UbiMeds: A Mobile Application to Improve Accessibility and Support Medication Adherence

Juan M. Silva
Multimedia Communications Research Laboratory (mcrlab)
University of Ottawa
jsilva@mcrlab.uottawa.ca

Alain Mouttham
Multimedia Communications Research Laboratory (mcrlab)
University of Ottawa
amouttham@mcrlab.uottawa.ca

Abdulmotaleb El Saddik
Multimedia Communications Research Laboratory (mcrlab)
University of Ottawa
abed@mcrlab.uottawa.ca

ABSTRACT
In this paper, we present UbiMeds, a mobile application and architecture that aims at supporting prescription medication adherence for aging and disabled population. We review the problem of medication adherence in general and from the accessibility perspective. We describe the design process guided by the accessibility issues identified in the non-adherence phenomenon. We present a proposed comprehensive architecture (including an iPhone application) aimed at improving accessibility in the practice of medication taking from patients, and supporting the intake tracking and monitoring by physicians and family members.

Categories and Subject Descriptors
H.3.5 [**Information Storage and Retrieval**]: Online Information Services – Web-based services

D.2.11 [**Software Engineering**]: Software Architectures – Domain- specific architectures

J.3 [**Life and Medical Sciences**] - Health

H.1.2 [**Models and Principles**]: User/Machine Systems – Human factors

H.3.4 [**Information Storage and Retrieval**]: Systems and Software – User profiles and alert services

General Terms
Design, Human Factors, Standardization.

Keywords
Mobile computing, ubiquitous web, medication adherence, web services, ambient intelligence.

1. INTRODUCTION
A common problem faced by health providing organizations and agencies around the world is that of “Medication Adherence”. Medication adherence is defined as the extent to which a patient complies and follows the indications from a physician in taking prescribed medicine. This problem has been proved to be widely spread and to be very costly for governments and health agencies.

MSIADU'09, October 23, 2009, Beijing, China.

This paper presents an approach to giving support to the practice of prescription adherence, taking a twofold approach; the medication taking from patients and the intake tracking and monitoring by physicians and family members. We have followed a design based on a number of accessibility issues that have been identified in relation to poor prescription adherence.

The proposed application aims at attending such issues by providing two major contributions. First, UbiMeds presents a user interface that would allow patients to have easy access to prescription information in a mobile phone platform. Second, a comprehensive architecture that allows automation of prescription scheduling, reminders and the constant monitoring from physicians about the patient’s medication adherence behavior. The goal is to improve management of medication and enable attending physicians to track progress of intake and modify the prescription information for the patient.

In the following sections we will present the context of the problem in more details (Section 2), showing some statistics from the World Health Organization and other government health agencies. Then we review some current systems and technologies that are related to prescription information management (Section 3). Next, we will review the design process followed, from analysis of target users, identification of accessibility issues, and platform selection, to interface and functional design (Section 4). Then we present the architecture of the proposed system (Section 5). In section 6 we draw our conclusions and discuss future work for the project.

2. MEDICATION ADHERENCE
Poor medication adherence is a well known problem for governments and health agencies around the world. It is defined as the lack of compliance of a patient to follow indications from a physician to take prescribed medicine.

Proper prescription medication usage is very important. Adhering to prescription indications (dosage, schedule, sequence, and other instructions) is particularly important for patients with chronic diseases. This compliance can make the difference between a fast recovery of a patient and a long, costly treatment and even possible hospitalization or death.

However, regardless of the possible sever consequences of poor medication adherence; the number of patients failing to comply with prescriptions is high. For example, the World Health Organization (WHO) reports that only about 43% of patients in developed nations take meds as prescribed for asthma [16].

This behavior is even more common on initially asymptomatic patients. According to a recent report from the National Council of Patient information in the U.S., only 50% of hypertension patients follow their drug regimen, even when this disease triples the risk of the patient to contract heart disease [4].

Non-adherence is an issue that affects all age groups. According to a recent survey by the US National Community Pharmacists Association (NCPA), 49% of people declared having forgotten to take prescribed medicine. 31% had not filled a prescription at some point during disease treatment, 29% had stopped taking medicine before the supply ran out and 24% had taken less than the recommended dosage [14].

