMS and MMS. On the other hand the price charged for GPRS communication is by far less expensive than both SMS and MMS. In particular if we consider the current prices in Ethiopia the charge for a single SMS is around 0.35 ETB (35cents), for MMS it is around 2.3 ETB per 50KB and for GPRS it is around 0.04 ETB (4cents) per 100 KB of data. So the overall cost of ODK based systems could even be less expensive than both SMS and MMS based systems [6].

Having studied related mobile based health data collection systems, we have observed the following limitations. There is no system developed for the purpose of VCT data collection or that can be directly used for this purpose. Furthermore all the above systems have user interfaces in English which might make them difficult to be used by health extension workers in Ethiopia especially those in rural areas.

The system to be developed in this project is ODK based and the mobile application will have a bilingual English and Amharic user interface which is not available in all of the above systems. Furthermore the server side application of the system is a web application that has features open for any user without authentication who is interested to have access to summarized VCT data.

3. SYSTEM ANALYSIS

3.1 CURRENT SYSTEM

The Ethiopian ministry of health collects various health related reports from all over the nation. Reports related to HIV/AIDS are one of the main reports collected monthly by the ministry. The reports are mainly focused on VCT (Voluntary Counselling and Testing) and ART (Anti-Retroviral Treatment). The VCT service is currently given in Ethiopia in VCT centres. These centres are found in most hospitals, clinics or other health institutions. In addition to this there are also mobile VCT centres which offer the service on streets or other public places. In rural areas VCT service is also given by health extension workers using HIV test kits. Every time a person uses the VCT service i.e. takes a voluntary counselling and testing for HIV, the health workers fill various details of the individual on paper forms. These details include age, sex, and the like.

Every month each VCT centre prepares a report summarizing the VCT service provided in the month. The reports are prepared on papers using tables. These reports are then forwarded to the corresponding zone health bureau. The reports are taken from the VCT centres to the zone health bureau by a person. These reports are then summarized and consolidated into a single report at the zone level. A sample VCT report format to be generated at the zone level is shown in figure 3.1.

The zone reports are taken by a person to the regional health bureau the same way. The regional health bureau again summarizes the reports from zones in the region and produces a consolidated regional report. The report is taken to the Ethiopian ministry of health again by a person.

Currently there are more than 1000 VCT centres in all regions of Ethiopia. VCT reports are generated from each centre monthly. This means that there will be more than 1000 reports generated each month. The reports from all the regional health bureaus in Ethiopia are compiled by HIV/AIDS Prevention and Control Office and made available for use [4, 13].

Table 3.1: Sample VCT report format

Monthly VCT Report										
Reporting Zone _____										
					Reporting month_____					
					Reporting date _____					
Age group										
	pre test counseling		**Tested**			**Post test counseled**		**Positive**		
	M	**F**	**M**	**F**	**T**	**M**	**F**	**M**	**F**	**T**
0-4										
5-14										
15-19										
20-24										
25-49										
50 and above										
Total										

The VCT data collected by the existing system is delayed and error prone. This is due to the fact that the data is gathered and recompiled at various administrative hierarchies. But this data could be collected using mobile phones using the existing mobile network infrastructure. This will reduce the delay as the data will be directly sent from VCT centres to a central VCT resource centre. Furthermore the data could be less error prone due to the absence of recompilation at various levels.

3.2 PROPOSED SYSTEM

3.2.1 Overview of the System

Taking the drawbacks of the current data collection system into account, we have proposed a mobile data collection system to support the current system. The proposed system will allow health workers at VCT centers to capture details of each VCT test with the help of mobile phone.

For every VCT client, the health worker will fill all the necessary details, including the results of the test, using the mobile phone. The health worker will then send this data to a central VCT resource center server. The mobile application of the system will have a bilingual user interface, Amharic and English. At the server side of the system, which will be made available via the Internet, Health professionals, researchers, or other interested parties can have access to up-to-date information on VCT all over the nation.

The server side interface of the system will be designed in such a way that it allows users to filter VCT information using various criteria like region, year and month. The system displays summarized VCT data in three various formats. The first one is in a table format which displays the VCT test result figures summarized according to the filter criteria and categorized into age groups and sex. The second one is in a Map format, where the system presents a map of Ehtiopia with all the 11 regions marked clearly. The user will be able to click on the region of his interest and get the summarized VCT test results of the current month. The last one is in excel format which presents summarized VCT test results of all regions divided into zones and categorized by sex. The system will also allow authorized system users to have access to personal details of VCT clients with positive result. These details are filled during the test if and only if the client is willing to provide them. These details include full name, address and others.

3.2.2 Functional Requirements

Main modules of the system include:

- Form Management Module
- Report Generation Module
- Utility Module

Form Management Module

This module is responsible for the management of forms both on the server side and the client side.

a) Upload new form to the server.
b) Download form from the server to the client mobile phone.
c) Fill/Save/Review/Edit/Send form
d) Receive/Parse/Save form submission

Utility Module

This module is responsible for managing access to the system

a) Add/Edit/Remove system user
b) Login/Logout system user

Report Generation Module

This module is responsible for generating different kinds of reports.

a) Search for specific records
b) View summarized results

3.2.3 Non-Functional Requirements

Non-Functional requirements describe user visible aspects of the system that are not designated to the functional behavior of the system. The requirement includes from user interface to security issues. Generally, Non-Functional requirements of the system can be viewed as follows:

User interface and Human factors

Two types of interfaces should be considered when talking about the human factor since users of the system will interface with the software to be deployed on a personal computer and a mobile phone. When we consider the user interface on the personal computer since the server side application of the system is a web application, users will access it through web browsers and the user interface will be designed in familiar web design styles. When we come to the mobile phone short and simple user interface that will allow the user to fill, save, edit and send forms will be generated. For better simplicity of the user interface, the user interface will have captions both in English and Amharic language.

Hardware and software consideration

The server side of the system should be accessible seamlessly using the major web browsers like Internet Explorer, Firefox, Chrome and Opera. The client side of the system should be accessible through mobile phones with the android platform.

Performance Characteristics

Since the system is going to be accessed by different users with different needs, it should be capable of handling and processing their queries quickly. Since the system is an online system, it is difficult to tell exactly how many users will be using the system at a time. However, if the system is being accessed by many, all the users must feel that they are the only one using the system. Besides the software, hardware will also be a great factor in the systems' performance. Generally, the system should be able to handle many users and it should be responsive.

Error Handling and Extreme Conditions

The system should be able to handle errors encountered during run time. Errors could rise from users and from the system. Errors that occurred from the wrong doing of users will be handled by

appropriate exception handling mechanisms. Generally, if an error occurs, the system will identify the error and notify the user so that he/she can take the appropriate corrections.

System Modifications

System modification is based on the interest and the need of the clients as well as the developers. As of the users' comment (feedback), the system will be modified to meet their requirement. In fact, the developers or any trained person that knows the code behind the system does this modification. Moreover, modifications can be achieved without a problem since the system is going to be designed using an object oriented approach.

Security and Privacy Issues

The system should be protected with different security features (techniques). Any user who wants to login to the system must have a user name and password. This protects the system from any unauthorized access. A user in any section will be given the right to access and/or modify the data related to that section. In addition, the system allows only one user to use a single user name at a time. Generally, the system should be secure to a level that, even when it is available online, critical information should not be available to non-authorized users.

Furthermore since the anonymity of every test client is important, the system should allow only authorized users to access personal details of the test clients.

3.3 ANALYSIS MODEL

3.3.1 Actors of the system

An actor describes any entity that interacts with the system. In this system, the interaction of actors with the system is through either the mobile application which runs in the mobile device or through the web interface. In the proposed system, the following actors were identified. The actors are listed in Table 3.1.

Table 3.2: Actors of the system

Actor	Description
Health Worker	This person is responsible for registering details of individuals taking the VCT test.
System Administrator	A system administrator is a person who is responsible for administering the whole system including adding new users and removing existing users.
System User	A system user is a person who has been given user name and password to access restricted reports on the server side of the system. This can be a researcher, government official and others.
User	A user is any person who accesses features of the web application of the system which do not require authentication.

3.3.2 Use Case Diagram

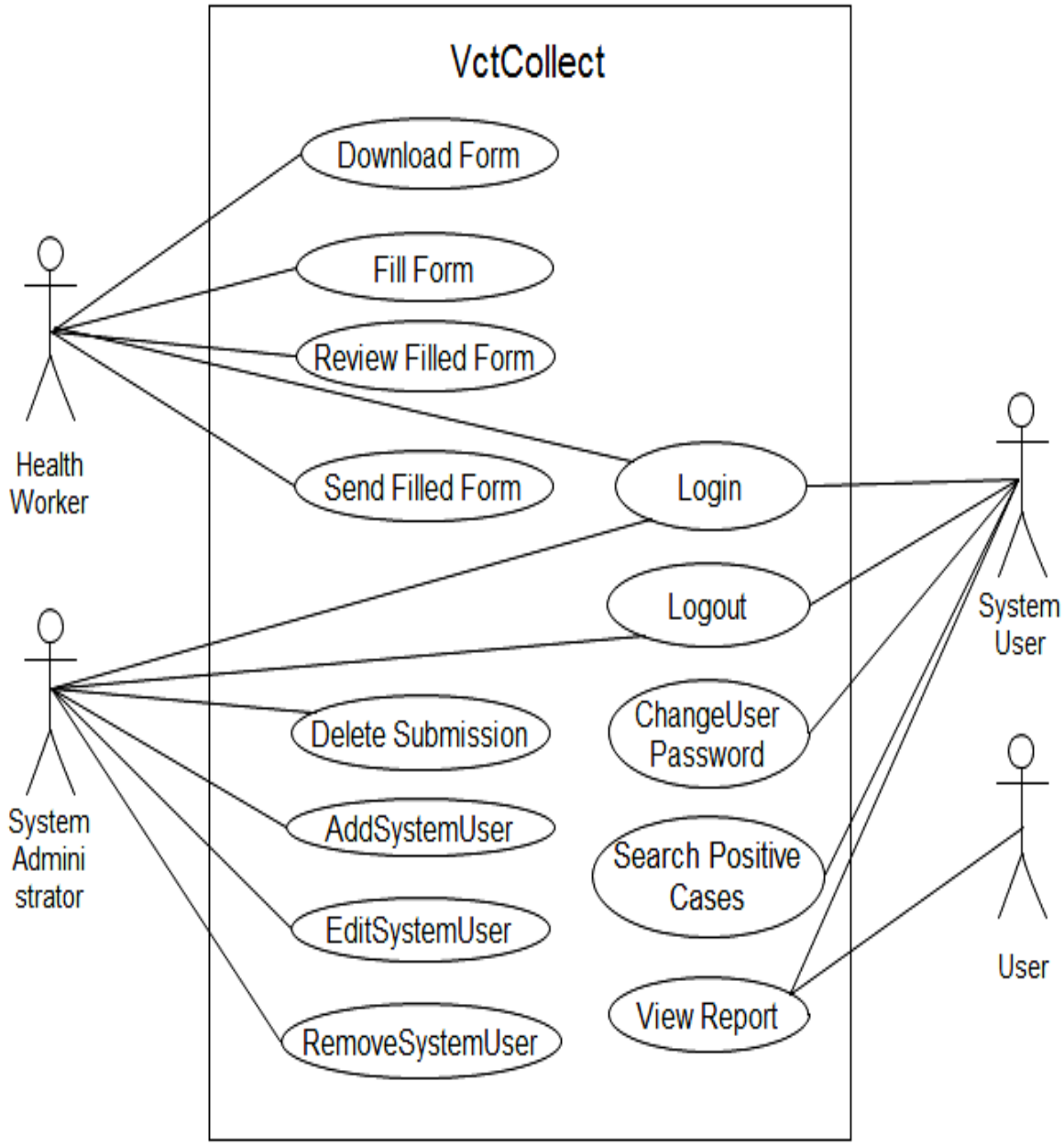


Figure 3.1: Use case diagram

3.3.3 Use Case Description

Use case Name	Download Form
Participating Actors	Health Worker
Description	The health worker needs to download a form the server for data entry.
Entry condition	The health worker is logged in.
Flow of events	The health worker selects on “Manage Files”. The system displays the form to download. The health worker selects the form. The health worker selects “Add the Selected File” The system displays an acknowledgment of successful download of the form.
Exit conditions	A new form is downloaded.

Use case Name	Fill Form
Participating Actors	Health Worker
Description	The health worker needs to fill the form whenever there is a VCT test.
Entry condition	The health worker is logged in.
Flow of events	The health worker selects on “Enter New Data”. The system displays the form to be filled. The health worker fills the form. The health worker selects “Save as Complete” A1 The system displays an acknowledgment of successful saving of the filled form.
A1	The health worker selects “Save as Incomplete” if the form is not filled completely.
Exit conditions	A form is filled.

Use case Name	Review Filled Form
Participating Actors	Health Worker
Description	The health worker needs to review filled form before uploading to the server.
Entry condition	The health worker is logged in.
Flow of events	The health worker selects on “Review Saved Data”. The system displays list of filled forms not uploaded to the server. [A1] The health worker selects the form. The health worker reviews the filled data and makes editions if necessary. The health worker selects “Save as Complete”. The system displays an acknowledgment of successful saving of the form.
A1	1. The system displays “Nothing to Display” message if there is no saved form.
Exit conditions	A filled form is reviewed/edited.

Use case Name	Send Filled Form
Participating Actors	Health Worker
Description	The health worker needs to upload a filled form to the server.
Entry condition	The health worker is logged in.
Flow of events	The health worker selects on “Send Completed Data”. The system displays list of filled forms ready to be uploaded to the server. [A1] The health worker selects the form. The health worker selects “Send”. The system displays an acknowledgment of successful uploading of the form.
A1	1. The system displays “Nothing to be sent” message if there is

	no filled form available.
Exit conditions	A filled form is sent to the server.
Use case Name	Delete Submission
Participating Actors	Administrator
Description	The administrator needs to delete a submission in case it is a wrong one.
Entry condition	The administrator is logged in.
Flow of events	The administrator selects on “Delete Submission”. The system displays list of submissions of a form. The administrator selects the submission to be deleted and clicks on “Delete Submission”. The system displays an acknowledgment of successful deletion of the submission.
Exit conditions	A submission is deleted from the server.

