

## Formal modelling and design of mobile prescription applications

Nicholas Ikhu-Omoregbe<sup>a</sup>

### Abstract

Adverse drug effects are a major cause of death in the world with tens of thousand deaths occurring each year because of medication or prescription errors. Many errors involve the prescription or administration of the wrong drug or dosage by care givers to patients due to illegible handwriting, dosage mistakes, confusing drug names. With the use of mobile devices such as personal digital assistants and smart phones some of these errors could be eliminated because they allow prescription information to be captured and viewed in type rather than handwriting. This paper presents a formal modelling, and design of a prescription application to improve health care services. This could lead to costs and life savings in healthcare centres across the world especially in developing countries where treatment processes are usually paper based.

*Keywords: Dosage, Drug, Health care, Mobile, Pharmacy, e-Prescription*

### 1. Introduction

The increasing adoption of mobile technology devices such as PDAs, cell phones, and laptops, for healthcare (mobile health care) delivery is having a great impact in the health care sector on a global scale. [Jen-Her W., Shu-Ching W., and Li-Min L., 2005, Joseph H. and Tan J., 2002]. In recent literature hand-held devices especially PDAs and smart phones have been reported to become increasingly prevalent for health care delivery [Trevor R., and Tapie R, 2004, Wickramasinghe N. and Misra S., 2004]. This is due to the flexibility and portability they offer to the physicians than some more computational desktop computers. Also, hand-held devices and the applications bundled within them are significantly cheaper and require very little training unlike most PC-based alternatives. Furthermore, mobile devices support features that allow remote users to synchronize personal databases and provide access to network services such as wireless e-mail, Web browsing, and Internet access, thus meeting the mobility needs of patients or medical practitioners who are always on the move.

Though wireless technologies offer numerous advantages and new capabilities to diverse applications in the medical domain, risks are equally inherent. One of the most significant sources of risks in wireless network is that of the principal technology for its communications medium, the airwave. Security infrastructure must be implemented in order to prevent unauthorized access to critical medical information, or prevent activities that could corrupt vital data consume network bandwidth, degrade network performance, or attacks that could prevent authorized users from accessing or using health care resources.

Other risks associated with wireless networks and hand-held devices and the solution to overcoming security threats are extensively discussed in [Tom K. and Les O, 2002].

With mobile technologies, medical practitioner are able to instantly update and retrieve patients' records from anywhere within a network coverage. This ensures that the patients' medical records are always current. Physicians with up to date information are likely to make better prescription decisions. Apart from enhancing quality of patient care, the adoption of e-Prescription applications could through the elimination of redundant paperwork, also facilitates more efficient and effective delivery of patient care. e-Prescription applications are designed to provide accurate billing and to eliminate the number of prescription errors as well as facilitate real-time access to medical records thereby decreasing back-and-front office inefficiencies associated with script writing [Anita M., Maria J., and Gunvor G., 2005]. e-Prescription applications could be designed to support functionality that automatically alert the physician if the medication prescribed will react adversely with other medications. Having determined some requirements for the system, in the next section we shall attempt to provide a formal model and a design of the the system.

### 2. Formal Modelling

The requirements phase of the systems life cycle is required to describe what the system is to accomplish rather than how it is accomplished [Srinivasan S, 2003]. Formal methods have been found to have great potentials for improving

<sup>a</sup>Department of Computer and Information Sciences  
Covenant University  
Ota, Nigeria  
nomoregbe@gmail.com

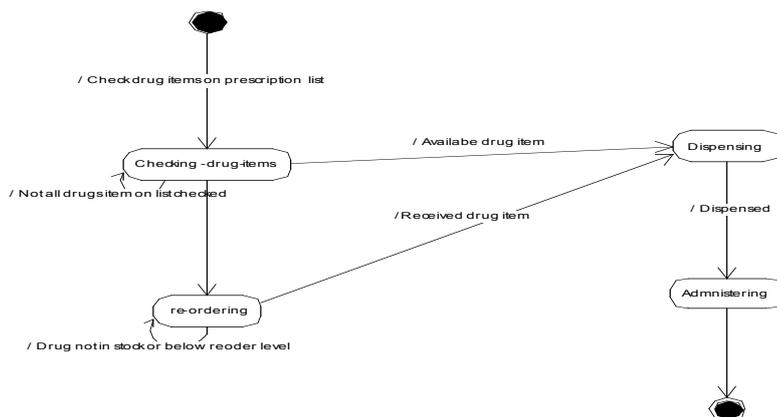
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the clarity and precision of requirements phase since specifications could contain contradictions, ambiguities, vagueness, incomplete statements and mixed level of abstractions especially when they are expressed in conventional methods such as English language or object oriented language [Sylvanus A.E., 1997, Jonathan P. and Michael G., 2004].

