Journal of Computer Science & Its Applications, June 2007, Vol. 14 No. 1

# Modelling, Design, And Deployment Of Mobile Health Care Applications

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*ABSTRACT*

***Health care delivery across many third world nations is usually cumbersome with enormous paper work, waste of life, time and resources, long queues, and ineffective treatment procedures. The use of mobile technology devices such as Personal Digital Assistants, Cell phone, Tablet PCs etc for health care delivery promises a revolution in modern health care. In recent times, it is not uncommon to have a number of personalized applications for prescription, drug reference, and applications for accessing daily schedules bundled with hand-held devices and used by physicians. However, applications that provide access to real-time medical records from point-of-care via mobile devices are still at their very low stage of adoption across the health sector for significant obstacles such as privacy and confidentiality of data, usability, interoperability, security issues, etc. In addition formalized applications integrated with the network for health care delivery are generally unavailable.***

***In this paper, we present a formal modelling, design, and deployment of health care applications using the Unified Modelling Language, mobile, and java-based technologies. The application presented in this paper provides easy access to medical information at the point-of-care which could bring about substantial cost and life savings at care centres.***

## 1.0 INTRODUCTION

Over the last decade, the need to develop and organize new ways of providing efficient health care services has resulted in a dramatic increase in the use of Information and Communication Technology (ICT) based solutions in health care delivery, generally known as e-Health. The expansion of health care facilitated by mobile communication is named mobile health care. While developed countries such as US, Canada, UK, Australia, for examples, have fully embraced the use of ICT in primary health care delivery, most developing countries are yet to fully embrace the concept for lack of infrastructure for ICT deployment in the health sector. Also, formalized health care applications integrated with the ideal infrastructures are generally unavailable [1, 2, 3].

Health care applications are primarily deployed at care centres to automate manual and routine health care processes such as data collection, making the operations of medical practitioners more error-free and efficient. Additionally, they take advantage of state-of-the-art information technology to offer more cost effective and timely health care services to patients by care provider.

The increasing capabilities and functionalities offered by mobile devices have made it possible to have personalized application for prescription, research, reference, patient education, drug interactions etc to be bundled with these devices for the use of physicians to enhance their performance in care centres [4, 5]. In recent times, research on applications based on wireless LAN to improve health care delivery are becoming more popular [6, 7] because of the increased demand for real-time access to medical information by medical and support personnel, the maturation of 802.11 standards, and the increasing capabilities and proliferation of WiFi-enabled devices.

Mobile health care applications are able to integrate patient medical information functionalities across various departments within a health care centre. Thus, allowing the review of patients' information real-time during treatment processes by clinicians. As medical professionals begin to realise the benefits of timely retrieval of patient information to and from the point-of-care via mobile devices, mobile health care solutions has continued to gain popularity, though, with some obstacles such as interoperability, security, usability, confidentiality, acceptability etc [1, 6].

This paper aims at introducing some formalization in the design process of mobile health care applications for greater reliability and acceptance by medical practitioners. The remaining parts of the paper are discussed as follow; in section 2, we present a modelling of some of the functionalities in the application using UML. In section 3 we provide the architectural design of the system. In section 4, we discuss the development and deployment of the system and conclude the paper in section 5.

## 2.0 SYSTEMS MODELLING

In the following section we used the Unified Modelling Language (UML) to capture and model some of the functionalities in the application. The UML is a visual language that provides a means to visualize, construct and document the artefacts of software systems [8].

The process of treating a patient requires some mobility of the patient or the medical personnel while the patient record moves electronically. The cooperation between the different personnel is captured in the collaboration diagram in Figure 1. Each personnel commit his investigation with the patient at every stage to the patients' record for future access by the care giver.