Use case Name	View Report
Participating Actors	User
Description	The user needs to view consolidated reports.
Entry condition	
Flow of events	The user selects on “Report”. The system displays “View Report Page”. The user enters the filter criteria. The system displays a consolidated report based on the user criteria.
Exit conditions	A report is viewed.

Use case Name	Search Positive Cases
Participating Actors	User
Description	The user needs to view details of clients with positive results.
Entry condition	

Flow of events	The user selects on “Positive Cases”. The system displays “Positive Cases Page”. The user enters the filter criteria. The system displays details of clients with positive test results based on the user criteria.
Exit conditions	Positive case details are viewed.

Use case Name	Login
Participating Actors	All system users
Description	Any user who wants to access the system’s functionalities should be able to login to the system
Entry condition	The user needs to be already registered.
Flow of events	
	1. The system displays a login form 2. The user enters his/her credentials 3. The user clicks on login button A1
A1	1. The system displays an error message 2. Got to step 1.
Exit conditions	The user is logged in.

Use case Name	Logout
Participating Actors	All system users
Description	Any user who accessed the system’s functionalities should be able to logout of the system
Entry condition	The user is logged in.
Flow of events	
	1. The user clicks on logout menu 2. The system displays the home page of the system.
Exit conditions	The user is logged out.
Use case Name	Add System users
Participating Actors	System Administrator

Description	As the system is designed to be operated by more than one user, the System administrator should be able to add System users.
Entry condition	The Operator is logged in to the system
Flow of events	
	1. The Administrator clicks on add user button 2. The system displays the add user form 3. The administrator enters the user details and selects the job title 4. The administrator clicks save button 5. The system adds the user to the system 6. The system displays an acknowledgment
Exit conditions	A new user is added.

Use case Name	Edit system user profile
Participating Actors	System Administrator
Description	The administrator may want to change the profile of the system user. These profiles may be the user name, password and roles.
Entry condition	The system user or the administrator is logged in to the system
Flow of events	
	The administrator clicks on Administration menu The system displays a list of administrative tasks The administrator clicks Edit system user profile The system displays list of system users The administrator selects a single user and clicks on change profile The system displays change profile form The administrator changes the users profile The administrator clicks on save The system saves the changed profile The system displays an acknowledgement
Exit conditions	The user profile is changed.

Use case Name	Change password
Participating Actors	System user
Description	The system users in their own behalf can change their own passwords.
Entry condition	The system user is logged in to the system
Flow of events	The user clicks on change password menu The system displays change password form The user enters his/her previous password and the new password The user clicks change The system stores the new password The system displays an acknowledgement
Exit conditions	The new password is stored

Use case Name	Remove System User
Participating Actors	System Administrator
Description	The system administrator needs to remove a system user.
Entry condition	The system administrator is logged in to the system
Flow of events	1 The administrator clicks on Administration menu The system displays a list of administrative tasks The administrator clicks Remove system user The system displays list of system users The administrator selects a single user and clicks on remove user The system displays an acknowledgement
Exit conditions	A system user is removed from the system

3.3.4 Class Diagram

This section present the class diagram for the proposed system which shows the classes of the system along with their attributes and methods , and their relationship.

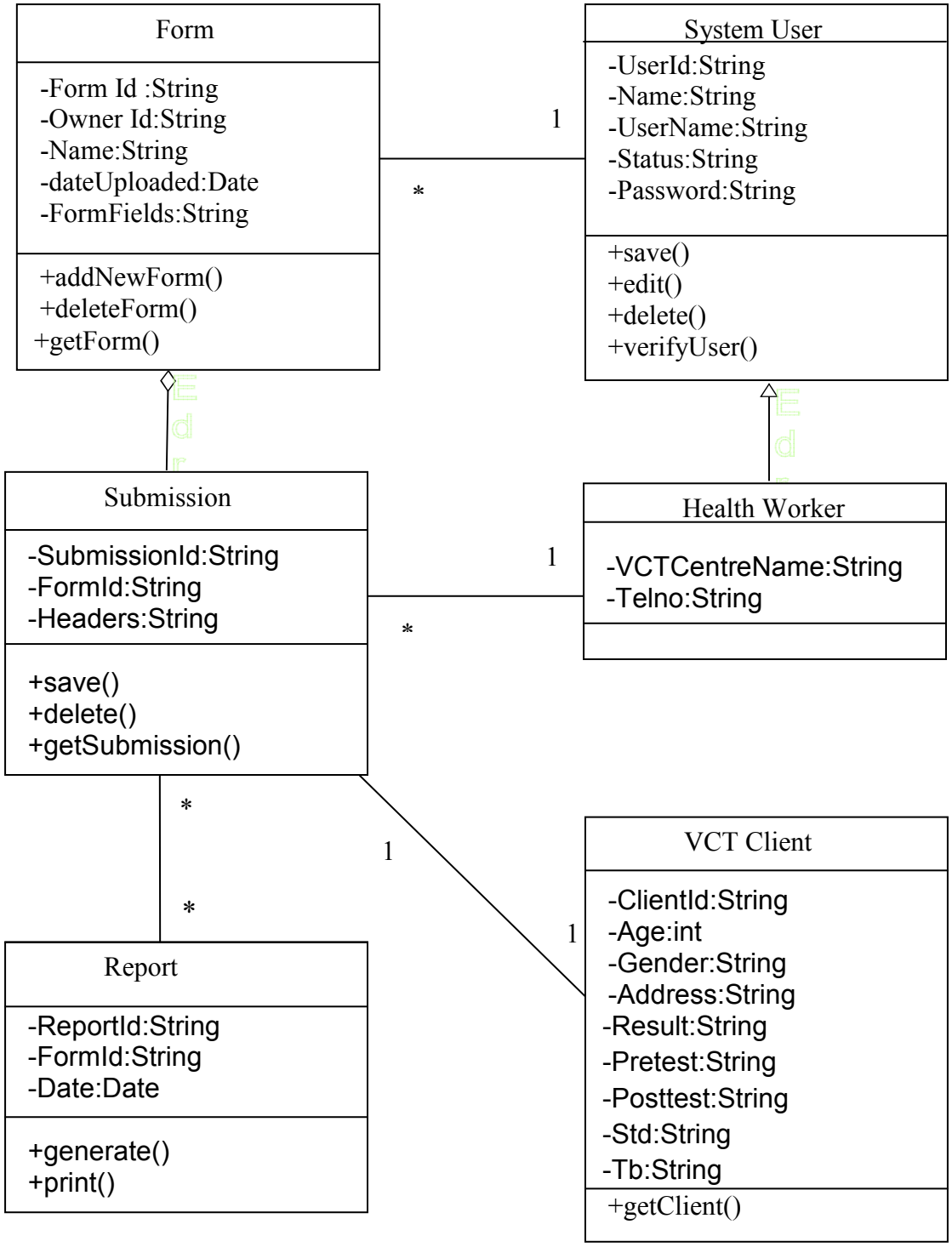


Figure 3.2: Class diagram

3.3.5 Sequence Diagram

This section presents sequence diagrams for the major functionalities of the system. Sequence diagrams help to visualize the interaction between various objects of the system.