Formal methods are generally recommended for the specification and design of safety-critical application such as health care and embedded systems, where a failure could result in loss of human life [Srinivasan S., 2003],[ Jonathan P. and Michael G., 2004]. A formal method consists of mathematical based notational tools for unambiguously specifying requirements for applications and support proofs for consistency, completeness and correctness for the eventual implementation of the product [Roger P., 2005], [Jonathan P. and Michael G., 2004]. Formal specifications focus primarily on functions and data; some elements of a system such as human computer interaction are best specified using graphical techniques such as Unified Modelling Language (UML) [Simon B, John S, Ken L, 2005, Roger P., 2005]. Since a UML diagram may not be ideal enough to provide all the relevant aspects of a specification. Object Constraints Language (OCL) is used to fill the gap for its mathematical notations and ease of use for specifying systems for developers [OMG, 2008, Simon B, John S, and Ken L., 2005]. Thus, in this paper we used UML and OCL for modeling and designing the system.

**Figure 1**  
State Chart for Medication



### 2.1 Modelling Medications

In a treatment process, physicians make prescription based on their interactions with patients and the report received from laboratory technicians after a recommended test has been performed. The prescription information generally consists of a list of drugs, mode of administration, quantity and period of administration. The drugs that a patient is allergic to are not to be prescribed or administered. To ensure this, the physician or the pharmacist keeps a database of such drugs and updates it as soon as other drugs that a patient reacts to or interacts with are identified. We model the above scenario in OCL as follows:

```

context Allergy inv
pre:
drug-> exist (d)
drug -> size () > 0
boolean allergy = false
  
```

```

if allergy ()
drug-> includes (d)
else
drug ->excludes (d)
end if
  
```

To add a newly identified drug to the allergic database, use the method allergicAdd() and model it as follows:

```

context AllergicAdd (d:drug )
pre:
not allergic ->include (d)
post:
allergic ->include (d)
and allergic ->size =(allergic@pre ) + 1
  
```

Before a patient is discharged or referred to another hospital the patient's expenditure details would be given to the patient. The expenditure would normally include things like costs for medication, laboratory services and hospitalization. The bill for medications is modelled as follows:

```

context drug::bill (quantity, unitPrice , date) : real
pre:
drug -> excludes(allergic) and quantity >=1 and unitPrice >0.0
post:
amount @ pre + quantity * unitprice
  
```

Once a doctor has diagnosed a patient's ailment, the doctor prescribes the medicines which are expected to be dispensed in the right quantity and taken in the right dosage for the treatment. At the dispensary, drugs are dispensed by the pharmacist based on instructions by the doctor. The UML state chart in Figure 1 captures this scenario.

