Design of a Medication Reminder and Feedback System for Thai Elders

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Abstract-— **Thailand is well on the way to her ageing society status. More Thai elders eventually will experience chronic diseases that come with old age. Along with such diseases, come various medication regimens to intrude upon their lifelong habits and medication-independent lifestyles—a challenge to many elders, where failure to maintain prescribed schedule could result in faster health deterioration. This paper proposes a design of a medication reminder and feedback system specifically targeting a wider population of elderly users. The design addresses the usability issues among most non-ICT Thai elders and ensures a wider reach to the targeted senior population by basing the core component design on non-smart-phone platforms. The proposed architecture incorporates a combination of an automated process technique, Voice over IP, SMS and web services to devise an effective reminder and feedback solution for both the Thai elders and supervising healthcare professionals. The resultant design is flexible, efficient, and could facilitate future changes.**

I. INTRODUCTION

The United Nations Population Fund, Thailand (UNFPA, Thailand) [1] has estimated that approximately in year 2020 the number of Thai elders, sixty years of age or older, will exceed the number of the children. The rate of increase of the number of Thai senior citizens has consistently been steep. Based on the projected growth against that of the other Southeast Asian countries as depicted in Figure 1, it can be argued that the Thai society has already been well on the way into its ageing status.

From the healthcare perspective, ageing are naturally accompanied by various chronic diseases. As an example, the most commonly found diseases among Thai elders based on data from the 3rd National Health Examination Survey (NHES III, 2004) include blood pressure, diabetes, and coronary thrombosis [5]. Most elders, upon an onset of such health problems, require regular monitoring by the healthcare professional. Very often, certain lifelong habits have to be corrected so as to avoid aggravating the current detrimental conditions. The elders also will inevitably come to depend more on prescribed medicine and a medication regimen to manage their health issues. One study has shown that people over 75 years old took an average of 7.9 pills per day [6]. While some cope well with such demanding changes in their normal routines, some do struggle to keep up. Particularly when the prescribed medication regimen involves a number of pills to be taken—quite possibly with differing schedules—strictly following the proper prescription could be a big challenge for the elders.

In an ongoing nation-wide endeavor, the information and communication technology (ICT) has been positively perceived by many Thai private agencies and by the government of Thailand as an essential underpinning to an effective and efficient solution to ageing society [2]. ICT technologies such as electronic services (e-services) have been envisaged to play a crucial role in supporting active and healthy lifestyles of the elders in terms of healthcare, education, resources, activities, work, and welfare [3]. Using ICT technologies, it is arguable that a solution may be obtained to assist and encourage the elders to strictly follow the prescribed medications.

This paper proposes a design of a medication reminder and feedback system that could encourage and remind the elders to take their scheduled medications. The proposed design will satisfy the following minimum requirements:

- it shall be suitable for use by a more generic population of Thai senior citizens (sixty years or older), and not just those already familiar with and readily accessible to the ICT technologies
- it shall be capable of functioning as both a reminder system for the elders and a feedback system for healthcare professionals
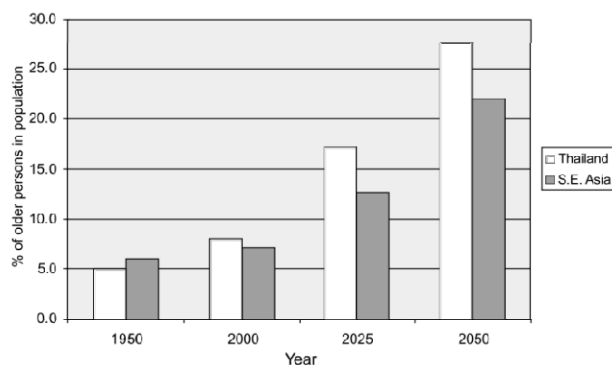

Figure 1. Projected percentage of senior population in Thailand and in other Southeast Asian countries (source: UNFPA [1]).