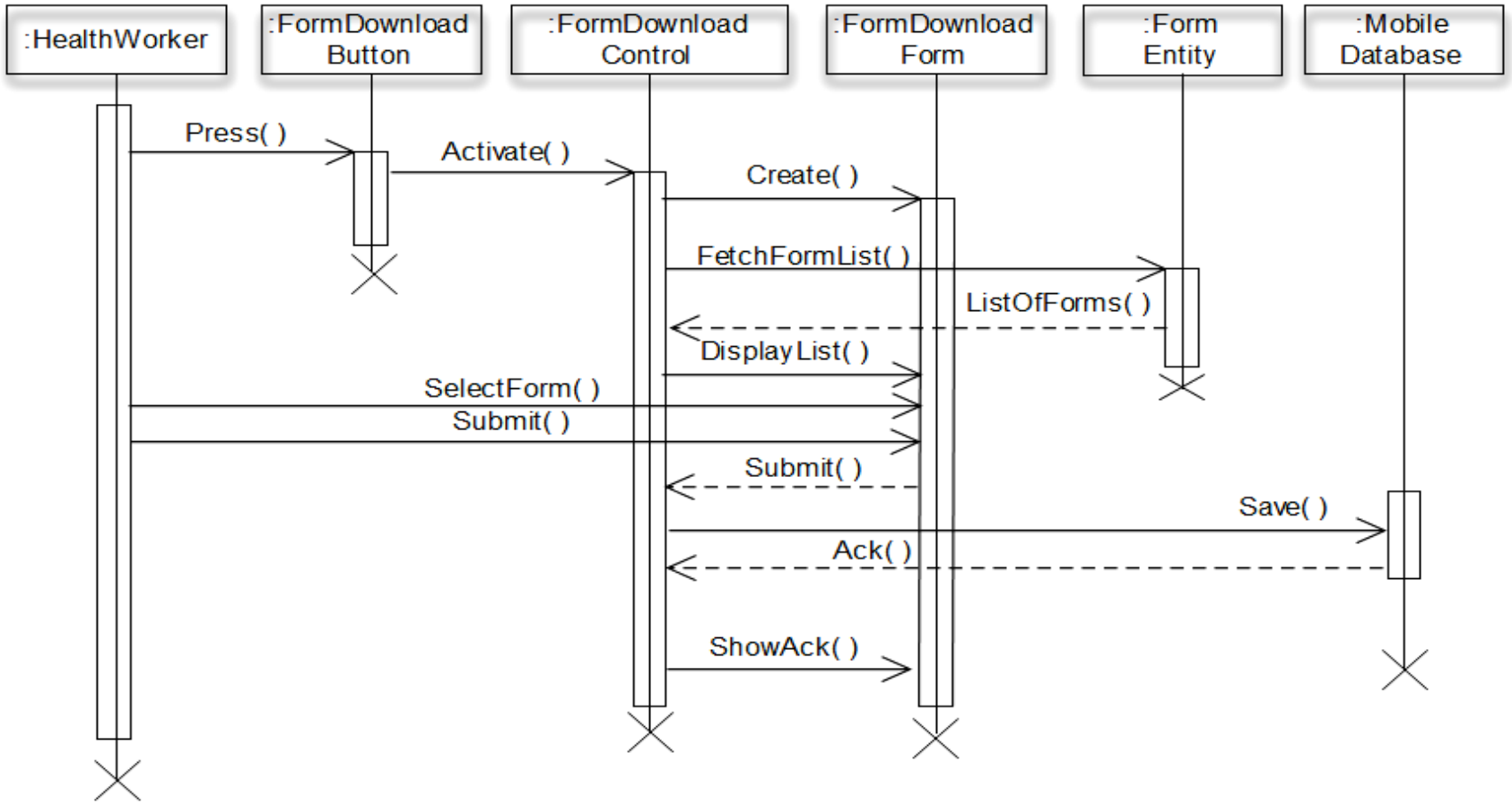


Figure 3.3: Form download sequence diagram

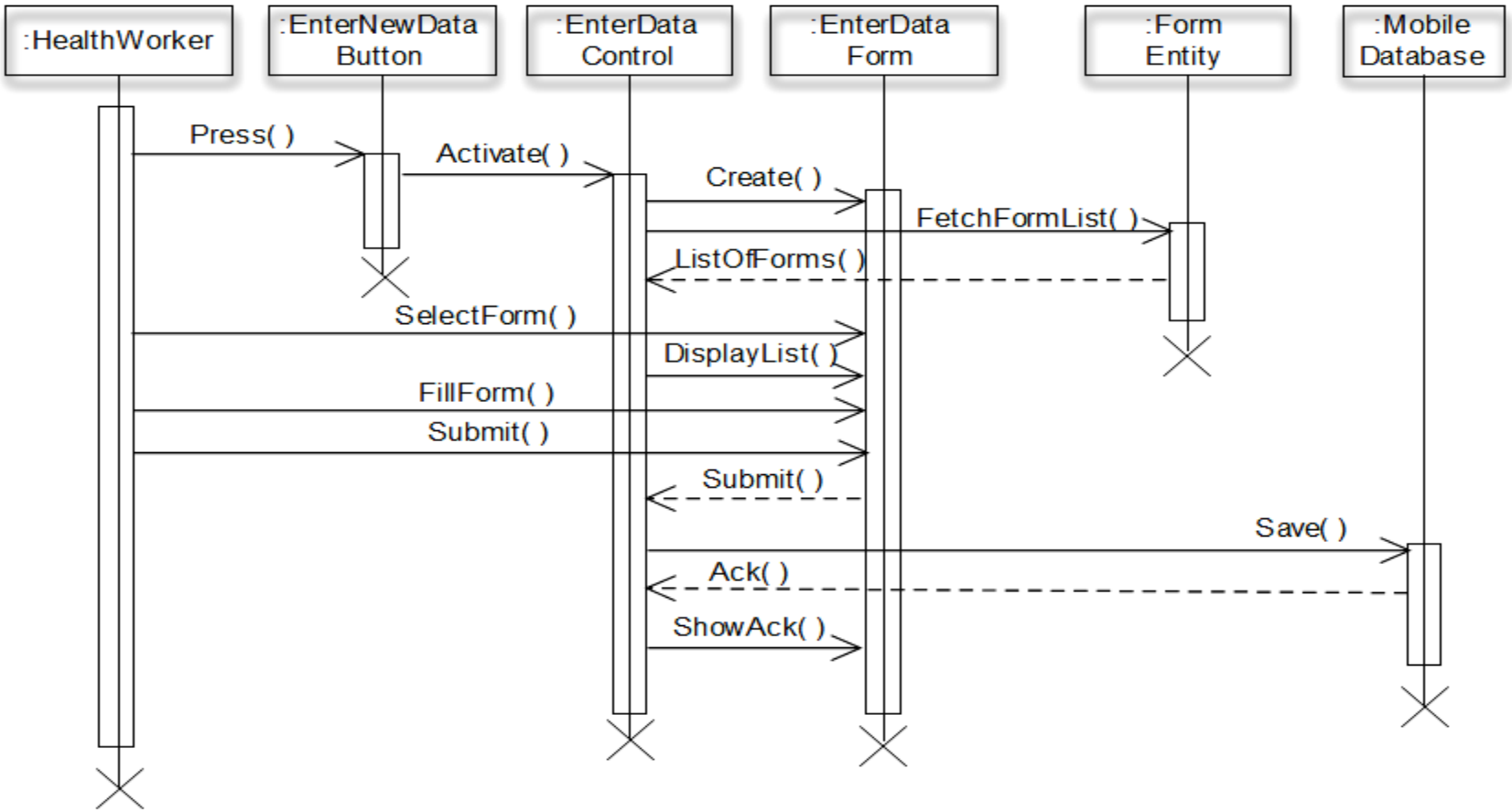


Figure 3.4: Fill form sequence diagram

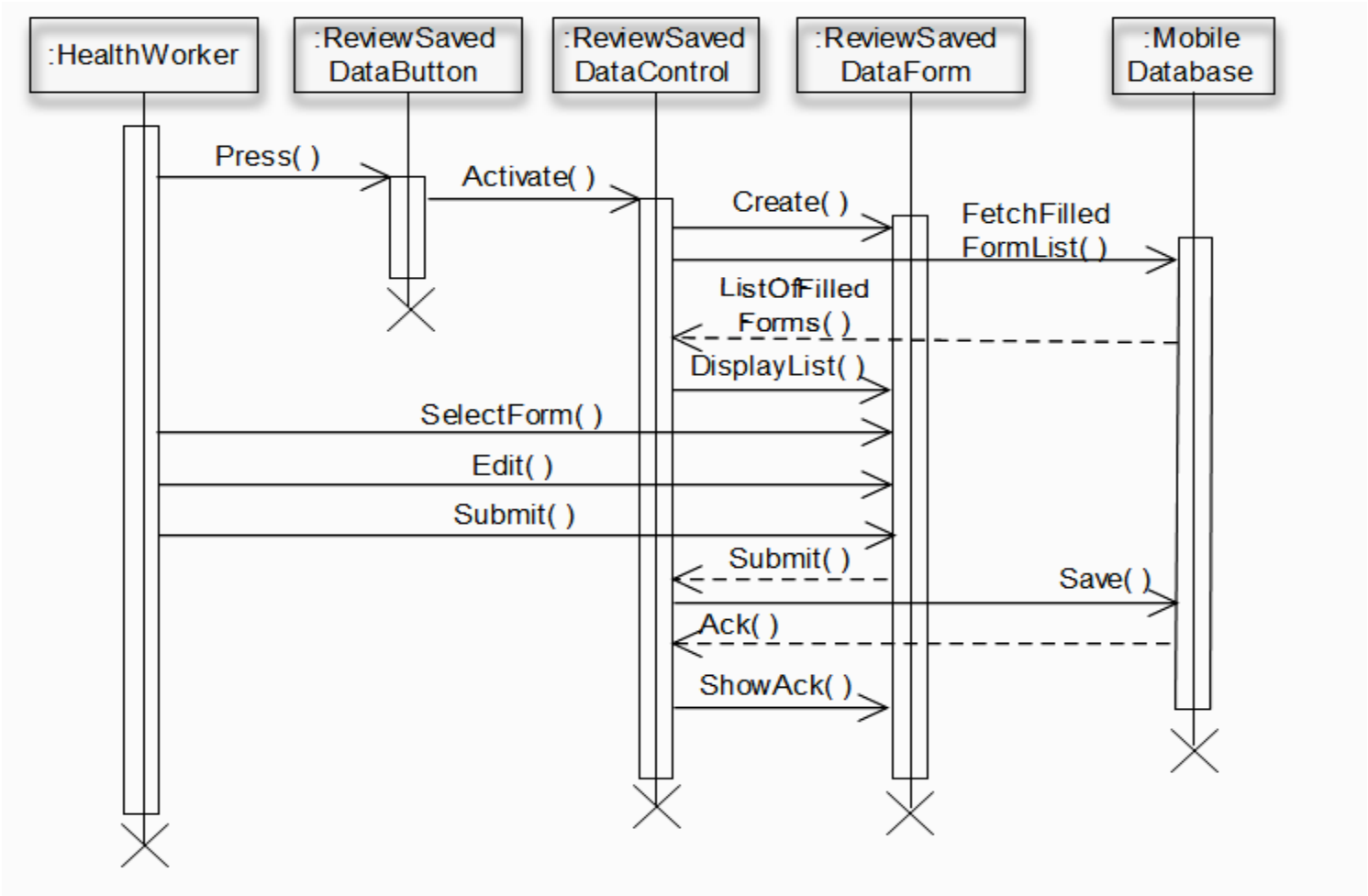


Figure 3.5: Review filled form sequence diagram

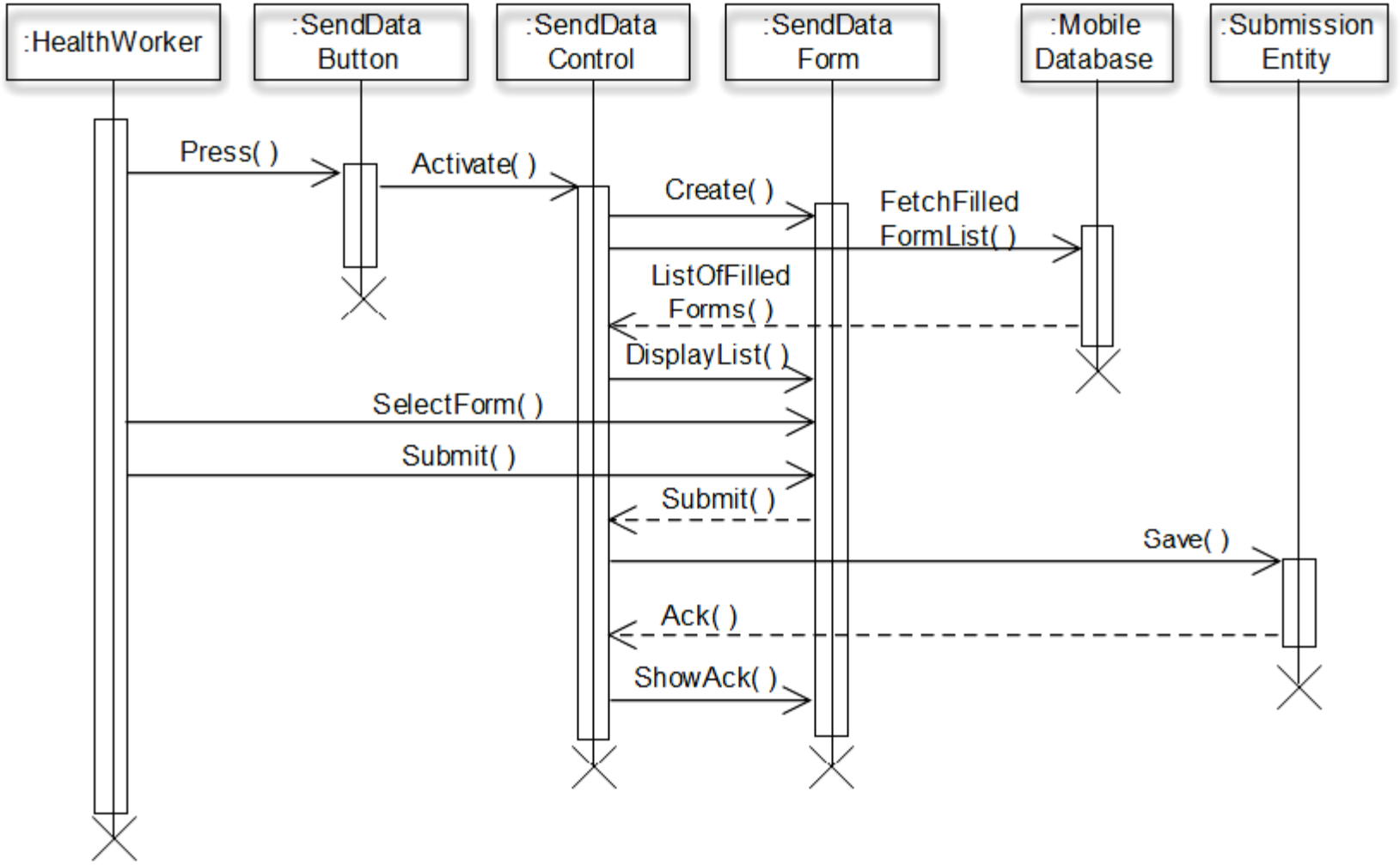


Figure 3.6: Send filled form sequence diagram

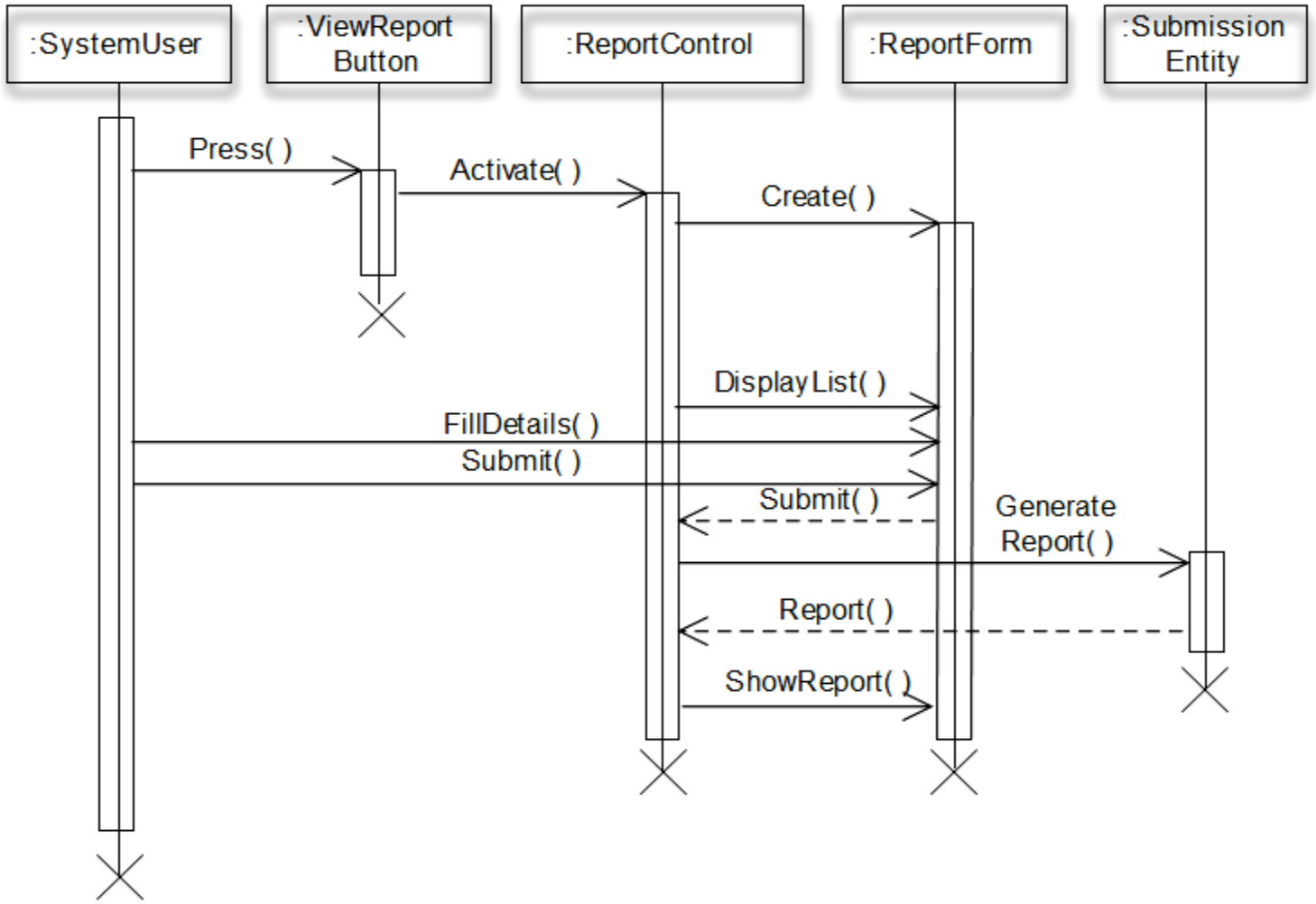


Figure 3.7: View report sequence diagram

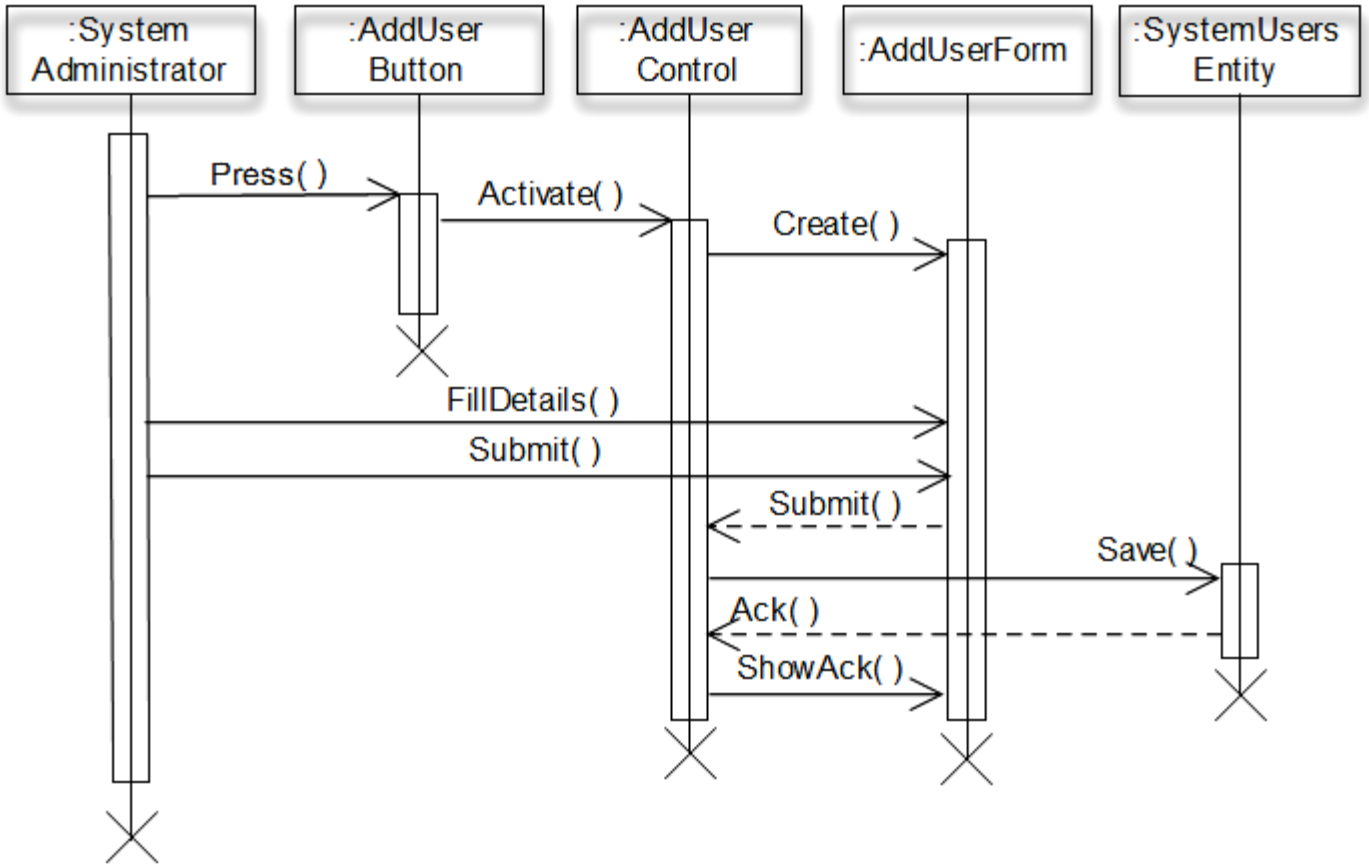


Figure 3.8: Add user sequence diagram

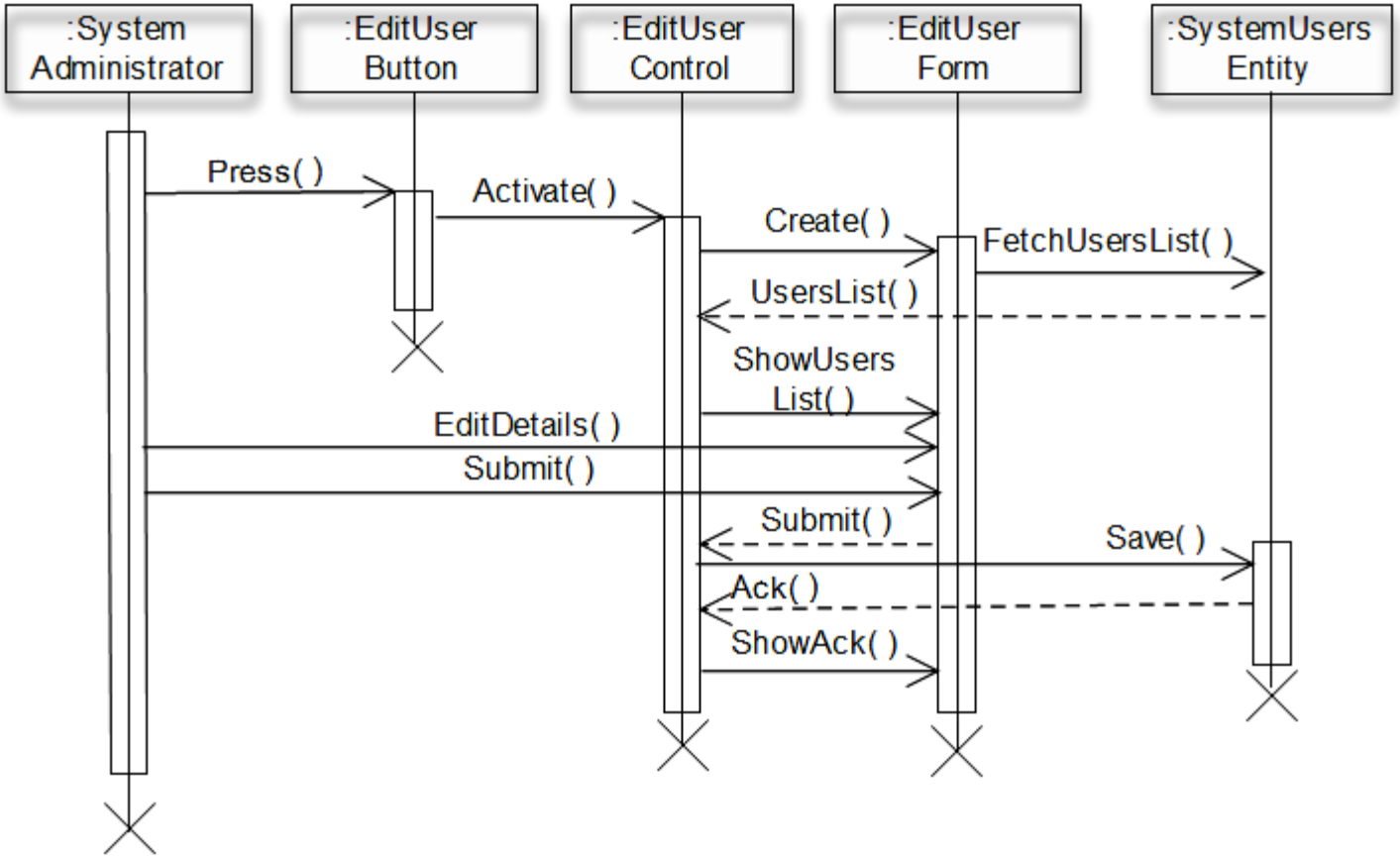


Figure 3.9: Edit user sequence diagram

4. DESIGN OF THE SYSTEM

The design goals represent the desired qualities that the system should have and provide a consistent set of criteria that should be taken into consideration when making design decisions. The following are outlined to be the design goals of the system.

4.1 DESIGN GOALS

The new system is considered to be successful if it meets the following sets of criteria's.

- **User Interface**: The user interface of the system should be easy to use by each user of the system with little training. Especially the user interface on the mobile device should be so simple to use as it is going to be used by health workers in remote areas, which may have less experience in using computerized systems.
- **Documentation**: System administrators and other users are provided with proper documentation about the system's features.
- **Performance**: The system should be able to serve a number of users which are expected to access it concurrently.
- **Robustness**: The system should be designed in such a way that users can't proceed having entered invalid input or data in all cases of interacting with the system.
- **Availability**: The system should be available 24 hours online to accept submissions from health workers and provide reports.
- **Security**: The system should be designed in such a way that every user be authenticated to access the systems resources except to generate consolidated reports which do not carry any sensitive personal details.
- **Modifiability**: The system should follow modular or object oriented design so that modification to some part of the system does not affect other parts.
- **Portability: -** The server side of the system should be easily accessible on various platforms like windows, UNIX or Macintosh etc via standard web browsers. The client side of the system should be accessible using any mobile device with the android platform.