Furthermore, this problem is very costly for health care providing agencies, organizations and governments. Only in the US, poor adherence is estimated to cost $177 billion in medical bills and lost productivity per year. It is also associated with up to 40% of nursing home admissions [5].

In 2003 the World Health Organization published a report that defined non-adherence as a critical issue for global health, identifying 5 broad dimensions that affect medication adherence that should be addressed [1]:

1) Social and economic factors
2) Health system and health care team related factors
3) Therapy related factors
4) Condition related factors
5) Patient related factors

From the assistive technologies perspective in this work, we have focused mostly in the last dimension; patient related factors. Also indirectly we address some of the issues related Therapy and Conditions by addressing the problems associated with the medications derived from these dimensions.

3. RELATED WORK AND APPLICATIONS

There are some technological solutions that address to some extent the problem of medication adherence. The applications and devices we have found in our survey can be categorized in four groups:

- Mobile health information management
- Electronic pillboxes
- Prescription reminder services and apps
- Smartphone medication trackers

The first group encompasses applications that run on mobile phones and that allow the user to have access and manage health related information stored on a remote server. These are general purpose applications for quick and mobile access to information. Some of them have some sort of reminder in the case of prescriptions, but nothing comprehensive or yet formally addressing accessibility issues related to prescription adherence.

A good example of this type of application is All One Mobile Health [2]. This is a comprehensive solution for health information management on the go, and for information sharing with family members or relatives (including prescription information). It has some basic reminder features for important physician appointments and when time to fill a prescription comes. However it has not been designed to address medication adherence, and does not provide automated scheduling or intake tracking functionality. Furthermore, using this application could be somewhat cumbersome, given the high number of features of the application, especially for elders or disabled users.

Another health information management system is the HealthPal PDA system [12]. This research work targets elder users, and the idea is to help them to keep all their health related information organized and on hand. It has an intuitive GUI, and it incorporates information management for four aspects of health care: physician visits, medication management, physical check up and lifestyle improvement. Again this is a very comprehensive assistive technology, and is not specifically focused on prescription adherence. Also in this case, integration with current Personal Health Record systems is out of scope.

Electronic pillboxes are a good solution for physical organization of pills and enforce on time take of medications. They are clearly aimed to improve medication adherence, however they require some work to initially configure the schedule and arrange the pills on the device. Most of them do not have connectivity capabilities to send information to family members or physicians. The Med-eMonitor from Informedix is one pillbox that can be connected to telephone lines and it will send information to attending physicians [9]. However there is no automated scheduling for the prescription or connectivity with existing electronic health records.

Prescription reminder services and desktop software is widely available in the industry. One of the major providers is OnTime Rx [11]. They offer phone services where the patient receives phone calls to remind them of taking their medication. They also offer some desktop and mobile applications to get reminders, but they are not designed for elders or disabled users. The user must create an account on a web portal, and then create the schedule on line for the reminders to work on the phone or any other device.

Finally there are already some applications targeting smart phones (including the iPhone). Most of these applications are stand alone (no communication with servers, physicians or Personal Health Record systems), and offer just basic functionality to keep track of which pills have been taken. The schedule has to be entered manually on the mobile interface of the phone.

Mobile and ubiquitous computing is becoming a widely spread technology. Furthermore, in Ambient Intelligence scenarios, the combination of such technologies with open intelligent avenues can deliver dynamic, interactive and targeted contents to specific users in a smart interface. In the next section we describe the design process of UbiMeds, where we have focused on creating a solution that will address accessibility issues involved in the non-adherence phenomenon from this perspective.

4. DESIGN PROCESS

The design process of the assistive technology proposed in this work was guided by literature review of the problem according to health experts.