A number of medication reminder and feedback systems exist today in a variety of forms and functions. Phone call services, SMS, MMS, WAP, and emails are readily available and conveniently utilized as a means to alert the users, e.g. the elders, the patients or the caregivers, of the

scheduled medication time (e.g. *OnTime-Rx*). Devices and tools as diverse as a medication reminder alarm clock, an alarm medicine casket, and reminder software applications on smart phones (e.g. mobile applications by Bayer HealthCare AG, Garland Systems, and Mobile Apps Gallery, to name a few) have also been developed. Methods of medication time reminder may be classified into the following categories.

Non-technological Approaches via Memorization, Recognition, Note-taking, and/or Human Assistants

This method is the simplest and the most basic for the elders. However, it is not effective for those who have been within the scope of short term memory loss and amnesia. Under such a circumstance, the punctuality of their medication schedule could be affected— consequently causing problems in medical treatment of the elders [14]. In this case, the presence of close relatives and/or caregivers at or around the medication time may be needed.

Embedded-Reminder Devices

Devices, e.g. clocks, watches, and various modern gadgets, have been developed with a reminder application pre-installed from the manufacturers (e.g. *OnTime-Rx*). These devices are typically designed for users, including the elders, who must take medications frequently and on a regular basis. The embedded applications usually include features that allow users to set up alarm schedules. Available options could range from voice and/or vibration, to short-message or picture, to suit the preference of each individual user. Nevertheless navigation and control of these embedded reminder devices can often prove to be troublesome for most elders, especially those with little or no experience with ICT.

Medication Reminder Service Providers

The elders can receive their medication reminders through such modern communication channels as SMS, MMS, phone calls, and/or emails. The benefit of these services is that the service providers will handle and operate information and services through or by using medication profiles, call reminders, SMS reminders, appointments, and/or electronic mails. However, the elders who have registered to this service need to give all schedules and necessary information to the service provider such as *Medication-Reminders.com*. The registered user also has to pay for the reminder service. Although this might be a convenient solution, most elders—as they have probably already retired—might be unwilling to spend on such a service. In addition, the elders who want to use this service may find it burdensome and time-consuming to always have to keep all relevant information up-to-date with the service provider. At presence, the service providers only provide time-based reminder to the customer without considering the context, or responses.

Mobile Applications on Smart Phones

Numerous mobile applications have been developed on smart phone platforms that can alert users of their scheduled medications. Features of these mobile applications resemble those being deployed as embedded devices. A distinguishing characteristic is that these mobile applications evolve around existing mainstream mobile platforms—leveraging their market prevalence and wider customer base penetration. Even though these applications tend to be more user-friendly than the embedded reminder solution, some difficulty remains that the users must manage their prescribed medications manually. Users, particularly the elders with little or no experiences with smart phones, could prematurely reject the applications due to perceived complexity.

A study by Islam, Leijdekkers and Gay [15] suggested that the elders respond favorably to the use of existing medication reminder solutions, especially those based on using mobile phones to receive the reminder service. However, as mentioned previously, this method had its drawbacks in terms of recurring cost, inadequate context awareness, and a one-way flow of information to the elders. In subsequent sections, the paper discusses an architectural design of a medication reminder and feedback system that specifically aims to address usability and accessibility issues for Thai elders. As Thai elders are mostly from the generation before the information age, digital divide could be a hindrance to an effective use of the proposed design— as discussed by Zhao [12], Morris and Venkatesh [22]—and will be treated as a critical constraint herein.

II. MATERIALS AND METHODS

Given their pervasiveness and versatility, smart phones—mobile phone units typically equipped with reasonably high processing power capable of supporting sophisticated software such as an operating system and mobile applications—appear to be a natural choice to base the solution upon . Nevertheless, Anantho's findings on lack of prior Internet experiences in many Thai elders [16] imply that smart phones could be too complex for the elders to use effectively. In addition, fact remains that most elderly users from the pre-Internet generation will not be comfortable with the use of ICT devices [12][22], and/or of web access on mobile phones [25].

A preliminary study to use smart phones as a reminder and feedback device was planned, in collaboration with the Primary Care Unit (PCU), Siriraj Hospital—one of the largest public hospitals in Thailand. A prototype of a smart-phone-based medication reminder and feedback system was developed out of an initial work by Kumjut, Kulprecharseth, Chamnankha [23], and presented to the healthcare professionals at Siriraj's PCU. During this planning stage, the PCU staffs expressed concerns over complexity of use and high cost of a smart phone unit that could prevent most of their patients from using the reminder system. The actual preliminary data collection failed completely because no single elderly patient with a smart phone could be found and enlisted. It was found instead that non-smart phones were a more common choice among PCU elderly patients.

