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Ubicomp Assistant: An Omnipresent Customizable Service using MARKS (Middleware Adaptability for Resource Discovery, Knowledge Usability and Self-healing)

Moushumi Sharmin, Shameem Ahmed, and Sheikh I. Ahamed
Marquette University, Milwaukee, WI, USA
{msharmin, sahmed02, iq}@mscs.mu.edu

ABSTRACT
Due to the pervasive nature of current short range, low-power wireless connectivity and easy availability of low-cost light weight mobile devices, it is necessary to have an omnipresent customizable service. It can be used by different types of users different fields such as education, healthcare, marketing, or business, at any time, and at any place. These devices can reach ubiquitously to neighboring devices using a free short range ad hoc network. Unfortunately, to the best of our knowledge, no one has designed such a service. In this paper, we present the details of the Ubicomp Assistant (UA), which is designed to accomplish the above objectives. To evaluate the design, we have developed an application which uses UA as a service. It uses MARKS (Middleware Adaptability for Resource Discovery, Knowledge Usability and Self-healing) as an underlying core service provider.

Keywords
Ubicomp Assistant, UA, Ubiquitous computing, MARKS.

1. INTRODUCTION
The volume of the world market for handheld mobile devices (PDA, smart phone, cell phone, etc.) is significantly increasing.. The worldwide penetration of handheld devices through 2005 is 500+ million, while this number was 200+ million in 1999 [1]. According to D.B. Stewart [2], in almost every aspect of world, there exist potential applications of pervasive computing technology. Hoping to provide more and more support in the users' personal and professional activities, many applications such as scheduler, notepad, calculator, file explorer, pocket word, and SQLCE query have been developed for those devices. Applications in other areas include games, financial software (Tip & Tax Calculator, Money Manager etc.), travel software (Mass transit map, Fuel Log, etc.), communication software (digital clock, address book etc), international software (currency converter, foreign language dictionaries, etc.), web based software (IE, e-mail, Pocket MSN etc.) [3]. These are largely used by regular users and. Some tools have also been developed to assist the application developers. However if an application developer wants to develop any application based on a wireless ad-hoc network, he needs to have the expertise on many core functionalities of OS and networking. Also he alone needs to manage everything (user interaction, context, and resource sensitivity, secure communication among devices, etc.) In most cases it is really a burden, sometimes almost impossible. A middleware based process can greatly help in this regard. Recently, some middleware have been developed (e.g. Gaia, Oxygen) which provide some specific service for some specific users in a specific place [5, 6].

Unfortunately, existing middleware solutions do not support any customizable ubiquitous service to be used by multiple users anywhere any time. One obvious but deficient solution is to design the particular service for specific users. In that case, not only the application developer but also the end user needs to be aware of which service should be used in which situation. So it would be really helpful if the service is not only omnipresent but also adaptable according to the users' need. Moreover, the service should have ad-hoc wireless infrastructure expertise. The ability to work within a heterogeneous platform and free availability would be pluses. These are the main aspirations behind UA.

The first prototype of the middleware named MARKS has been developed recently [7]. It supports both core and supplementary services like Knowledge Usability [8], SAFE-RD [9], GETS Self-healing [7], PerAd service, Security service, etc. However, those services are also context specific. To make MARKS really ubiquitous, UA has been appended to it as a component.

In section 2, we present some scenarios to describe the necessity of the UA service. The related works are presented in section 3. The characteristics and functional requirements are presented in section 4.and 5 respectively. How our UA maintains the required characteristics are presented in section 6. The evaluation process is shown in section 7. We conclude with some novel directions of our future research in section 8.

2. MOTIVATION
In spite of the physical constraints of hand held devices, most of the capabilities of the resource-rich devices (such as desktop PCs) are incorporated in these devices. MARKS has been developed with that in mind. UA, an integral part of MARKS, is a service which can be used by various users in different situations Here we are presenting some pragmatic scenarios where our UA can be efficiently used.