On a first stage we aimed at clearly identifying the target users of the system. Then, we delimited a set of accessibility problems related to poor adherence from patients. Once we had identified the issues, we defined the functional requirements to address them. Next, we moved on to selecting an IT platform on which we could develop a mobile application for prescription management and which would allow for the implementation of the functional requirements. Keeping requirements and accessibility in mind we have designed a series of ‘views’ that compose the overall user interface for the application in the selected platform. Finally we present a scenario that illustrates the use of the proposed application design.

Each one of these stages is described in more detail in the subsequent sections.

4.1 Target User Group

The major causes for non-adherence are the high number of medication a patient has to handle in their daily routine and the fact that patients forget about taking them or take them inadequately [1,7,3,6]. From literature review (see section 4.2) about the problem of medication non-adherence it is clear to us that the aging population, along with patients with certain cognitive and visual disabilities, is the most affected by this problem. Hence, this is the target users we aim to assist with our present work.

However, since non-adherence is an issue that in fact involves patients from all age groups, we foresee that a system such as UbiMeds can potentially be of use to pretty much anyone taking prescribed medications. Also, considering the usability issues that we found associated with non-adherence (see next section), we could conclude that almost any patient under prescribed medicine, regardless of age or health condition could be considered a disabled patient in that sense.

In fact, according to the World Health Organization (WHO), only about 50 percent of patients typically take their medicines as prescribed [5], and all those patients would be potential users for this assistive technology.

4.2 Accessibility Issues

There are many factors that contribute to non-adherence. The research community in the field categorizes these factors in four general groups [4]:

a) Medication Related

b) Patient Related

c) Prescriber Related

d) Pharmacy Related

For each of these general groups we find different types of factors: social, economic, medical, and policy related. In the present work we have focused on identifying from all these, those that have a relevance from the accessibility perspective.

The issues described below are the ones that we address in the functional requirements defined for the application as can be seen on section 4.3

4.2.1 Medication Related Issues

One of the main issues with taking prescribed medications properly is the amount of different types of drugs to be taken and the complexity of the schedule. This is particularly difficult for patients with poor health literacy, or to elders and other patients with memory problems. It is estimated that patients 65 and over take the more prescribed medication and over the counter medicine than any other age group [1]. According to a survey from the American Society of Health-System Pharmacists (ASHP), more than one third of the population on this age group (33%) takes 8 or more prescription for the treatment of their health conditions [7].

4.2.2 Patient Related Issues

From the patient perspective, one of the main issues with non-adherence is simply forgetfulness [3]. This is often caused by some cognitive disability like in the case of elders or other memory impaired patients, or even by an extremely busy life in the case of younger and more active people.

A second factor related to patients is health literacy. This is simply the ability to understand the instructions given by the physician for taking the medicine. Some studies show that 80% of a set of people being followed could not clearly remember the instruction given by a physician just 10 to 80 minutes earlier [6].

Finally there are a number of patient related factors that deal with the attitude and perception of patients toward the usefulness of the drugs or fears about the use of high risk drugs or becoming dependant. Many of the issues related to these attitudes, perceptions and fears can be overcome with education of the patient about the treatment and drug usage [15].

4.2.3 Prescriber and Pharmacy Related Issues

The last group of factors for non-adherence to be addressed is that pertaining to the way that prescribers (typically physicians) and pharmacies communicate with the patient.

The primary issue is lack of information in the patient from the prescriber. According to a phone survey conducted by the Food and Drug Administration (FDA), only 66 percent of people declared receiving information from the physician about how frequency of medication intake and only 64% were informed about the proper dosage. In the case of information received from pharmacies, the numbers drop to 31% and 29% respectively [8].

Another issue is the physicians' overstatement about patients' compliance with prescriptions. Some studies show that physicians overestimate the adherence of their patients up to a 50% [10]. This seems to show a need for physicians to have means of tracking patients' compliance.

In addition to this, there are issues related to readability of the written information provided to the patient. Often wording of directions is confusing, type font on labels is too small, handwriting in prescription is illegible, complex technical jargon is hard to understand, instructions are given in different formats (label, flyer, prescription etc.) and even misplaced decimal points or additional zeros are found on the indications.

Table 1 shows a summary of the four major groups of factors for non-adherence along with the related issues faced by patients.