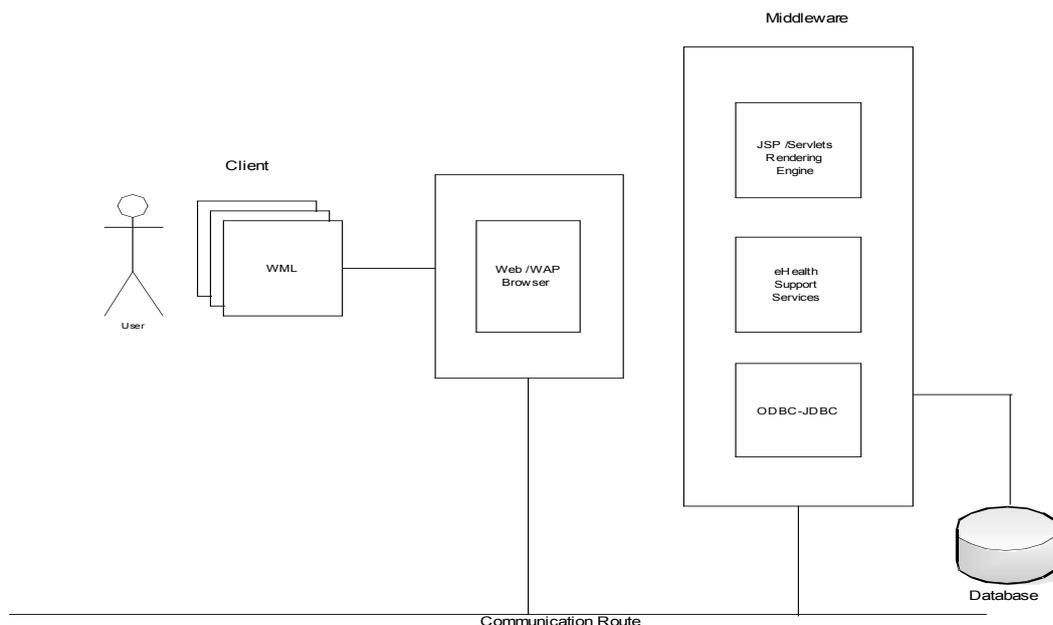
Where a drug is not available, it is reordered from the store or the manufacturer and dispensed to patient.

### 2.2 System Architecture

The architecture for the design and deployment of the application uses a zero-layer, three-tier, always connected infrastructures that should have 99.9% availability. The presentation tier has application code that is able to render WML and JSP pages to mobile devices, pocket PC, PDA, and Smart Phone. The pages are viewable through the use of Pocket PC Internet Explorer, Web and WAP browser. The WAP browser will suffice to display database queries submitted to the server. In Figure 2, the client is thin and typically includes a graphical users' interface written in WML that runs from a micro browser. The application server tier provides access to data tier and implements business logic and data validation.

The application server is responsible for all database transaction handling. The communication between the client and e-Prescription application and between the e-Prescription server and the application server tier is handled by HTTP and the wireless application protocol. Communication between application server and database is performed via JDBC-ODBC drivers. The data layer stores and maintains all the data for the system. Due to the privacy of medical information, the system implements a role-based access control

**Figure 2**  
Architecture for  
e-Prescription  
Application



security policy, network security protocols and other techniques (such as firewall, password control, secure access, antivirus, etc.) [Ikhu-Omoregbe N, Ehikioya S and Ayo C., 2007]

Openwave V7 Simulator provided a cost effective platform for the rapid prototyping of the system. The prototype was demonstrated on Covenant University Health Centre infrastructure with an **O<sub>2</sub> Xda Mini S** PDA running Windows Mobile 5.0 operating system.

When medications are prescribed to a patients, the details are recorded in the central server. The pharmacist is able to retrieve a patient's medication information in order to dispense the appropriate drugs as soon as the patient completes his encounter with the doctor. This leads to savings in time. A patient's medication information includes information like patient's identity, drug identity, method of administration, etc. The medication is monitored by the pharmacist Figure 3 depicts patient's medication details retrieved by a physician.

### 3. Description of Application

The application is patient-centred and WAP-based providing documentation for every step of medication treatment process. The system automatically forwards the medication/prescription information to the central server for review and dispensing of drugs by the pharmacist. It helps to eliminate transcription errors and minimizes the time delays between the patient's consultation session with the physician and the collection and administration of drugs by making patient medication information available electronically, accessible anytime and anywhere.

### 4. Conclusions

The e-Prescription application discussed in this paper, allows physicians with handheld devices within a care centre to capture and view patients' medication details. This is a step toward enhancing the efforts being made to avoid problems of prescriptions by pharmacists. The access to the patient's medical records real-time improves patient's care by ensuring that correct information such as the appropriate medication to be administered is retrievable and legible. In addition, the application improves efficiencies of health care services by eliminating time-consuming call-backs that may be associated with treatment processes.

**Figure 3**  
Users interactions with  
systems



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