4.2 PROPOSED SYSTEM GENERAL ARCHITECTURE

As shown in figure 4.1 the system has three major components; the mobile client, the web server and the web client. The mobile client is the client side of the system that runs on the android mobile phone. Health workers at VCT centers will use the application on the mobile phone to fill forms and send them to the server side application of the system. The communication between the mobile phone and the server side of the system is using GPRS mobile network. The server side application of the system, along with the database of the system, resides on a web server. The web client represents system users that access the server application of the system through web browsers.

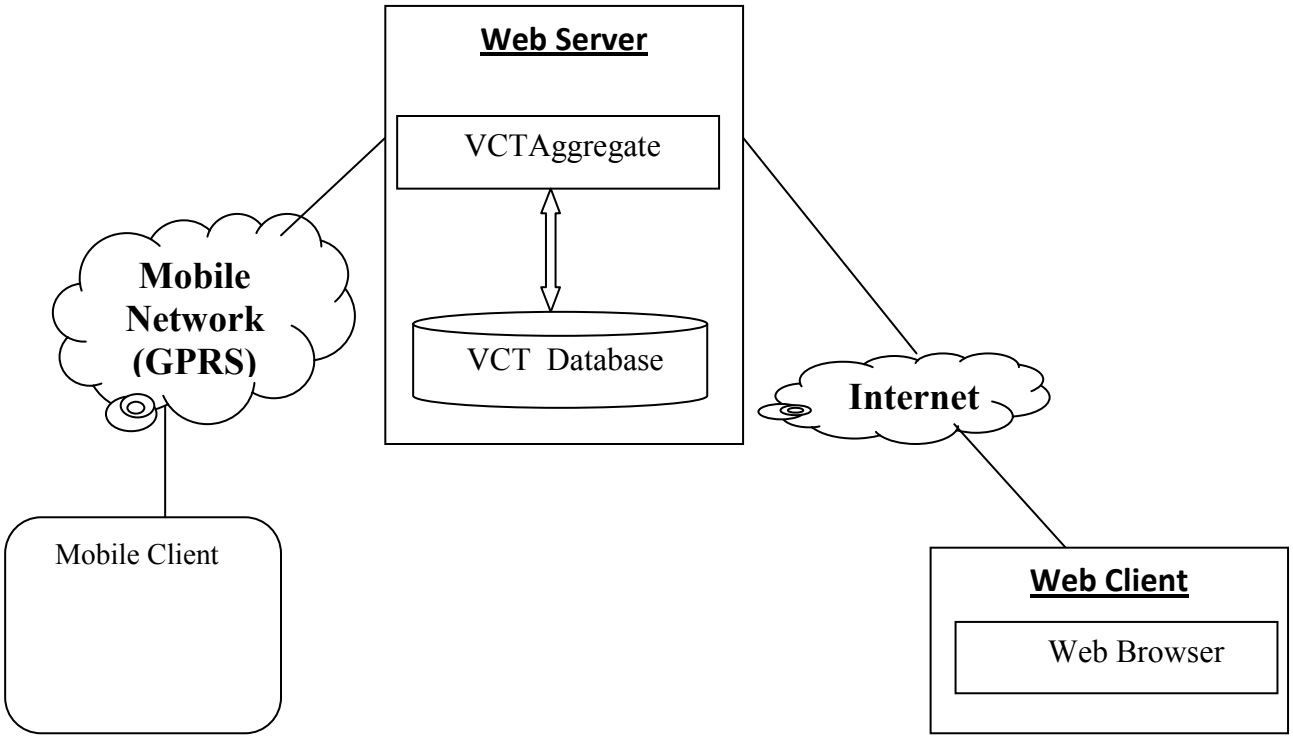


Figure 4.1: Proposed system architecture

4.3 SYSTEM DECOMPOSITION

The system will be built on a layered architecture. A layered architecture makes it easier to maintain or modify one part of the system without affecting the others. If for example the users need a modification on the User interface, they could get it without affecting the whole or the rest of the system. All layers will be interacting only with the layer right next to them. No layer will be interacting with a layer it doesn't have direct access to. This policy shall make the code readable and maintainable. The following diagram shows the layers that the system will be constructed on.

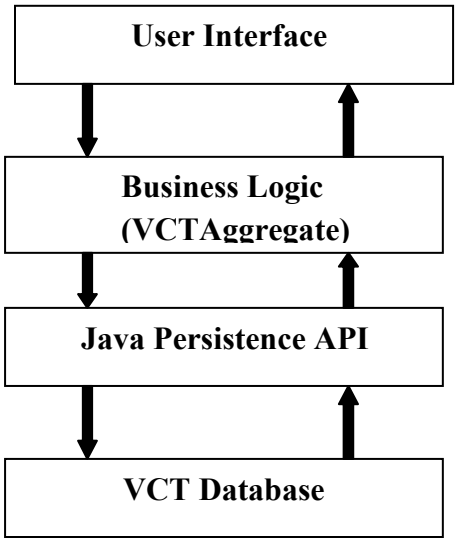


Figure 4.2: Layered Architecture of the System

As shown in figure 4.2, the system will have four logical layers to achieve its design goals. The next section will describe the layers in detail.

The User Interface: the user interface layer is the layer on which all the user interface codes are implemented. This makes the whole implementation easier to modify because a change in one layer will not affect other layers.

Business Logic Layer: this layer is a layer that really implements the business requirements and constraints. The business logic layer implements all the functional requirements without the User interface. On the business logic layer, the system should have the following sub systems. These sub systems interact to achieve the final goal. Details of the sub system can be found at the functional requirement section.