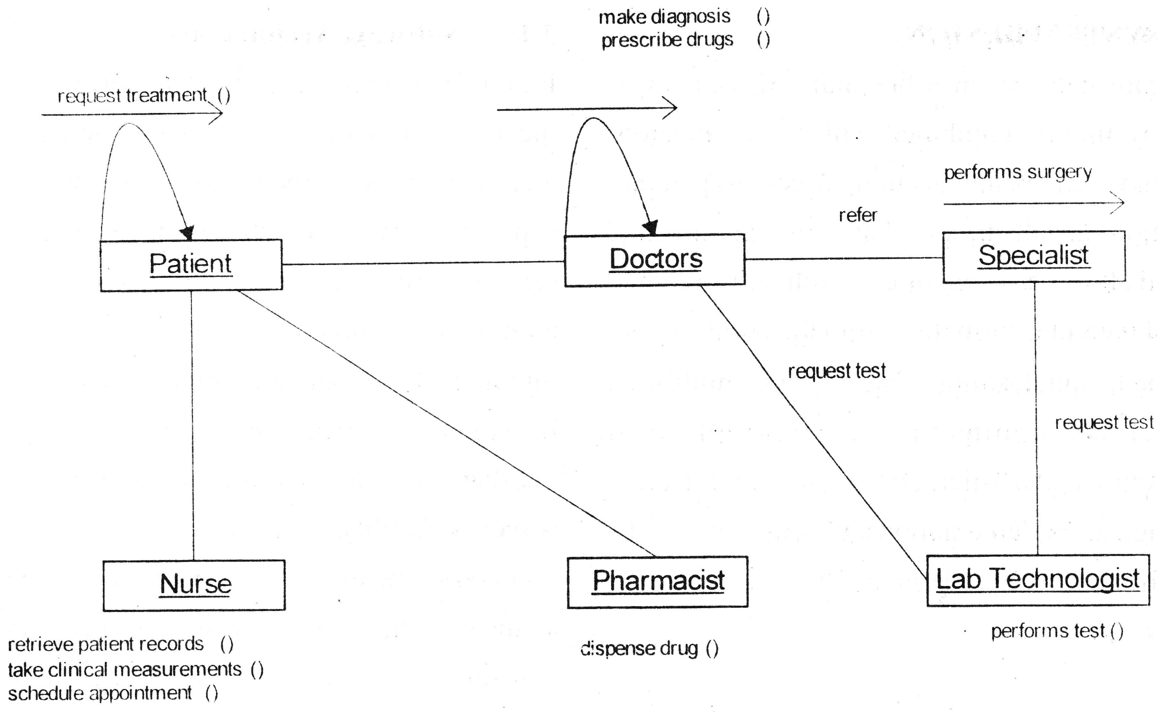


Figure 1: Collaboration Diagram

The applications allow patients and other authorized care givers within the hospital and wireless network to populate, view or query the patients' records from their mobile devices. When a query is performed, the request is initially sent to the WAP gateway. The gateway then forwards the request to the HTTP server, which runs the scripts to provide the required information from the database. The gateway then encodes the HTTP response and returns the results to the browser as WML. Figure 2 is used to represent this scenario.