Non-smart phones are older generation mobile telephony devices currently at the low end of the mobile phone price range. Their features are very basic—limited only to most often use functions such as voice and message communication. Development of non-smart phone applications is possible, yet again limited in features and functionalities due to the unsophisticated nature of the host

platforms. Application's portability and ease of deployment also are some well-known issues. Although non-smart phones today still posses the largest market share, a study by Dediu [9] reveals that their share has been continuously eaten away by the smart-phones.

In light of the new findings from the preliminary study, the authors re-assessed and further analyzed the requirements and constraints of the proposed medication reminder and feedback system. Even though smart phones were versatile and could support a range of applications to perform the reminder and/or feedback functions, they failed to penetrate satisfactorily into a general population of senior Thai citizens. Evidences from several other studies [8][13][14][16][17, 18] further suggested that most elders now (at least sixty years old in year 2010, i.e. the baby boomer generation) either did not own smart phone devices or would reject them or feel intimidated by them. On the contrary, Zhang and Sha discussed in their paper that non-smart phones were actually suitable for elderly users in terms of cost, function, and usability [7]. Furthermore, in underserved areas most likely to be found in developing countries such as Thailand, non-smart phones are a cost-effective tool for reaching out to the users [19]. For these reasons, the proposed architecture was designed around a non-smart phone platform to effect the desired wider reach among Thai elders.

As non-smart phone capabilities are mostly limited to voice and message communication with little support for portable and customizable applications, the proposed architectural design takes a client-server approach to allow for needed processing requirements to be carried out by a cluster of more powerful servers—leaving a non-smart phone to behave as a thin client responsible only for what it does best: voice and message communication. To better leverage the voice and message features of non-smartphone, VoIP and SMS technologies are integrated into the proposed design to allow the elders to receive a communication in a familiar form of voice and messages which would further enhance perceived ease of use [17][18] and could result in the elders to better accept the system [4]. Use of VoIP as a communication means in particular, provides an added benefit in that it can be used with landline telephone units as well.

Table 1. List of software and related technologies being used

Languages
• Python-Django
• Piston (Django Web Service APIs)
• Python-Celery (Process Scheduling)
• JSON & XML
• Lau script
• Bluebox (Freeswitch, PHP Web Interface)
Web Standards
• HTML5, CSS3
• Javascript Framework (jQuery)
Databases
• SQLite
• MySQL
Servers (VMs localhost)
• Apache2
• Python-Mod_WSGI
• MySQL Server
• Freeswitch (VoIP server)

Feedback from an elderly user with a non-smart phone platform presents another challenge to the design. Lack of a robust application support results in an inferior feedback-process automation. Any application developed to alleviate such a feedback issue will most likely be rendered rather useless because of problems such as complex application navigation and control, and platform incompatibility. It is inevitable that manual actions from the elderly users are necessary in order to provide pre-defined feedback to the healthcare professionals. In trying to maintain a traditional way of telephone operations so as to promote ease of use to Thai elders, the proposed architecture includes an interactive speech response (IVR) system to handle feedback inputs from non-smart phones. An IVR solution works well with the VoIP technology; it does not require any change in a way to operate a mobile phone by an elderly user. Effectively, it has potential to encourage Thai elders to better accept and use the proposed system.

To successfully design and effectively implement the system as proposed, a number of software technologies as listed in Table 1 were used. The development and test platform (32-bit, i386 desktop) ran the Ubuntu 11.10 operating system with 4GB of memory on the Intel Core i7 processor with L3 cache. The whole project ran together on a virtual machine—an i386 Ubuntu Server 11.04 with 1GB of memory.

III. THE PROPOSED SYSTEM ARCHITECTURE

This section shows the resultant architecture of the proposed medication reminder and feedback system. As a proof of concept, the initial workable prototype of the proposed design has also been implemented. Discussion of the results as well as future research pointers will then ensue in the next section.