Table 1. Accessibility Issues in Non-adherence

General Group	Accessibility Issue
Medication	• Too many drugs to remember • Complex schedule to follow • Different directions for each drug • Drugs with similar names or similar containers

Patient	• Forgetfulness
	• Health literacy
	• Education about conditions and drugs
	• Disabilities
	    ○ Memory Impaired
	    ○ Cognitive problems
	    ○ Aging population

Prescriber	• Lack of communication with the patient • Poor monitoring of patient compliance • Illegible handwriting on prescriptions • Wording of directions • Complex technical jargon
Pharmacy	• Type font in labels too small • Instruction come in different formats • Errors when printing dosage and other information

4.3 Functional Requirements

In section 4.2 we have analyzed the problems faced by patients when trying to adhere to the prescription regime. As a result of that analysis, we have come to realize a set of functionality items that should be implemented in an assistive technological solution for medication adherence.

The contribution of our proposed solution is twofold; the design of a graphic user interface that addresses accessibility issues faced by patients when taking prescribed medicine, and the design of a comprehensive architecture that allows automation of prescription scheduling, reminders and the constant monitoring from physicians about the patient's medication adherence behavior.

Next, we describe each one of the requirements, and then on table 2 we summarize how these requirements address the identified accessibility issues.

Mobile Application. Given the nature of ubiquity and mobility in the process of following a prescription regime, we have decided that a mobile application will be an adequate solution. This will ensure availability of prescription information at all times and place.

Solution Based on Personal Health Records. One of the main design features of the application is its leverage on Personal Health Records (PHR) as the source of prescription information. Personal Health Records are increasingly being used as a repository for all sorts of health related information. This information is managed by the patient, but given the nature of Web Based PHRs, the information can also updated directly by physicians. This fact enable a proper convey of information about the way drugs should be taken.

Centralized Information Management. Even when the end user application is based on a mobile device, the whole application should work on the basis of a centralized information management system. This will ensure to have a central point to handle communication with physicians, pharmacies and third party Personal Health Records, enable advance administration for the overall system, as well as ensure security of data and handle 'off line' times on the mobile device.

Automated Scheduling. Following complex schedules and keeping track of a high number of drugs can be overcome using an automated scheduler. This functionality would enable the application to query prescription information from a central repository (updated by the physician) and create a personalized schedule for the patient. This information would always be up to date according to the physician's directions. For this purpose we propose the user of Electronic Personal Health Records (PHR) as the source of prescription information. Web Based PHRs store medication information that can be kept up to date by the family doctor remotely and without patient intervention.

Automated Reminders. In addition to provide an up to date schedule for the prescriptions, the system should be able to proactively remind patients when it is time to take some medicine. Visual and auditive alerts have been considered for this purpose. Additional functionality as 'snooze' can help to ensure that the patient does not skip any drug during the day. This will deal with issues such as forgetfulness and be of great help to the memory impaired.

Intake Tracking. In order to address issues about contraindications and proper tracking of patient recovery, the system should be able to track how well the user is adhering to the drug prescription regime. In our design, providing feedback about which drugs have been taken is as easy as pressing a single button. The system will then communicate back to the central server and record information about the schedule of the intake occurrence. Additionally the system should be aware of the expected intake behavior and proactively raise alerts (like SMS sent to attending physician and family members) if the patient fails to comply with the schedule, according to some threshold specified by the physician.

Visual Aids. In order to address issues related to legibility of instructions and visual disabilities, the system has been designed with a series of carefully selected set of icons, font type and color selections and images to easily comprehend the information.

Text to speech. This feature will allow the patient to hear the instructions about the way he/she should take the medicine. This is useful for visually impaired individuals.

News and additional information. The system implements a feature for aggregating information from medication databases and from news RSS feeds in order to educate the patient about the drugs he/she is taking.

Separation of information concerns. The mobile application interface views have been carefully designed to avoid overload of information. Patients can 'dig' as much as they want to get additional information, or they can just get the most important directions with s simple glance at the screen.