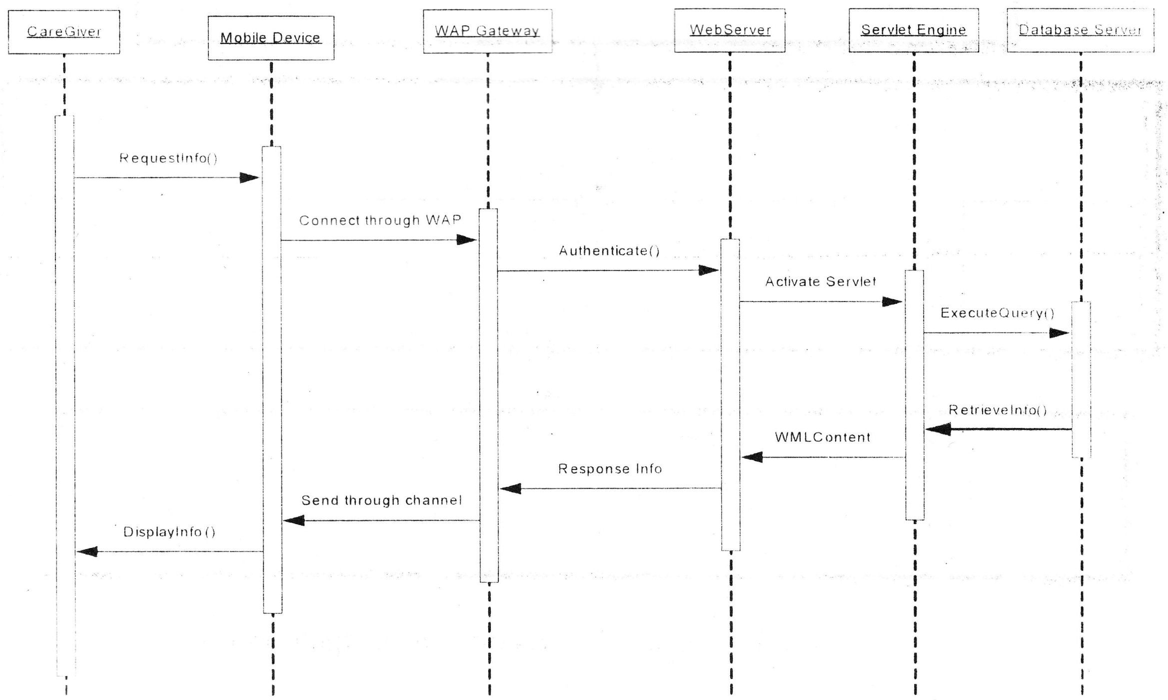


Figure 2: Sequence Diagram for Access the System

## 3.0 SYSTEM DESIGN

Health care delivery in a hospital environment is essentially mobile combined with the tremendous need to have timely and accurate access to patients' information at all times. Thus the architecture presented allows easy capture, search, retrieval, and update of patient information from the point-of-care within the hospital setting. We present a multi-tier, client-server architecture for the physical infrastructure and a 3-tier, client-server architecture for the logical implementation and deployment. The two architectures are depicted by Figure 3 and Figure 4 respectively.

### 3.1 Software Architecture

Figure 3 gives an overall logical (software) view of the architecture of the health care application. The architecture shows the locations of the each of the supports service in the system. The support services are extensively discussed in [9]. The architecture consists of the client interface, middleware and database repository. The database is separated from the client through the middleware. The middleware concept helps to solve scalability, load balancing, transactional processing and interoperability issues by providing a means that allows different hardware and software from different manufactures to share common patient medical information.