A. System Architecture

Recognizing the functional limitation of non-smart phones, the design took a fat-server, thin-client approach. A non-smart phone client maintained the inherent features that primarily supported voice and messages; it required no installation of additional software.
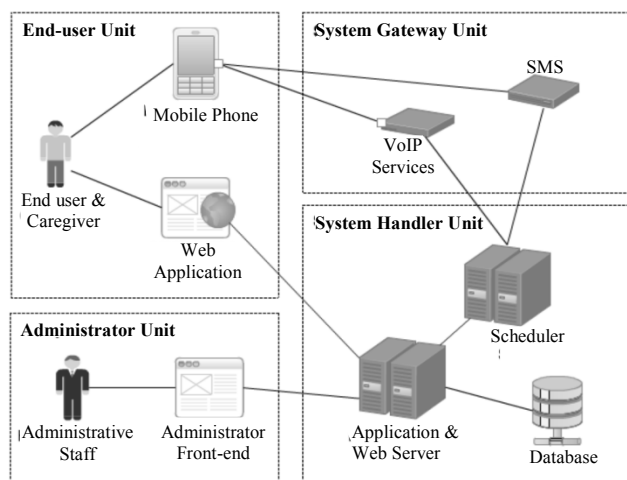

Figure 2. The proposed architecture consists of four main units: end-user unit, administrator unit, system gateway unit, and system handler unit

Figure 2 illustrates how the four main units, namely the end-user unit, administrator unit, system gateway unit and system handler unit, interact. The *administrator unit* supports tasks pertaining to management of the end users' profiles and medication records. The administrator front-end is a web-based gateway that connects to the application and web server of the system handler unit; it facilitates the administrative staff in managing end users' information. The administrative staff is responsible for such specific tasks as registration of new end users and management of their profiles, appointments, history data, and medication records that include drug usage instruction. Naturally, it is highly probable that the administrator unit will reside in a hospital where the administrative staff could be a station nurse or a pharmacist, and the end users are Thai elders or patients in general.

The *end-user unit* consists of two components: a web application and a mobile front-end, i.e. the end user's non-smart phone. This unit allows end users/caregivers to update and modify the profiles via a web application using a web browser. The web application component could also be designed to further assist the end users/caregivers in medication treatment monitoring [21]. If the Internet connection is available, the application will allow the end users/caregivers to update their profiles and exchange the information with the application and web server of the system handler unit in real-time. The mobile front-end provides personal medication assistant to the end user via a non-smart phone.
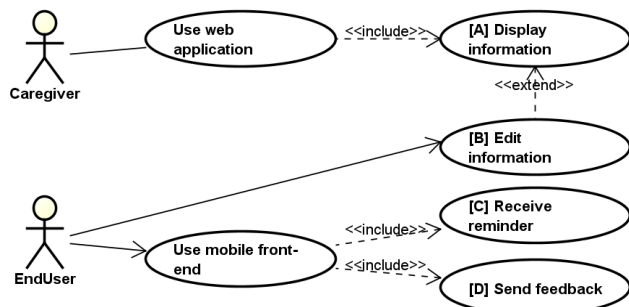

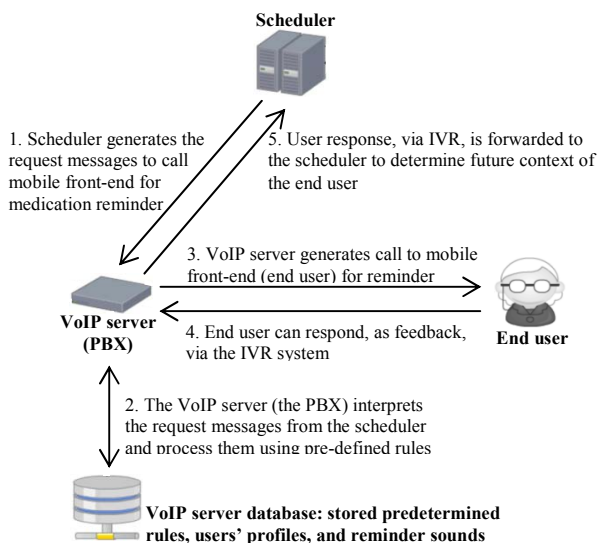Figure 3. Different use cases for end users/caregivers.