Table 2. Functional Requirements and Accessibility Issues

Requirement	Accessibility Issue Addressed
Mobility	• Ubiquitous and Mobile nature of prescription adherence process
Centralization and Intake Tracking	• Lack of communication with the patient • Poor monitoring of patient compliance • Errors when printing dosage and other information
Automated Scheduling	• Too many drugs to remember • Complex schedule to follow • Different directions for each drug • Health literacy

Automated Reminders/ Text to Speech	• Forgetfulness
	• Disabilities
	  ○ Memory Impaired
	  ○ Cognitive problems
	  ○ Aging population

Information Concerns / Visual Aids	• Drugs with similar names or similar containers • Type font in labels too small

	• Instruction come in different formats • Illegible handwriting on prescriptions • Wording of directions • Complex technical jargon
News/Additional Information	• Education about conditions and drugs

Table 2 shows the same set of usability issues depicted on table 1, but this time they are grouped based on the Functional Requirement that addresses each of them.

4.4 Platform Selection

Given the needs for an internet enabled mobile application, a rich graphical interface, and ease of use of the mobile device itself, we have selected the iPhone as the mobile smart phone on which the application should run. The application is a native application on the iPhone, developed using the latest SDK 3.0 and the Objective C programming language for the target device iPhone 3Gs.

For the centralized information management system, we have chosen a standard web server (Apache) running on a Linux computer, and a rapid development, and yet powerful, web programming language (PHP).

For the Personal Health Record we have used Google Health. It has an extensive, standards based, data API for interacting with the patient's record and PHP libraries are available to use the API.

4.5 Interface Design

The design of the interface has been done taking into account the functional requirements, accessibility issues and the aim to avoid overload of information. That last requirement is particularly important when designing interfaces for mobile devices, given the space constrain on the screen of the mobile device.

The interface is composed of a series of views. Each view has a specific purpose, and the information contained in the view is meant to fulfill that purpose. Each view is shown to the user at different points of time and according to direct request by means of the tap gestures on the touch screen of the iPhone, or by events happening internally on the application.

The views for the interface are described as follows:

Application icon view. The first view is a pretty basic one, however it is very useful from the user perspective. It basically consists of an icon depicting the UbiMeds application on the home screen of the iPhone. The dynamic aspect of the view consists of a small number indicator on the top right corner of the icon, which basically shows the number of prescriptions that are due within the next 2 hours. This view allows for the patient to be more aware of upcoming taking times for his prescriptions.

Summary View. This is the first view that loads when the application is launched on the iPhone. It shows a quick summary of the number of 'active' prescriptions (those from the personal health record that the patient is currently taking) and color coding indicating the status of intake. If any drugs have been missed they will be highlighted in red. This view also shows the names and times of any medications that are due over the next 2 hours. At the bottom of the screen the user can see a navigation toolbar showing icons and text that allows the user to move between views: Summary, Browse, New, and Settings.

Figure 1. Summary View.

Browse View. This is a typical vertical list view of all active prescription medications. Each list item shows the name of the prescription and alias (which can be set by the user to better remember the medication) along with the next due time. The list can be sorted alphabetically by name, or by alias, or by the sequence on which medications are due. When the user 'taps' (touch with the finger on the screen) over an entry of the list, he is taken to the Detail View for that medication.

Figure 2. Browse View.

Details View. This is the view that organizes and contains information about a specific medication. This view is composed of 4 sub views accessible through the navigation bar at the bottom of the view. The first sub-view (Specifics) shows Drug information such as name, directions, dosage and schedule in a very compact and concise manner. If the user wants more information he can switch to the second sub-view (Additional Info), which shows additional drug information, and additional comments entered by either the patient or the physician. The third sub view is for displaying additional information from medical databases (Definitions), and the fourth sub-view (News) shows latest news and other feeds from the web, specific to that medication.

New View. This is the view that allows the user to enter a new medication. This is an optional feature, since medication information can be updated by the physician via the Personal Health Record interface.

Settings View. From this view the user can change all the configuration options for the application, such as types of alerts, time to snooze alerts, enable/disable reporting to physician etc.