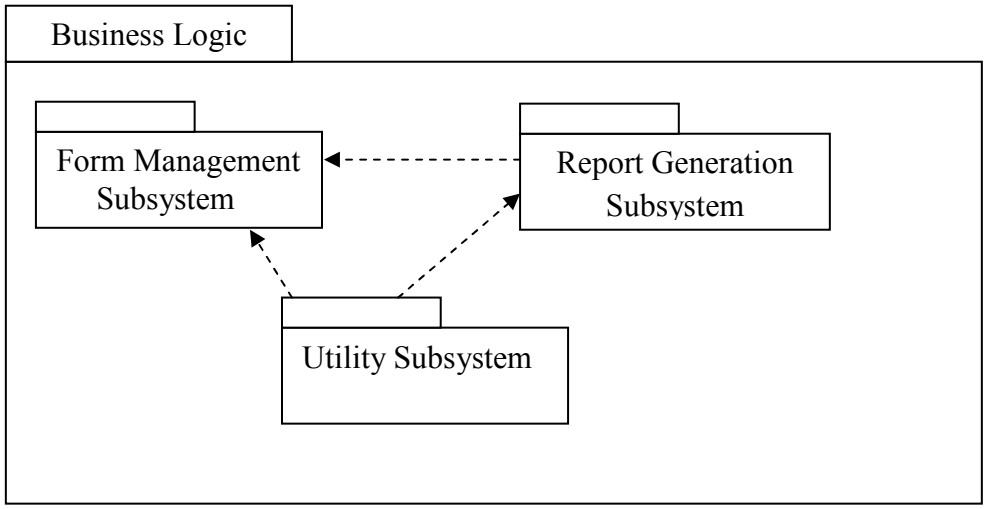


Figure 4.3: Business logic layer

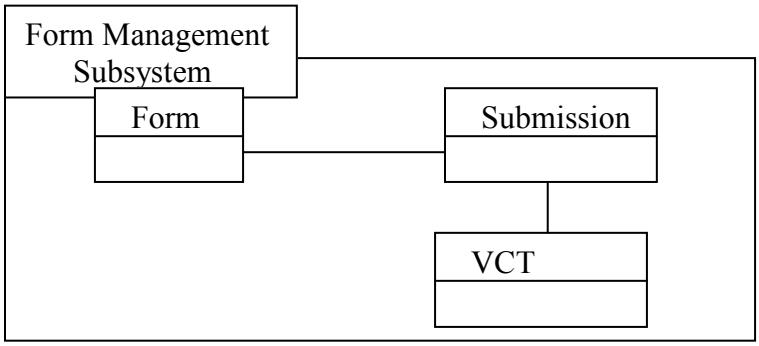


Figure 4.4: Form Management Subsystem

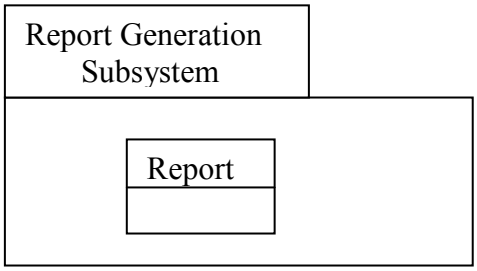


Figure 4.5: Report Management Subsystem

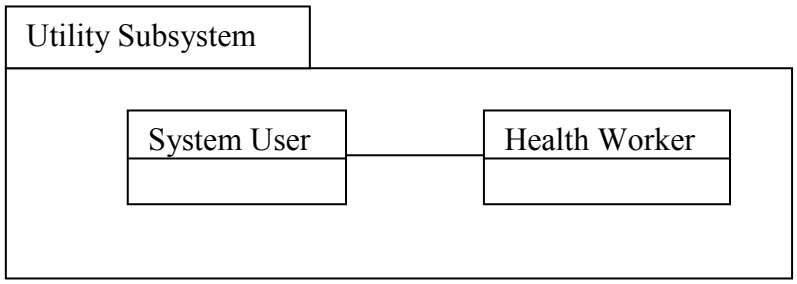


Figure 4.6: Utility Subsystem

Java Persistence API: this layer is responsible for connecting the database with the business layer. This layer shall support basic database operations like creating new rows, deleting, updating etc. in the object oriented name space.

VCT Database: The system will be using a database for its persistent data storage.

4.4 HARDWARE SOFTWARE MAPPING

The hardware software/mapping of system shows the relationship between nodes and independent software components. In line with that the following diagram shows the nodes and components used in the system. Since the system is web-based client nodes should have browser components, whereas the web-server machine will have IIS. The same web-server or an independent machine, will host the database. Figure 4.7 shows the deployment diagram which includes the mobile application deployed on the mobile device of the user, the application server where all the business logic functionalities are deployed on and the database server. The system will be using client/server architecture.

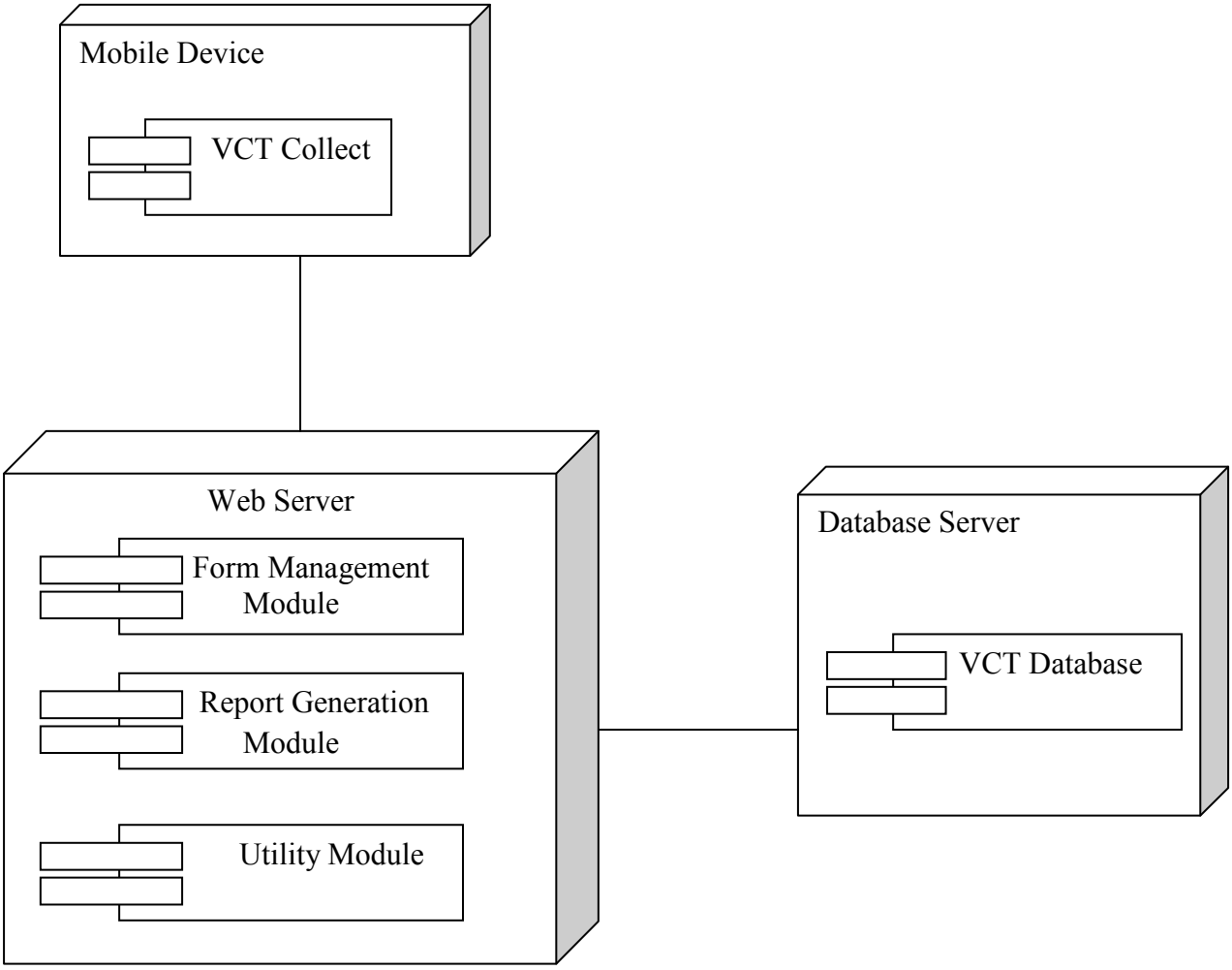


Figure 4.7: Deployment diagram

4.5 PERSISTENT DATA MANAGEMENT

Form <<table>>	Type	Null
FormId <<PK>>	varchar(12)	No
Name	varchar(15)	No
DateUploaded	Date	No
FormFields	varchar(200)	No

Submission <<table>>	Type	Null
SubmissionId <<PK>>	varchar(12)	No
FormId <<FK>>	varchar(12)	No
SubmissionFields	varchar(200)	No

System User <<table>>	Type	Null
UserName	varchar(20)	No
UserId <<PK>>	varchar(12)	No
Name	varchar(30)	No
Status	varchar(10)	No
Password	varchar(15)	No

VCT Client <<table>>	Type	Null
ClientId <<PK>>	varchar(12)	No
Name	varchar(30)	No
Age	int	No
Gender	varchar(2)	No
Address	varchar(30)	Yes
Result	varchar(2)	No
STD	varchar(2)	No
TB	varchar(2)	No

Health Worker <<table>>	Type	Null
UserId <<PK>>	varchar(12)	No
VCTCenter	varchar(15)	No
Telno	varchar(13	No

Report <<table>>	Type	Null
ReportId <<PK>>	varchar(13)	No
Date <<FK>>	Date	No

Figure 4.8: Database diagram

5. IMPLEMENTATION

This section presents the various tools used during the implementation of the system and the prototype of the system.

5.1 DEVELOPMENT ENVIRONMENT

Java 2 Enterprise Edition (J2EE)

The java programming language is used to develop both the server side application of the system and the client side application of the system.

Java Server Pages (JSP)

Java Server Pages is used to design the web interface for the server side application of the system.

Android SDK

The plug in android ADT is used to facilitate the development of the client side application of the system which runs on android mobile phone.

Java Persistence API

Java Persistence API is used to manage persistence data storage of the system using the Java Data Objects.

Eclipse Galileo 3.5

The eclipse Galileo 3.5 is used as an integrated development environment.

Google SDK

Google SDK is used as a web server to test on the localhost and to upload to the Google App Engine server for testing.

Android Emulator

Android emulator was used to test the mobile application before deploying on the actual device.

ODK

The Open Data Kit source code is used as a framework for the basic services of the application of the system.

5.2 THE PROTOTYPE

The System is composed of web application handling the business logic of the system and a mobile application which enables health workers to fill and send VCT data. This section, a brief overview is given regarding the basic component of the system.

5.2.1 The Web Application

Figure 5.1: Home page

Figure 5.1 shows the home page of the web application of the system. The menu links at the top right of the page lead to the major functionalities of the system which will be described below. The links under "VCT Centers by Region" section provide information on VCT centers found in different regions.

If a user wants to search for summarized VCT test results in a table format he/she can go to the result summary menu and click on Table Summary. The results will be displayed in a table format as shown on Figure 5.2.