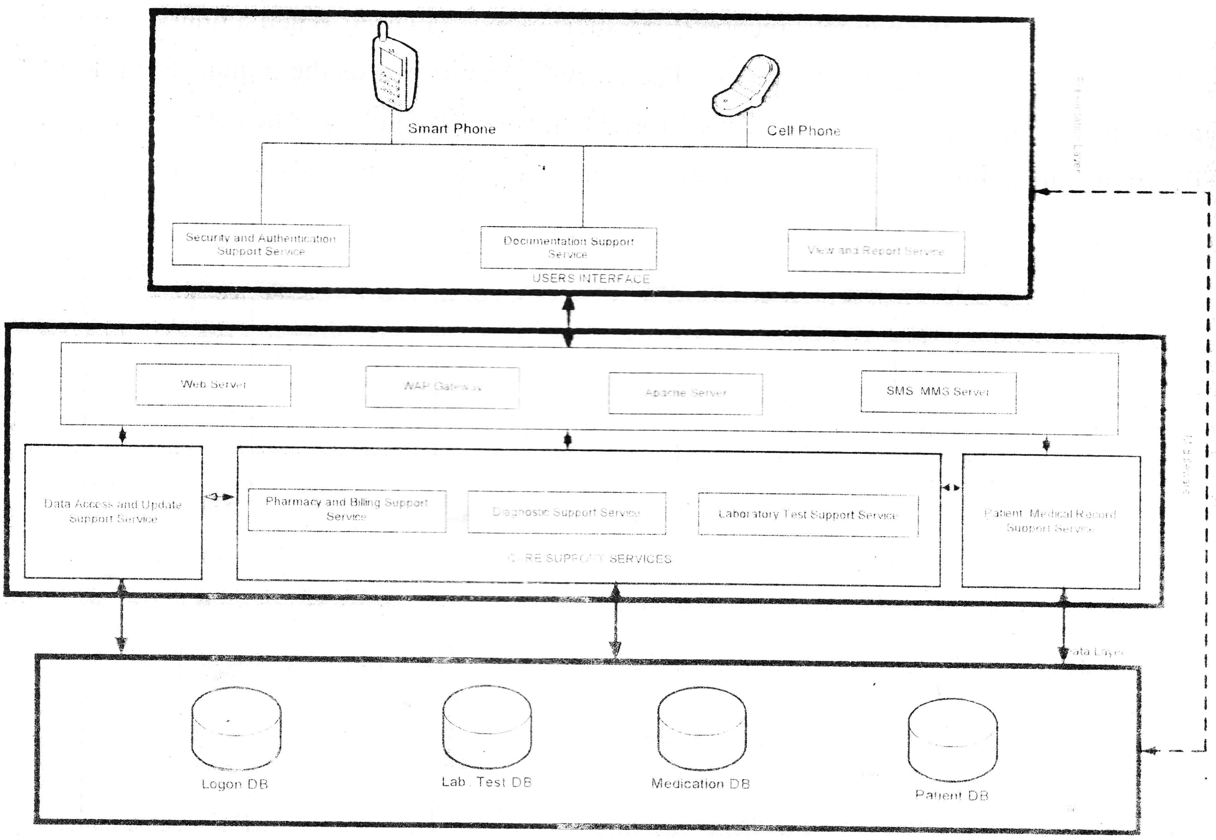


Figure 3: Software Architecture for the Application

The mobile clients have a zero application code layer on it. The client has as its component the Security and Authentication Support Service (SASS), Documentation Support Service (DSS) and the View and Report Service (VRS). These support services do not store or process any form of data. They only provide an interface for the middle layer and the data layer. Data or files are not stored on the mobile devices due to resource constraints associated with hand-held devices. Currently, server side-processing solutions offer the best alternative in most dynamic situations because they carter for the limited memory and processing power of many mobile devices [10].

It is important that any mobile access to the e-Health enterprise application be strictly controlled and regulated. The architecture is secure and uses some form of role-based access control and database-enabled authorization that integrate user's identity and role to gain access to the system. The architecture's security is further enhanced by services such as encryption and certificate management supported by the Internet and the wireless application protocols.

### 3.1.1 Middleware

The servers hold all the application code and it is organized in three-tier architecture. The presentation tier communicates with business and data access tier of the application and database tier and writes back to it during an update. The middle-tier contains most of the application logic and translates clients' requests into database queries and other actions and translates query results to client devices. The applications supported by this middle-tier are Data Access and Update Support Service (DAUSS), Patient Medical Record Support Service (PMRSS) and the core e-Health support application which consist of the Diagnostic Support Service (DSS), Pharmacy and Billing Support Services (PBSS) as well as and the Laboratory Test Support Service (LTSS)

Users access the application from various handheld devices within the hospital. The application user's interface allows users to access the required database. All users are authenticated before they can access any of the modules in the system. Once a user has been authenticated, the user's query is passed to the database server for execution. A user can only access the support services for which s / he is authorised. The client application interfaces to the application layer using TCP / IP and the WAP. The database server provides data services and data base management system function. The Open Data Base Connectivity (ODBC) is used to support data logic resulting from database queries. The application enables authorised medical personnel access to the database from the point-of- care within the hospital.

The application is developed to use WAP and allows micro browsers to be used as the interface; the information from the database is presented in a compartible form to the browser by the use of Wireless Mark up Language (WML). WAP and WML technologies are used to solve problems of platform independence and portability [11].

### 3.1.2 Data Layer

The data layer is responsible for the storage, retrieval, maintenance and integrity of the data manipulation within the system. Though we used MS Access for the implementation of the data layer, the architecture presented in Figure 3 allows MS SQL / SQL stored procedures and Java-based APIs to be implemented. Stored procedures are complex queries stored in a compiled form inside the database, which can be executed by the Database Management System (DBMS) on the server side to improve the maintenance and performance of client-server applications [12, 13]. Stored procedures in MS SQL server / SQL when implemented could be used to retrieve large patients' data and enhance the report functionality of the application.

## 3.2 Hardware Architecture

This architecture consists of a complete range of robust high performance client and server platforms with integrated enterprise application and data extendable to care providers at the point-of-care.