Alert View. This is the view that shows when the user receives a reminder alert and launches the application, it is similar to the 'specifics' tab within the Details view, and shows a button to enter the feedback about the user having taken the medication.

Figure 3. Alert View.

4.6 Use Scenario

The following scenario illustrates the use of UbiMeds as designed in the previous sections. It is important to note how the application usage described here addresses the functional requirements.

Mr. Johnson is 65 years old, in recent years he's had a decline on his overall health, suffering from several chronic illnesses such as hypertension and diabetes. 6 months ago he had a heart attack. As a result from these conditions Mr. Johnson has to constantly take prescribed medicine to control his health problems. He has been prescribed 8 different medications for the different conditions that affect him. It is quite cumbersome for him to keep track of all the medications that he has to take: type of medicine, dosage, how many times per day, at what time, in what order, before or after meals etc...

In order to help on his daily routine for taking the prescribed medicine, Mr. Johnson makes use of UbiMeds, a mobile personal system that runs on Mr. Johnson's iPhone and aids him on keeping track of drug intake. Additionally Mr. Johnson has an en electronic personal health record where his family doctor has access in order to enter information about all prescriptions that he has to take. This information is then used by UbiMeds to automatically create a schedule for all prescriptions that he has to follow. The schedule is kept up to date without Mr. Johnson's intervention.

Every time a medicine is due to be taken, the phone will proactively alert Mr. Johnson about this. When he checks for the alert on his phone, UbiMeds is loaded with all the information for the drug that is due to be taken at the time. The interface is easy to use by means of the touch screen of the device and information is properly organized in the screen to avoid cluttering and confusion. Text font is easy to read and visual clues and pictures help to avoid error in taking the medication. Additionally the application will read aloud the direction for the medication, when the systems settings are configured to do so.

Once Mr. Johnson takes his medicine as indicated, he just taps with his finger the "checked" icon to acknowledge that he has taken the medicine. The feedback entered in the mobile application is used to update the personal health record. This centralization of information allows for his doctor and relatives to closely monitor his progress and see a report of adherence to the drug schedule. Additionally, if Mr. Johnson fails to take his heart medicine even once, an SMS (text message) is sent to his attending physician and his daughter, so they can take further actions.

This process repeats every time he has to take any of the drugs on his Personal Health Record profile. This way Mr. Johnson does not need to keep track or remember what is the next drug to take, nor struggle with confusing or illegible instructions on container labels.

Whenever Mr. Johnson gets a prescription for a new medication, he likes to be well informed about it and find out its proper usage and other information. He can easily access medical database information and news related to his medicine from the mobile device, he just have to select the medication go to the additional information section, which will automatically retrieve this information for him.

On the other side, Mr. Johnson's physician can keep a close monitoring of his performance taking prescriptions. The physician can log into any computer with internet connection and access a portal that allows him to access the shared section of the personal health record. The he can keep prescriptions and related information up to date. Also, he can see detailed reports about how Mr. Johnson is doing on his regime.

This concludes the design process followed for UbiMeds. In the following section we describe the architectural view for the mobile application, the centralized information management, and the personal health records.

5. ARCHITECURE OVERVIEW

The proposed assistive technology presented in this work is realized by different architectural elements that work together to fulfill the functional requirements.

On a higher level, the architecture is composed of three main components. First there is a mobile application running on a touch screen enabled smart phone (iPhone in our implementation) and acts as point of interaction with the patient. Second we have the centralized module that handles requests and events, which originate on the mobile platform, and pushes information when any events are raised on the server side. Then there is a Personal Health Record system which handles patient medical information and presents an interface for the physicians to review and track the progress of the patient regime.

The first two of these components belong strictly to the UbiMeds architecture. The third component (PHR system) is a third party service for which UbiMeds implements an interface module for communication. This module is loosely coupled, so UbiMeds can be easily adapted to any third party public Personal Health Record system.

Figure 4 depicts the UbiMeds architecture, showing the components and how they are distributed over servers and devices. Inside each component's outer box, we can see the inner modules and how they are interconnected.