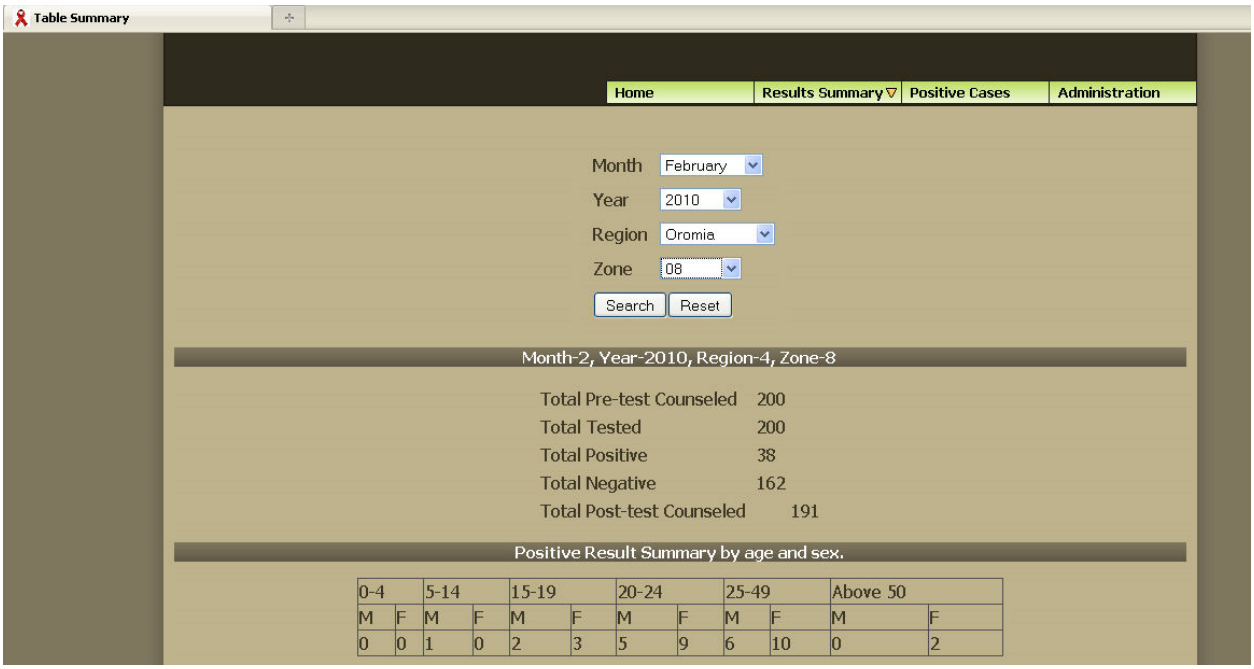


Figure 5.2: Table summary

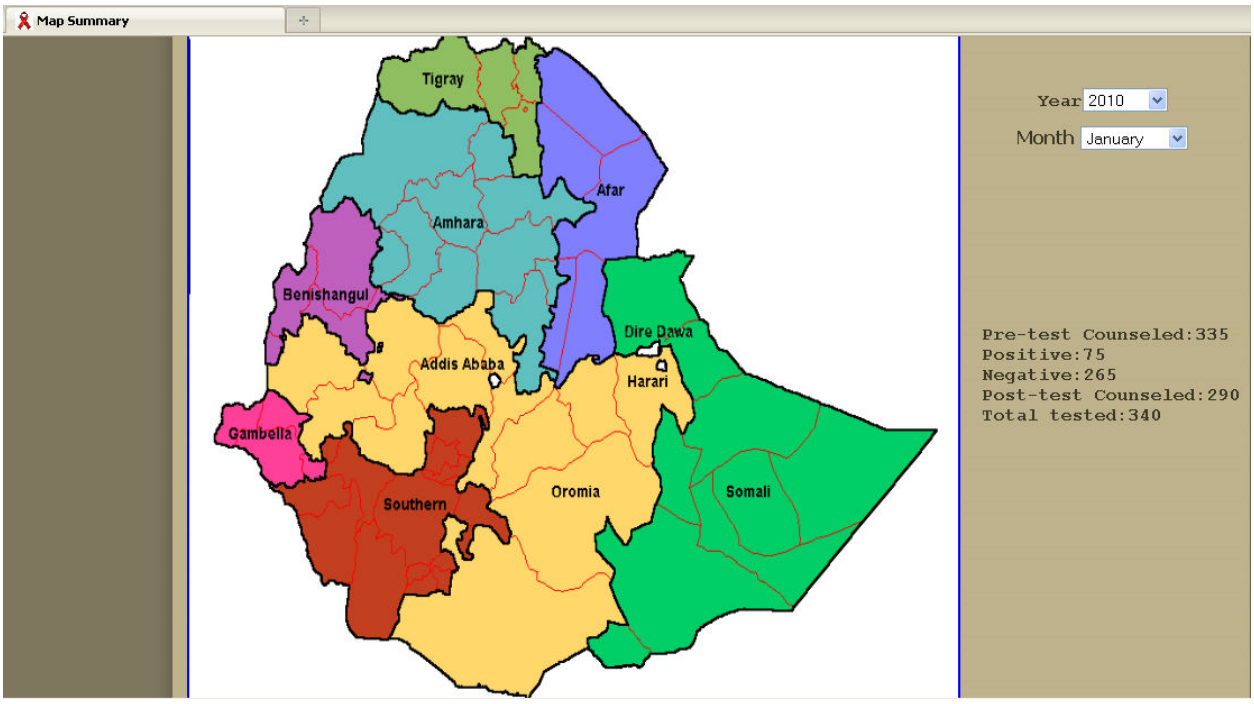


Figure 5.3: Map summary

If a user wants to search for summarized VCT test results using maps he/she can go to the result summary menu and click on Map Summary. The user can click on a region of his interest and the

summarized test results will be displayed on the right side of the map.Figure 5.3 for instance, shows the summarized result after month and year are selected and Amhara region is clicked.

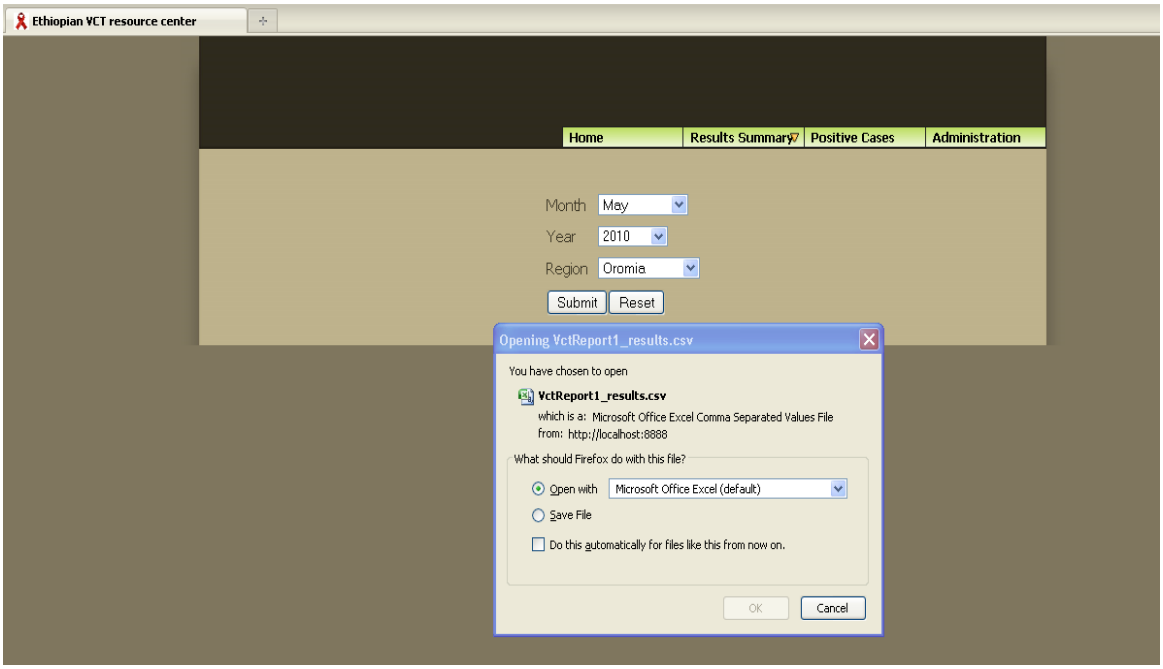


Figure 5.4: Excel report

If a user wants to search for summarized VCT test results and download the result in an excel format he/she can go to the result summary menu and click on Excel Report. The summarized VCT test result will be made available for download in an excel format as shown on Figure 5.4.

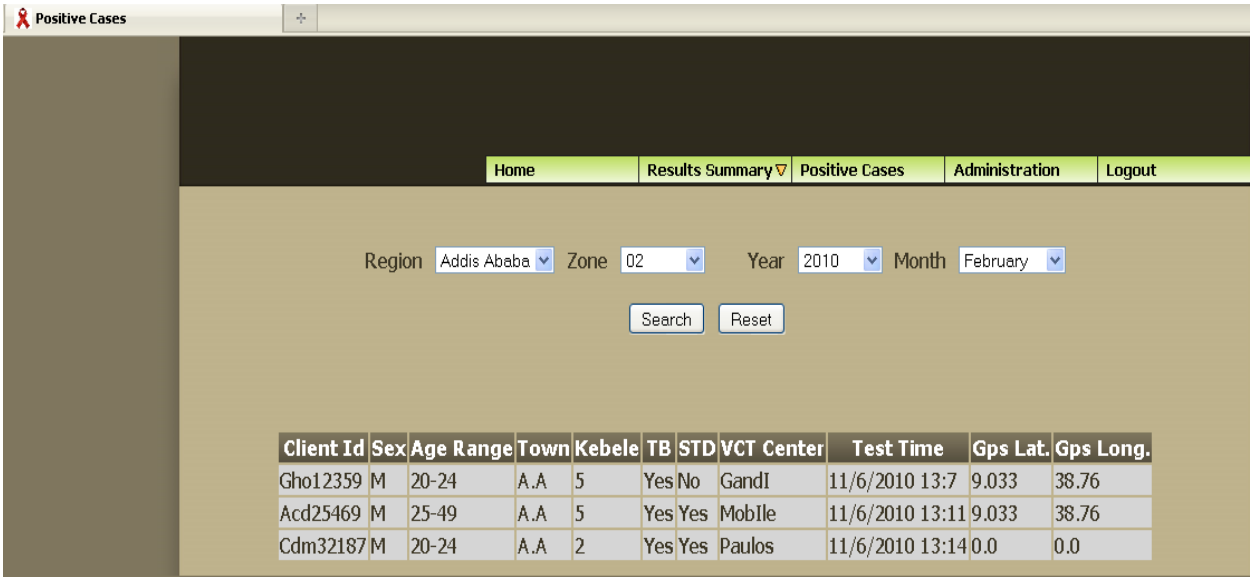


Figure 5.5: Positive cases

If a user wants to view details of VCT clients with positive results he/she can click on the Positive Cases menu. The system displays personal details of VCT clients with positive result as shown on Figure 5.5.

5.2.1 The Mobile Application

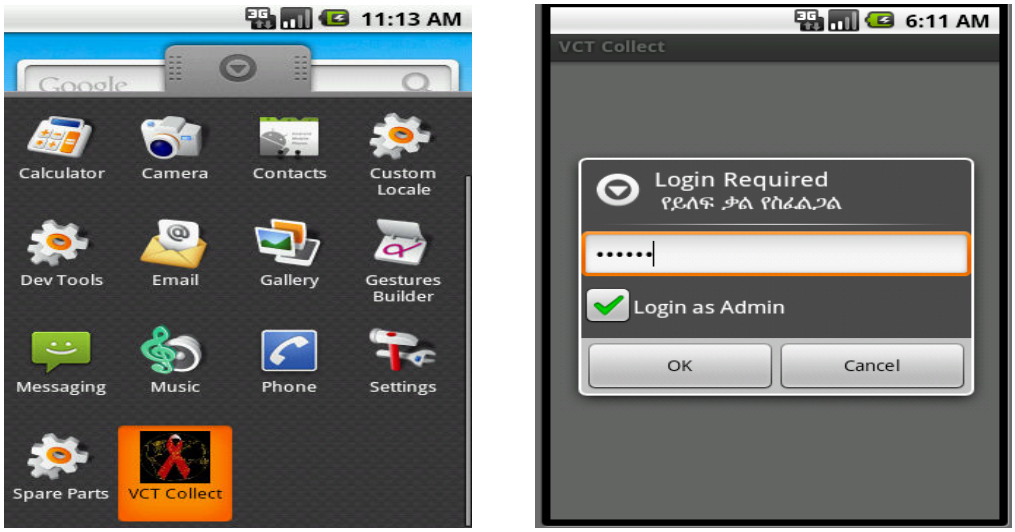


Figure 5.6: Log in

Figure 5.6 shows the first window that appears when the health worker opens the mobile application of the system. The application can only be accessed by authorized users which have a password. The health worker can log in as a user or administrator.

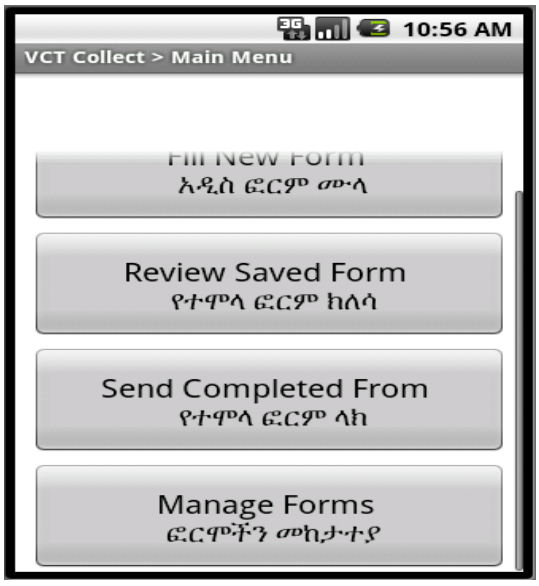
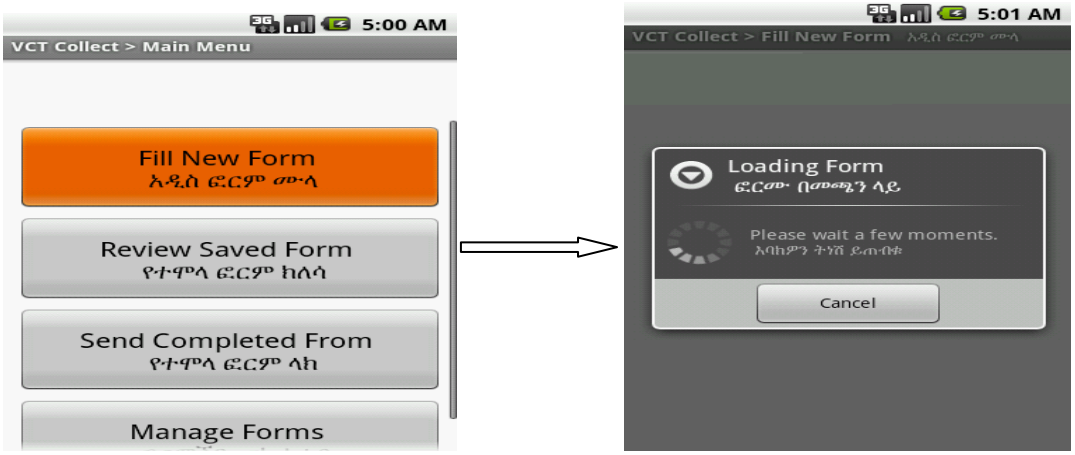


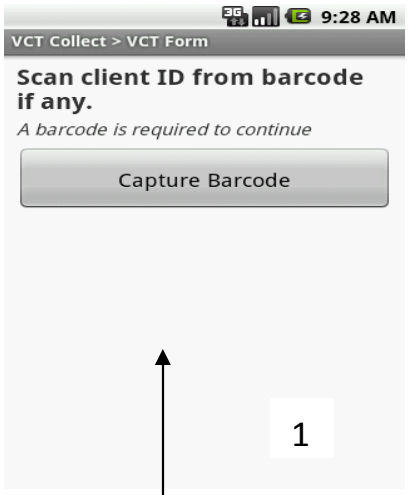
Figure 5.7: Main Menu

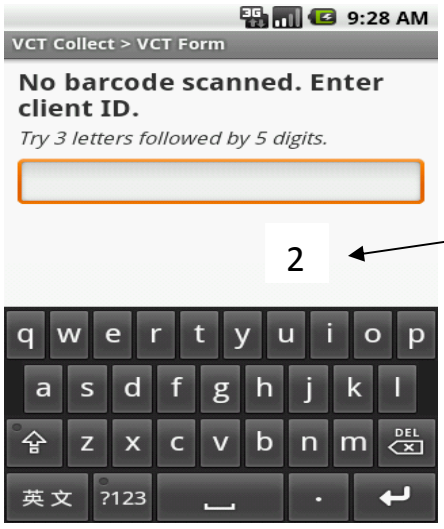
If the health worker logs in successfully the main menu of the system will be displayed as shown on Figure 5.7.