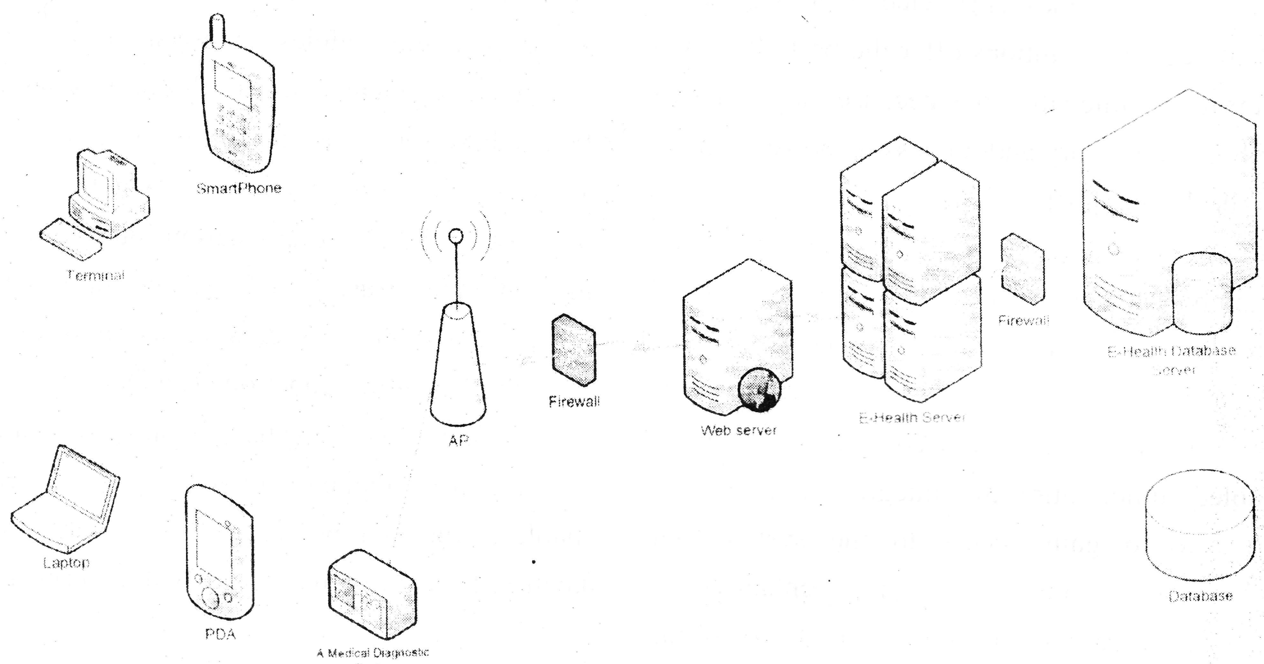


Figure 4: Hardware Architecture for the Application

The client systems include PDA, cell phone and smart phone and other handheld medical devices that combine real time access to enterprise systems and data with processing power for local analysis. The client devices have features to connect to enterprise resources and application over wired LAN, 802.11 based wirelesses LAN or high speed wireless wide area network with viewing surface ideal for recording, searching, analysing and reviewing patients' information.

The servers are used to maintain connectivity to enterprise resources for the mobile health care providers that include the doctors, nurses, laboratory technologist and other support staff. The availability of an enterprise's application and servers is crucial to health care centre where patient medical records must be available 24x7x365.

A major benefit of the multi-tier architecture used is that it increases application scalability and performance by enabling several care givers to be connected concurrently to the system. In a multi-tier architecture only application servers connect directly to databases. In this way, the application server can process multiple requests from many care givers within the wireless network through a pool of pre-allocated database connection, thus reducing the database server load. Furthermore, the load on the application server tier is balanced by using multiple application servers. The multi-tiering of the servers support the implementation of thinner clients, since most of the logic would be made to runs in the application server and database tier [14, 15].

Firewalls are set up to filter all network traffic moving in and out of the e-Health system. The hardware architecture is highly secure and utilizes multiple layers of firewall protection to create several regions of trust. The front most firewall guards the e-Health enterprise system from the Internet, while the innermost firewall defends the corporate intranet. Further, the semi trusted region between these two firewalls is typically referred to as Demilitarized Zone (DMZ), and could be hosted by Internet Service Providers [16].

The robust servers provide, real-time access to point-of-care database originating from systems across the enterprise system within the mobile environment to facilitate timely and accurate care delivery and practice management.

### 3.1.3 Interface Design

Every authenticated user of the application has some permissible task which he can perform within the system. The pseudocode in Figure 5 describes an authentication procedure for the various users of the system.