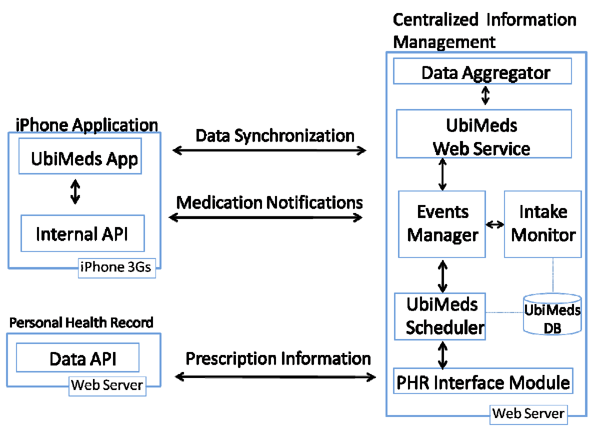

Figure 4. UbiMeds Architecture

Next, we present a description of the purpose and functionality requirements addressed by each module.

UbiMeds Application. This module consists of a mobile application running on an iPhone 3Gs device. Its purpose is to work as the main interaction point with the patient. It presents information in an organized and easy to use graphic interface, using the touch screen capabilities of the device. The application makes requests to the UbiMeds web service to retrieve and synchronize prescription and additional information to be presented to the patient. It also receives event notifications from the Event Manager on the server, whenever a prescription is due according to the schedule. This application fulfills the mobility requirement and its graphic interface addresses the issues related to accessibility of information identified in section 3.2, and realizes the text to speech requirement.

UbiMeds Web Service. Whenever the mobile application requires information, it makes a request to the web service. This service running on a Web Server is responsible of retrieving prescription, news and other information from different sources and then formats all information for sending it as response to the mobile application; it is the point of interaction between the mobile app and the rest of the modules on the Centralized Information Management component. This module, along with others, addresses the requirement for centralization of information.

Events Manager. This module's purpose is to handle events that are raised either by the mobile application (drug intake feedback events), or raised by the scheduler (alerts when it is time to take medicine or when the user has failed to do so). The event manager attends to the requirement of automated reminders and to the intake tracking requirement.

Scheduler. This module is in charge of creating the entire schedule of prescriptions for the patient. It makes requests to the PHR interface module for information, and based on it updates the schedule database. The schedule runs as a CRON job on the web server. This means that the scheduler runs periodically performing 2 tasks: First it updates the schedule database with latest prescription schedule information. Then it verifies for medications that are due to be taken at that time, and raises events accordingly. This module addresses the requirements for automated scheduling, reminders and intake tracking.

Intake Monitor. This module keeps a record of medications taken by the patient, it is constantly checking for the intake history on the database to see if the user has failed to take medication beyond a pre-configured threshold, and raises an alert to the physician, or relatives if this is the case. Alerts can be in form of emails, and SMS.

PHR Interface. This module acts as a proxy to the personal health information of a patient (including his/her prescription information). It works by interacting with the data API specific to each PHR system. This module has a loose coupling scheme with the rest of the modules in the centralized component. This allows for a quick reconfiguration or extension to include new Personal Health Records available on the web. This module, along with the scheduler, fulfills the requirements for the automated scheduling.

Data Aggregator. When the patient makes requests for additional drug information or related news for a specific medication, this module retrieves such information from online medical databases and other RSS news servers. This module addresses the requirement for news and additional prescription information.

UbiMeds Database. This is the storage component for the architecture. This repository is used by the scheduler to keep an up to date schedule of the prescriptions of the patient. It is also used by the Intake Monitor to look for anomalies on the patient's intake behavior.

6. CONCLUSIONS AND FUTURE WORK

In this paper we have presented UbiMeds, a mobile application solution that integrates with current Personal Health Record systems to provide automated scheduling, reminders and tracking of prescription drugs intake, including proactive alerts sent to physicians and relatives when the patient fails to adhere to the prescription regime. The goal has been to improve accessibility for elder and disabled users in the process of taking medications and to improve awareness for caregivers and family members about the progress of the patient.