Figure 5.8: Download new form

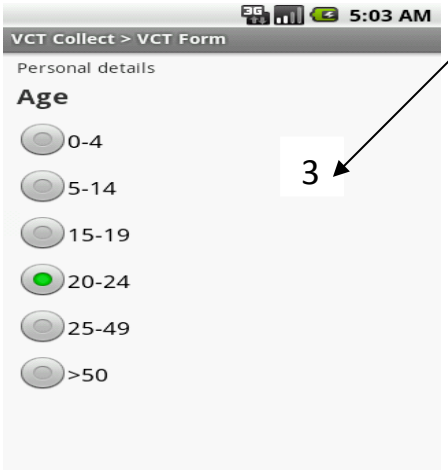
If the health worker wants to download a new form for first time use he/she will click on Manage Forms button which brings the form download window as shown on figure 5.8.

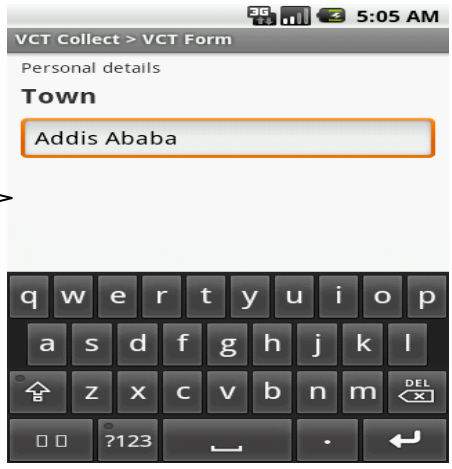


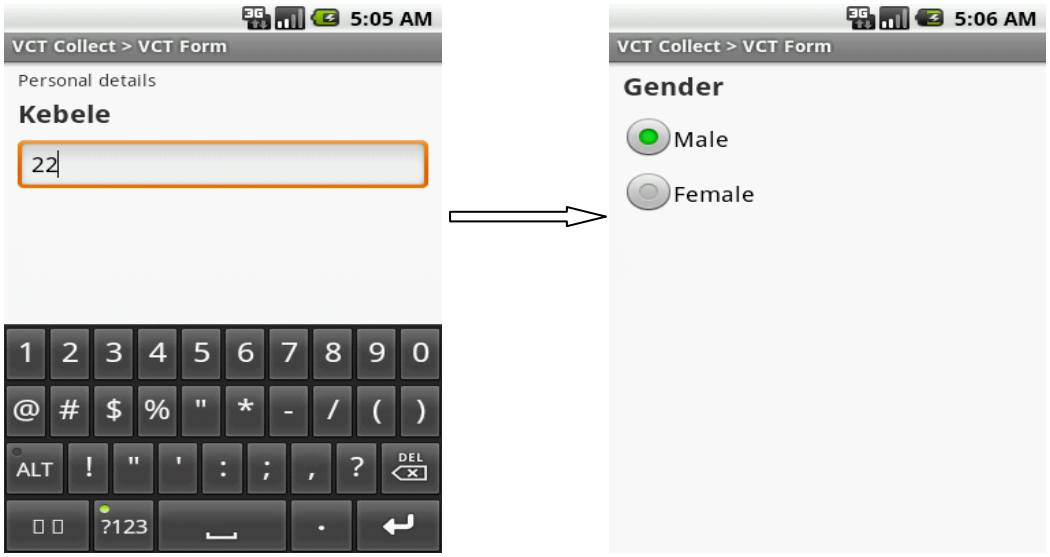


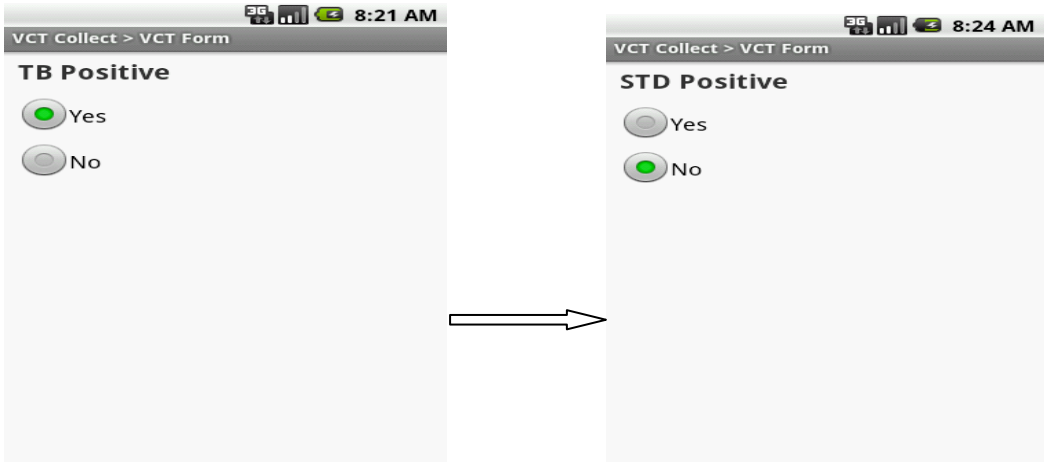


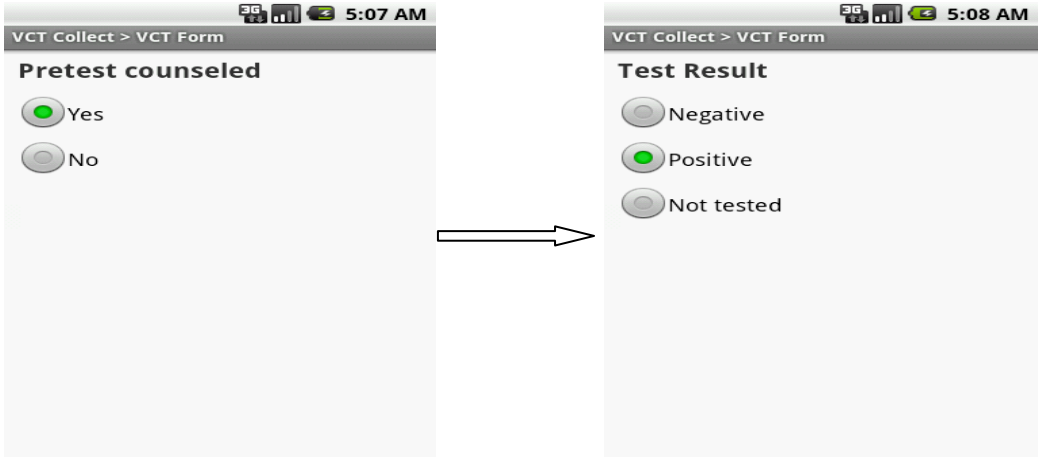
If a barcode ID is scanned at 1, 2 is skipped. If a barcode ID is not there the health worker is expected to enter client ID manually.






5:05 AM
VCT Collect > VCT Form
Personal details
Kebele
22
5:06 AM
VCT Collect > VCT Form
Gender
Male
Female


8:21 AM
VCT Collect > VCT Form
TB Positive
Yes
No
8:24 AM
VCT Collect > VCT Form
STD Positive
Yes
No


5:07 AM
VCT Collect > VCT Form
Pretest counseled
Yes
No
5:08 AM
VCT Collect > VCT Form
Test Result
Negative
Positive
Not tested

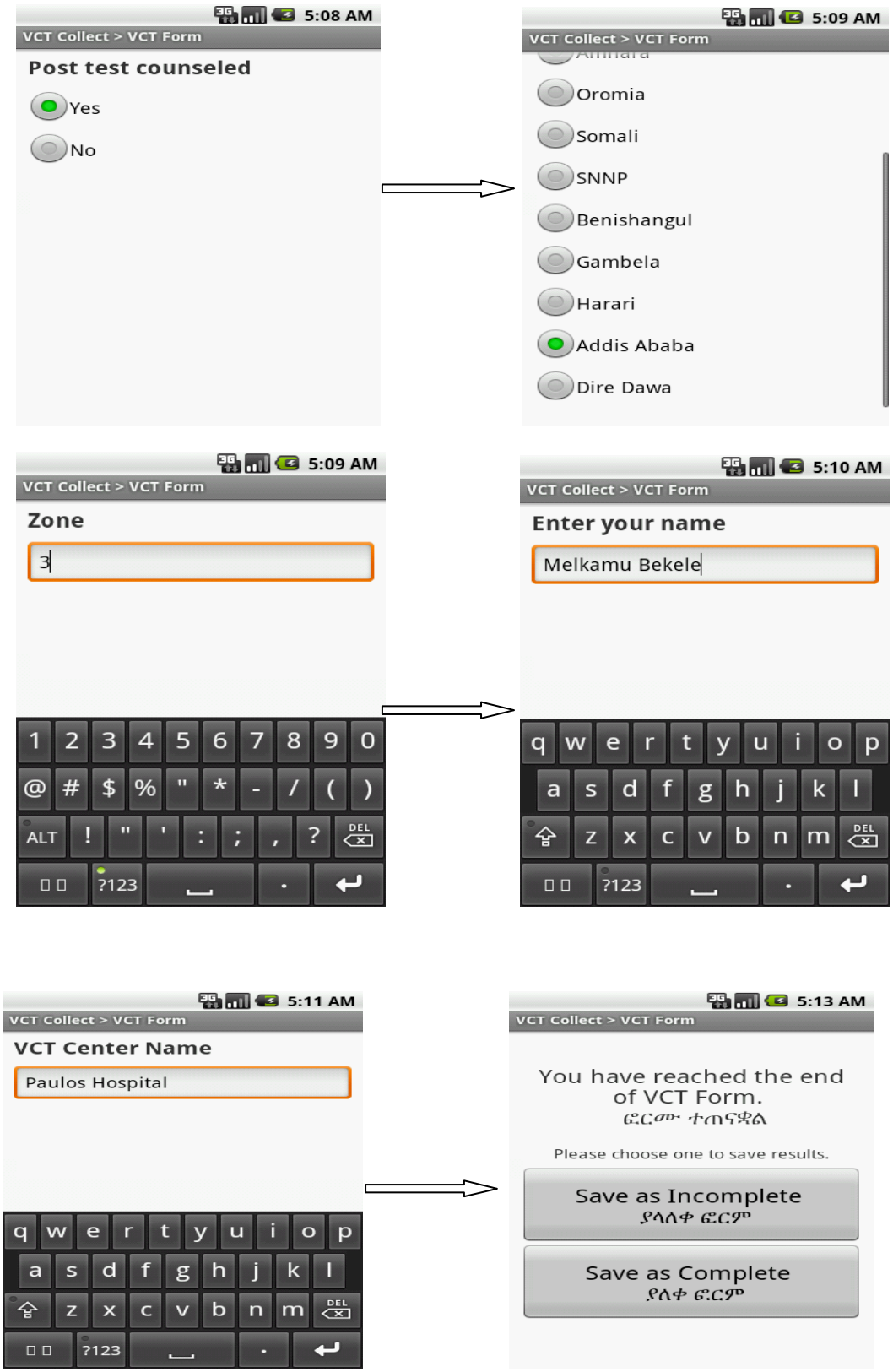


Figure 5.9: Fill form

If the health worker wants to fill a form he/she will click on Fill New Form which loads the form to be filled. The system will display each data field of the form on a single page. When the health worker reaches the end of the form he/she can save the data as completed form or incomplete form if there is some detail to be filled later as shown on figure 5.9.

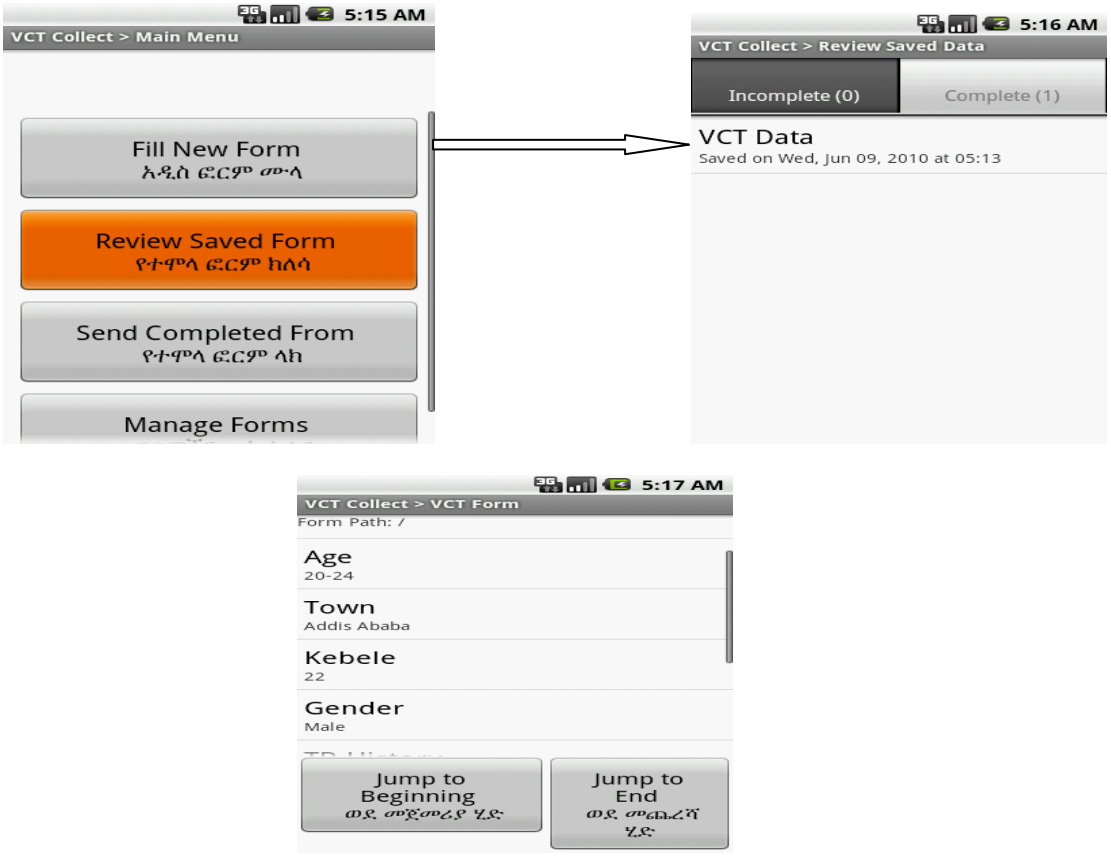


Figure 5.10: Review filled form

If the health worker wants to review and edit filled form he/she can click on Review Filled Forms which will display the filled data and allow the health worker to edit as shown on figure 5.10.