Figure 4. A process flow of the VoIP service.

Figure 3 captures the main use cases where the end user/caregiver interacts with the system as follows:

A. End user/caregiver displays basic information: ID, name, age, gender, medication details, amount of remained medicines, and next appointments,

B. End user edits information that includes preferences and medication timetable,

C. End user receives a reminder to take prescribed medications,

D. End user sends feedback—the IVR system will create options for the end user to interact with. For example, the system could be programmed to wait for the end user to press a number on the numeric keypad and interpret the received key value based on the predefined meanings such as *acknowledge to receiving the reminder* or *compliance to taking medication*. Based on current end user information such as medication taken or skipped, as well as the end user response to the system, the user context might be inferred that could be used to adjust the reminder pattern.

The *system gateway unit* consists of the VoIP and SMS components; it is responsible for initiating a call or messaging service to the mobile front-end according to the request from the scheduler. As depicted in Figure 4, the VoIP server receives a request message from the scheduler and generates a telephone call to the mobile front-end. The VoIP service relies on the IVR system to determine the end user's response. The IVR response, once determined, will then be forwarded to the scheduler for further processing.

SMS—a messaging service—provides a redundant communication channel to VoIP. When the end user does not answer VoIP calls, the scheduler will generate a reminder message and have the SMS gateway send it to the mobile front-end.
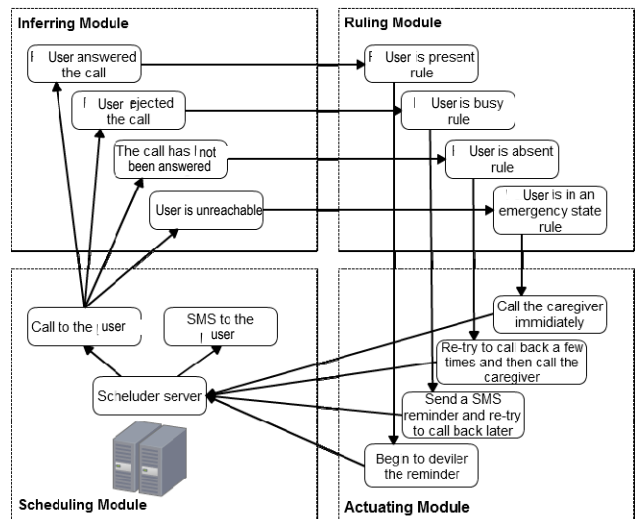
Figure 5. A process flow of the System Handler Unit.

The *system handler unit* is responsible for efficiently providing necessary information to the system gateway unit (VoIP and SMS); it consists of two components, namely, the application and web server—*the server*—and the scheduler. The server permits the end users to update their information through the web application and/or the administrator front-end via a web browser. Such web technologies as

Representational State Transfer (REST) and Simple Object Access Protocol (SOAP) are employed to transmit the information defined in the JavaScript Object Notation (JSON) and the eXtensible Mark-up Language (XML) format. Once the server completes processing the received information, it sends the acquired medication timetable to the scheduler via REST and SOAP web services. The scheduler then, based on the timetable and the derived user's context, triggers the VoIP calling and/or SMS messaging services to remind users of their due medications. The server also furnishes an authentication method that supports different access privileges on end users' information by different roles such as an end user, nurse, doctor, and pharmacist.

To deal with the complexity of the system handler unit and to support future extensions and/or modifications, the unit is divided into four modules as shown in Figure 5. The *scheduling module* comprises a scheduler server—the system brain that synchronizes the data and medication timetables stored in the server. The scheduling server also handles system logic and schedules the reminder services to the users. It calls VoIP and SMS gateways by using a separate set of application programming interfaces (APIs).

The *inferring module* translates users' actions into data. For instance, whether a call has been answered, rejected, unanswered, or unreachable, it will be temporarily stored in the scheduler server database. Later on, the data will be processed with the system predefined rules, each of which consists of a condition and an action.