**Pseudocode: AuthenticateUser ( )**

```
//Variable declaration
String userId, password, myrole
User i : User i in  the users list
//The operation forward is used to redirect control to the desired page
getUser (userId, password)
IF((useri.Id  = =  userId)  &&  (useri.password  = =password)) THEN
    CASE
        IF (myrole = ="admin") THEN
            Forward page =admin_page
        ELSE IF (myrole = ="doctor") THEN
            Forward page =doctor_page
        ELSE IF (myrole = ="pharmacist") THEN
            Forward page = pharmacist_page
        ELSE IF (myrole = ="labtech") THEN
            Forward page =Lab_tech_page
        ELSE IF (myrole = ="nurse") THEN
            Forward page =nurse_page
        ELSE
            Forward page =relogin_page
        ENDIF
    ENDCASE
System.out ("Unsuccessful");
ENDIF
```

Figure 5: Pseudocode for the Users' Interface

## 4.0 SYSTEMS DEVELOPMENT AND DEPLOYMENT

The application was developed using wireless markup language (WML) and java-based technologies. WML is used to present results to the mobile clients. The choice of the java language is due to high portability across multiple platforms

[11]. Java Server Pages were used in addition to WML to add interactivity functionality to the static WML pages by providing access to an MS Access database through ODBC-JDBC Bridge.

The prototype application was implemented and tested on a client-server architecture separated by a mobile network at the Covenant University Health Centre. The application was deployed on an Apache server running on a Windows operating system. The client application accessed the server application via a Windows CE micro browser on a PDA.

Openwave V7 Simulator provided a cost effective platform for testing the application at the development stage being free on the Internet.

The application is launched with a welcome message and the hyperlinks to some (Sign in, Admin, and Help) of the functionalities within the system. See Figure 6. Once the log-in process is successful, the user would further provide his role (i.e. nurse, doctor, pharmacist, lab tech) in the health care centre. See Figure 7.

To facilitate the efficient and effective mobile health care, it is essential to provide the functionality which directly supports the user in their preferred way of performing their task. Figure 7 shows the task that can be performed by a medical doctor.