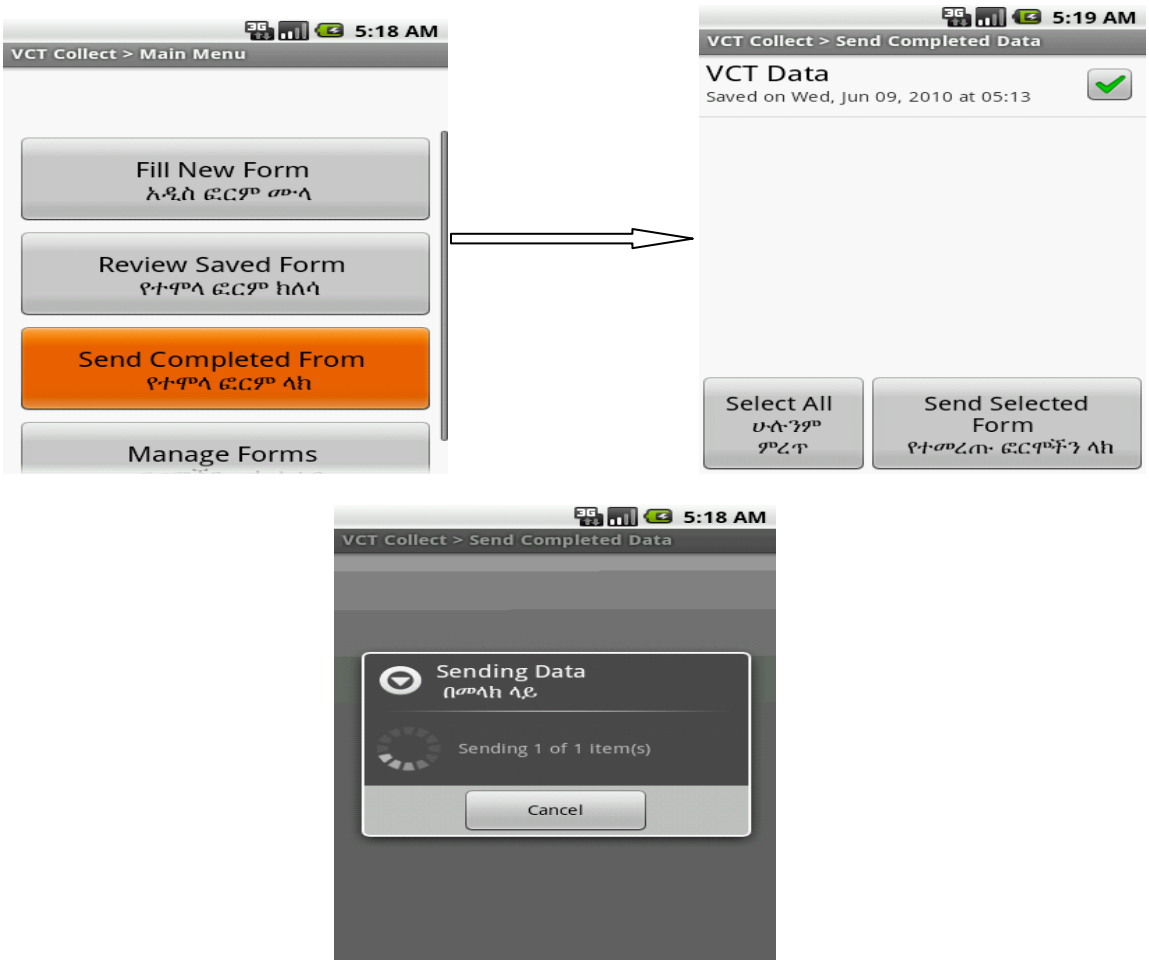


Figure 5.11: Send form

Finally when the health worker wants to send a filled form data he/she will click on Send Filled Forms and the system will send the data to the server side application of the system as shown on figure 5.11.

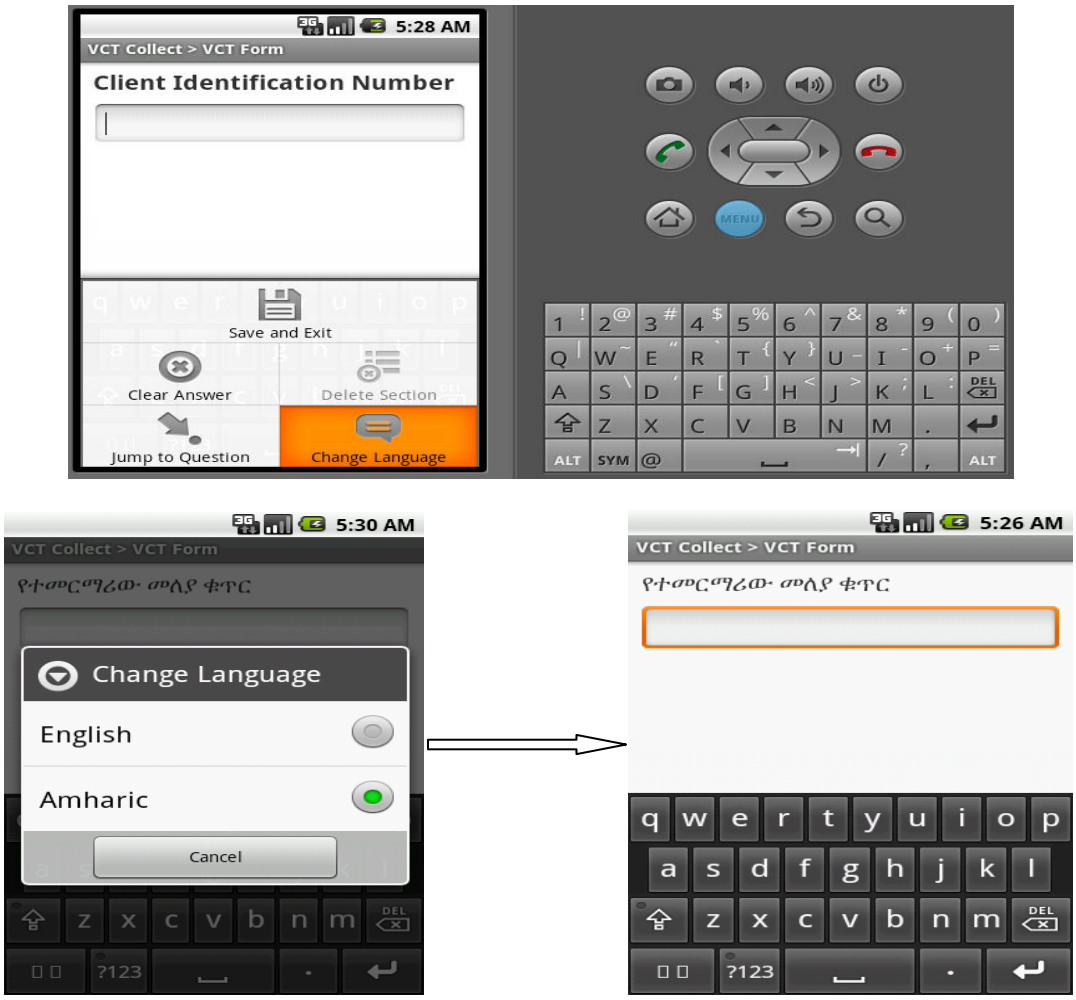


Figure 5.12: Change Language

If the user wants to change the the language of the form English to Amharic or vice versa he/she can press the menu button and select change language as shown in Figure 5.12.

5.3 TESTING

Testing is done to find the difference between the expected behavior specified by the system model and the actual observed behavior of the developed prototype. It is done with the aim of finding error so that errors can be corrected early.

To test the system ,the mobile application of the system has been installed on an android based mobile phone with GPRS enabled sim card. The server side web application of the system has been uploaded on google ‘s application server on free hosting. Adequate VCT data has been collected to test the application.

Adequate amount of data has been sent from the mobile application to the server over the GPRS network. We have been able to observe that it takes about 20-30 seconds to send a single filled form during working hours.

The server side application of the system has been tested using the major web browsers, Internet Explorer 8, Firefox 3.6 and Google Chrome 4.1. The web application has a fair response time even under slow Internet connection.

With regard to the security of the system , all components both on the mobile application and web application which require authentication have been tested and the system doesn't allow unauthorized users access to these resources.

6. CONCLUSION AND FUTURE WORK

Ethiopia is one of the sub-Saharan countries with high HIV prevalence rate. One mechanism to fight the spread of this fatal disease is to encourage people to take voluntary counseling and testing services to know their status. Currently this service is given in all parts of Ethiopia but the test result data is not made available on time for decision makers working on prevention and treatment activities.

In this project we have tried to analyze the existing data collection system being utilized by the Ethiopian Ministry of Health. Based on the information gathered we have designed a mobile based VCT data collection system that takes into consideration the current situation and available technologies. After designing the system we have tried to use appropriate devices and technologies to implement the designed system based on the current requirements identified. After implementing the system we have tried to test and evaluate the developed system.

In identifying the problems of the existing system, we have found out that the existing VCT data collection mechanism is based on papers and passes through various administrational levels before the final destination. Due to this up-to-date VCT data at a national level is not made available on time to those in need of it.

Due to the expansion of mobile network in Ethiopia and decreasing price of mobile devices, we have proposed a mobile based VCT data collection system. We believe that the system will make the data collection system more efficient, up-to-date and less error prone. Furthermore the system will reduce costs spent to transport paper forms from one administrational level to the other especially from rural areas.

The following can be mentioned as the contribution of this project work:

- Studied existing VCT data collection system and identified its problems.
- Analyzed the requirements for a mobile based VCT data collection system.
- Designed and developed a mobile VCT data collection system based on the ODK framework.
- Tested the system practically using android based mobile phone with a GPRS enabled sim card.

Even if the system captures the GPS location data of the mobile phone along with the VCT data, due to lack of time, the system is not developed to automatically identify the exact zone and woreda of the health worker. Because of this the health worker is expected to enter the region and zone the VCT test is conducted. One of the major future works to be mentioned is to enhance the system to automatically identify the exact location of the health worker based on the GPS data to be sent along with the VCT data.

Currently the mobile application of the system is designed to run on android mobile phones only. This is due to the fact that the android mobile phone operating system is open to design various types of applications with their own fonts like Amharic. Another possible future work to be mentioned is to expand the mobile application to work on other platforms that can support Amharic fonts.

REFERENCES

[1] Yaw Anokwa , Carl Hartung et al, “Open Source Data Collection in the Developing world." IEEE Computer magazine October 2009

[2] “Piloting Mhealth: A Research Scan”, http://mobileactive.org/tagging/mobile-health ,Emily Blynn , Last accessed Feb.04.10

[3] http://www.cellular-news.com/story/36863.php , Last accessed, April 18.2010

[4] “HIV Care and ART Update in Ethiopia” ,www.etharc.com , Ethiopian AIDS Resource Center ,Last accessed Feb.03.10

[5] By Nicole McIntyre “mHealth for Development: The Opportunity of Mobile Technology for Healthcare in the Developing World”, http://www.unfoundation.org/global-issues/technology/mhealth-report.html, Last accessed May 24.2010

[6] “Tariff And Usage Charges”, http://www.ethionet.et/services/tariffandusagecharge.html, ETC ,Last accessed June 10,2010

[7] Rachel H. Gormley, Kelly E. Quinley et al, “Use of Mobile Telemedicine for Cervical Cancer Screening in Gaborone, Botswana” , http://clickdiagnostics.com/wp-content/uploads/2009/11/Cervical-Cancer-Screening-in-Gaborone-Botswana.pdf, Last accessed May 24.2010

[8] Pablo E. Campos et.al, “Design and Implementation of Cell-PREVEN: A Real-Time Surveillance System for Adverse Events Using Cell Phones in Peru. September 2005”

[9] “Teledermatology: Its Role in Dermatosurgery” ,Journal of Cutaneous and Aesthetic Surgery - Jul-Dec 2008

[10] G. Anderson, S.D. Asare et.al, “Information storage and retrieval techniques for mobile healthcare”

[11] http://www.mida-intl.org/MIDA/How_Does_MIDA_Work.html ,Last accessed on May 24.2010

[12] “Open Data Kit”, http://code.google.com/p/opendatakit/ ,Last accessed May 24.2010

[13] Nigussie Tadesse, “Implementation of an antiretroviral therapy module Ethiopia: issues and challenges.”,www.ifipwg94.org.br/fullpapers/R0043-1.pdf, Last accessed May 24.2010

[14] “MMS-Building on the success of SMS”, http://handwritten.net/mv/papers, L. Novak

Declaration I, the undersigned, declare that this project is my original work and has not been presented for a degree in any other university, and that all source of materials used for the project have been duly acknowledged.

Declared by: Name: _____

Signature: _____

Date: _____

Confirmed by advisor: Name: _____

Signature: _____

Date: _____

Place and date of submission: Addis Ababa, June 2010.