The next step for UbiMeds project would involve a usability study with actual patients with complex medication schedule. Such evaluation would allow to assess the extent to which the design principles of UbiMeds improve accessibility on the issues identified in this work.

Another possible topic to consider in future work would be that of privacy. Since pervasive computing and ambient intelligence technologies involve the dissemination and sharing of information, privacy issues are important to be considered. This is particularly critical on applications where health related information is involved. Within the context of our approach we should look into more depth at the implications of using third party service such a Google Health or Microsoft Vault to store the health records.

This is the initial work of what will become a structured framework that will enable the delivery of personalized services in an Ambient Intelligence scenario.

Future work on our medication adherence solution could involve embedding computational systems in everyday objects such as medication containers, medicine cabinets, dinner tables, etc. This will allow the deployment of a pervasive computing environment that can be leveraged to provide a higher level of interaction and services. Additionally we are looking into effective ways of deriving relevant context information (location, activity, medical context etc.) that can also contribute to the overall quality of the service provided to the patient. For example, we are looking at deriving additional medical context from the Personal Health Record that could help to create a personalized health profile. This would allow us to develop an adaptive user interface that reacts and behaves according to the particular disability of the patient.

From our perspective, mobile and ubiquitous communications and devices are a promising platform to enhance the quality of life and the seamless ubiquitous availability of services to people [13].

In the context of health this translates into a better delivery of care, keeping the patient in the middle and services and providers around him. From the point of view of the ageing members of society, these assistive technologies will improve their autonomy and their quality of life, as human capabilities fade.

7. REFERENCES

[1] Adherence to Long-Term Therapies: Evidence for Action. World Health Organization 2003.

[2] AllOne Mobile Health. http://allonemobile.com

[3] Cramer JA, Spilker B. eds. Patient Compliance in Medical Practice and Clinical Trials. New York: Raven Press, 1991: 387-392

[4] Enhancing prescription medicine adherence: A national action plan. National Council on Patient Information and Education, August 2007. http://www.talkaboutrx.org/documents/enhancing_prescription_medicine_adherence.pdf

[5] Ernst FR and Grizzle AJ, "Drug-Related Morbidity and Mortality: Updating the Cost-of-Illness Model," 4141 Journal of the American Pharmaceutical Assn 192. March/April 2001

[6] Gottlieb H. Medication Nonadherence: Finding Solutions to a Costly Medical Problem. Drug Benefit Trends. 2000; 1212 (6): 57-6262.

[7] Medication Use Among Older Americans. Research Conducted by International Communications Research for the American Society of Health-System Pharmacists. 2001. www.ashp.org

[8] Medicine Information Received by Consumers . U.S. Food and Drug Administration, posted December 2006 at http://www.fda.gov/cder/Offices/ODS/y2ktitle.htm)

[9] Med-eMonitor Electronic Pillbox. http://www.informedix.com

[10] Mushin AI, Appel FA. Diagnosing Potential Noncompliance: Physicians Ability in a Behavioral Dimension of Medical Care. Arch Intrn Med. 1977; 13137: 31318-321321321

[11] OnTime Rx. Prescription reminder services. http://www.ontimerx.com

[12] Shih-Chen Fan, et al. Health pal: a PDA phone that will take care of your health. ISIC. IEEE International Conference on Systems, Man and Cybernetics, 2007. 7-10 Oct. 2007 Page(s):3703 - 3708

[13] Silva, J. M., Mahfujur Rahman, A., and El Saddik, A. 2008. Web 3.0: a vision for bridging the gap between real and virtual. In Proceeding of the 1st ACM international Workshop on Communicability Design and Evaluation in Cultural and Ecological Multimedia System (Vancouver, British Columbia, Canada, October 31 - 31, 2008).

[14] "Take As Directed: A Prescription Not Followed." Research conducted by The Polling Company.™ National Community Pharmacists Association. December 15, 2006

[15] To Err is Human; Building a Safer Health System. Institute of Medicine. National Academies Press. 2000

[16] World Health Organization. http://www.who.int