The *ruling module* is a core component to manage medication compliance. The module analyzes users' inferred behaviors with predefined conditions so that proper actions could be initiated. For each rule, the condition part describes users' behaviors which should be followed by an action. The action part describes the action that should be provided to the users. If the satisfying rules are matched, the module executes the rules and the user's ruling events are created.

The *actuating module* processes the outputs that result from interacting with the end user using VoIP and SMS and conducts the commands that the ruling module generates. The actuating module consists of a mobile phone device directly interacting with the end user where feedback information is obtained via the IVR system back to scheduler server.

B. Implementation

A proof-of-concept implementation of the proposed design was successfully carried out. The development and test platform (32-bit, i386 desktop) ran the Ubuntu 11.10 operating system with 4GB of memory on the Intel Core i7 processor with L3 cache. The whole project ran together on a virtual machine—an i386 Ubuntu Server 11.04 with 1GB of memory. The early version of a VoIP server was provided by a commercial VoIP service (*True Net Talk*), while the actual implementation based on Freeswitch was under development. As per the SMS service, commercial gateway APIs was used that allowed easy integration into the overall system.

IV. DISCUSSION AND CONCLUSIONS

This research attempts to design a medication reminder and feedback system that has a wider reach to Thai senior citizens. The paper sees mobile phones as a convenient means to realize such a reminder system as they already have penetrated well into all parts of the country. Evidences from various studies, see [8][13][14][16][17, 18], including the findings from the preliminary study with the Primary Care Unit (PCU), Siriraj hospital, suggest that non-smart phones actually better address the objective of this research—that is a medication reminder and feedback system that could achieve a wider reach to Thai elders—for they are less intimidating, more familiar devices to many Thai elders, and the penetration among Thai elders seems to be more substantive than that of the smart phones.

The resultant design also bears the characteristics that are favorable to future extensions such as a possible incorporation of smart phones to appeal more to the technologically advanced Thai elderly users, or use of newly available technologies that could improve the system performance even further. Being simple coupled with being platform independent, the resultant design is highly flexible and efficient. Usability concerns have been addressed and some solution built right into the system architecture as can be seen from the use of the familiar voice technology along with a thin client approach that requires almost no change to how the mobile front-end is operated. Automation has also been introduced for better efficiency and ease of use via such components as the scheduler and the IVR. The use of such standard data exchange formats as XML and JSON also helps ensure compatibility among mobile devices—at present or in the future—allowing kinds of the mobile front-end devices to expand with the technology and become more prevalent.

As mobile phones today are prevalently common, and as the resulting design is mobile-phone centric, the design can effectively be applied and adapted to specific use in hospitals or other healthcare services—in both public and private sectors. Because the design targets a larger and generic group of Thai elders from the very beginning, it is well-suited to be adopted and sponsored by the Thai government to promote the electronic health in Thailand.

It should be noted that a complete solution to the medication reminder and feedback system depends not only on the system architecture but also on the user-friendliness of the non-smart phone devices as well as on the effectiveness and efficiency of the communication from the system to the end user. As per the former, some studies [7][10] suggested that the keys, the screen, the fonts and the icons on a non-smart phone device should be clear and easy to read. Thai language must also be supported. Phiriyapokanon, in his thesis, discussed in great detail the usability issues and guidelines for the design of the elderly-friendly interfaces [11]. As for the latter, the communication from the system to the end user, i.e. the reminder, should be structured in the simplest way possible. Most elders will already feel anxious and/or intimidated by the technology [4], a complex communication will cause the elderly users to lose concentration, fall behind in the process, and eventually see no worth and reject the solution system.

Another issue identified by this paper from test-running the prototype was that the load capacity of any one VoIP server was rather limited. The current VoIP solution from the commercial VoIP service provider could make only about 5 phone calls simultaneously before the lag time became too distractive and the call quality too poor—rendering a large-scale deployment of the system useless. Under such a circumstance, a more powerful VoIP server would be needed along with an efficient reminder-scheduling policy for better management of concurrent schedules. Use of Skype as a substitution for VoIP is also under exploration where the change-over, if necessary, would benefit from the extensibility of the design and require only little effort.

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