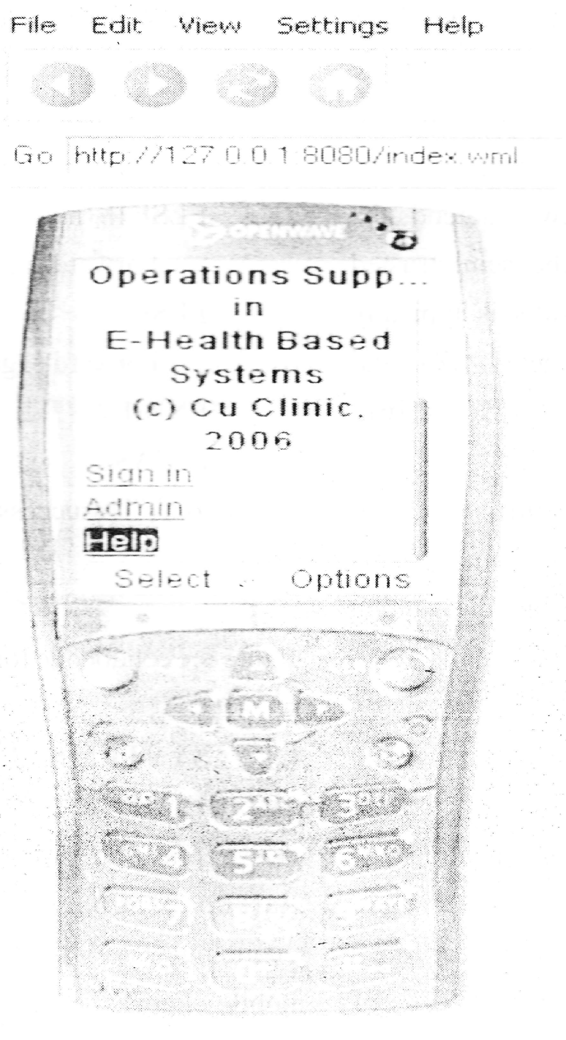


Figure 6: Welcome Page

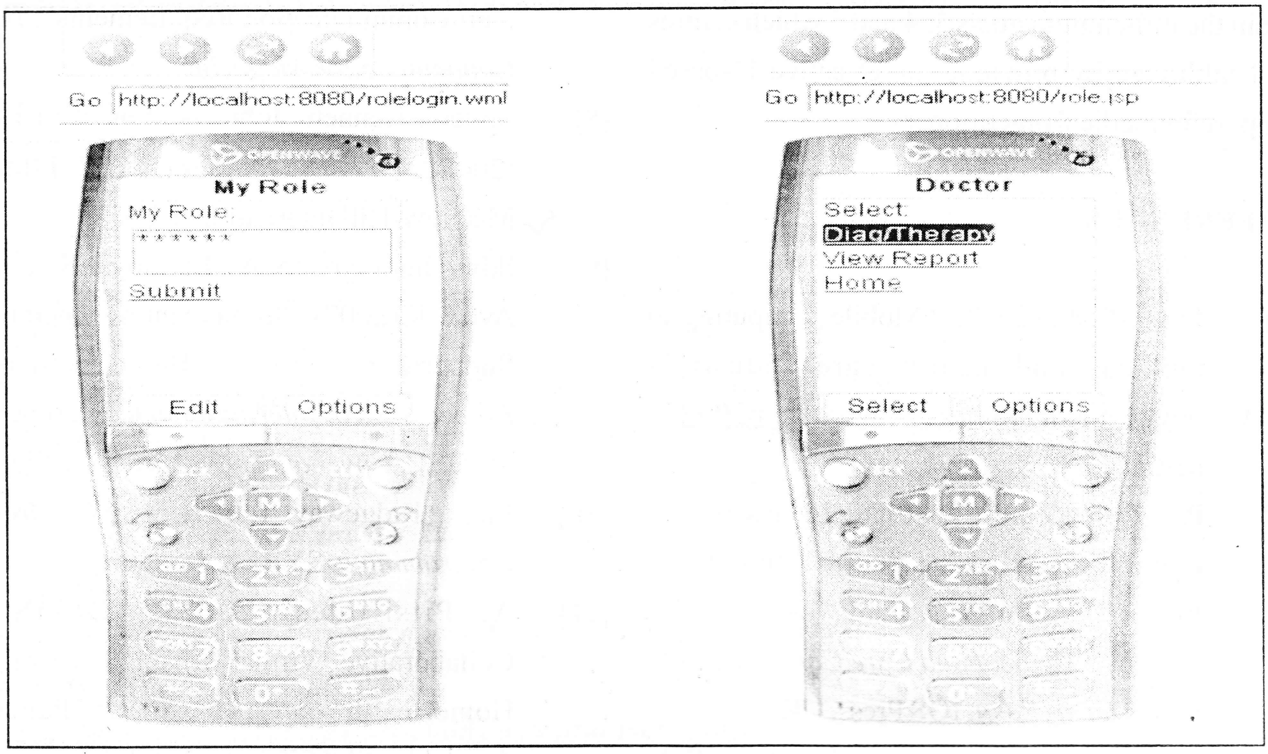


Figure 7: Role Authentication and Doctor's Function

The interface provided in the doctor's module allows him to capture each of the variables required for diagnosis in a usable pattern. During an interaction with a patient, a doctor captures some information which influences the diagnosis and medication prescribed to a patient. The information is recorded and transmitted via mobile device to the central server.

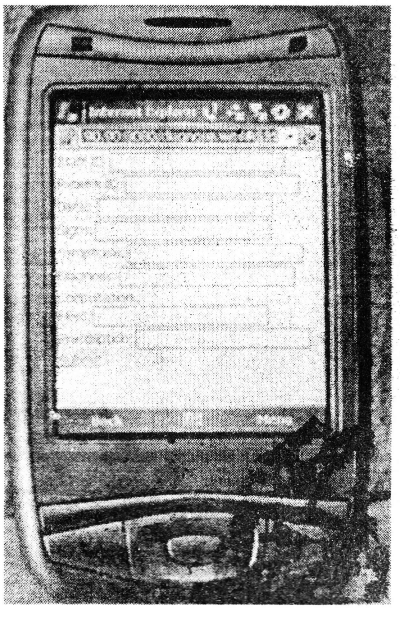

Figure 8: $O_2$ Xda Mini S running the Doctor's Module

Figure 8 shows a live deployment of the mobile health care application on an **$O_2$ Xda Mini S** PDA running Windows Mobile 5.0 operating system.

## CONCLUSION

This paper has practically demonstrated the feasibility of deploying mobile health care application on mobile devices such as mobile phones and PDA in enhancing the effectiveness of health care professionals in the delivery of services to patients.

The application when deployed would ensure live savings by enabling access to patient information via handheld devices within the hospital environment. This will eliminate medical errors usually resulting from enormous paper work associated with most treatment procedures in any typical hospital in developing countries of the world.

Finally, the adoption of the product of this research in care centres offers a good contribution for countries to attain the millennium goals 3, 4 and 5 which centres on health care by providing an effective IT-based support for medical practitioners.

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