Scenario 1
After visiting a museum, the instructor (Dr. Factor) and her students are returning to their institute by bus. Dr. Factor has prepared a questionnaire in her PDA and has passed it over to the students' PDA, to evaluate their understanding. After getting the questions, each student has started answering. Since Joseph (a student) has some confusion about a specific question; he sent a

query to the instructor and received feedback from the instructor within a very short time. Within a pre-specified time, every student sent their answers to Dr. Factor and the grading gets done automatically and the results are distributed to the students accordingly.

Scenario 2

Dr. Jackson, a conference attendee, really likes the presentation of Dr. Ross and wants to have the presentation slides. However, those slides are not available on in internet. Being late, Mr. Peterson, another conference attendee has missed some important points of the presentation and also wants those slides. Both Dr. Jackson and Mr. Peterson start their UA in their PDAs and request the file from Dr. Ross's PDA. Since these two people are trusted (since they registered for the conference and they were also passed through the trust model) Dr. Ross's UA agrees to send and the requested files are transferred to the PDAs wirelessly.

Scenario 3

After getting to the Starbucks, besides having coffee, fun lover Jim wants to chat with nearby interested people. He launches the UA application in his PDA and UA finds the nearby trusted PDAs. Then Jim starts chatting with Laura and Rachel, stting in the same coffee shop. All of a sudden, UA shows that one of his buddies named Jerry is also available short range. Without any delay, he starts chatting with Jerry too, without disconnecting from connection with Laura and Rachel.

UA is a complete service provider for all of the above scenarios. Any application developer can develop customizable applications according to their user's need by using UA.

3. RELATED WORKS

In the Oxygen project [6], 'intelligent space' occupied by cameras, microphones, displays, sound output systems, radar systems, wireless networks and controls for physical entities, were introduced. People can interact by using speech, hand gestures, drawing, and body movement. Gaia [5] is another project also based on active space. However, our approach is different from others. We mainly consider that the user may be present anywhere and may want to get services at any time.

In [2], the need for a new software engineering method has been mentioned. Why the software should be "miniature software" was also detailed in that paper. In UA, we have not only deployed that "miniature" concept but also developed the service to help developers implement the customizable application. In SEREFE [11], a new architecture for SEREndipitous File Exchange was presented. By using SEREFE, one user can easily share information with others which reduces the need to plan in advance what files they will share and when they will share them. However, in this architecture, having internet connectivity is a basic requirement. On the contrary, in our approach, Internet connectivity is not needed. Having wireless communication facility and using the MARKS are the only requirements. In Conference Assistant [10], a prototype for assisting conference attendees in choosing presentations to attend, taking notes, and retrieving those notes was presented. They also discussed the important relationship between context-awareness and wearable computing. However, in our approach, conference Assistant is a part of UA, though the user interface and file transfer utility are different from each other. ConChat [4] is a context aware chat program that improves electronic communication. It provides contextual information and resolves potential semantic conflictst between users. UA also provides chatting facility among the users and keeps and keeps context and keeps context moedl.

4. CHARACTERISTICS OF UA

To fulfill all the major requirements of a specific user, UA must encompass the following prime criteria:

C1) Customizable

Since UA can be used by various types of users, the role of the users, the user interfaces and operations should be customizable.

C2) Multidimensional utility

UA is used for creating, editing, and distributing a survey or an exam on the fly. It has chatting options, file transfer, and note taking facility. It should also be able to maintain different types of databases (exams, survey questionnaires, patients, etc.).

C3) Heterogeneous platform

Different users may use different types of computing devices like PCs, laptops, PDAs, smart phones. UA should be executable in any of these devices.

C4) Omnipresent seamless service capability

UA should be able to be used anytime, anywhere seamlessly. An occurrence of any inconvenience (refusing the user access to the network, partial file transfer due to an unknown reason, etc.) may undermine the users' confidence in the whole process.

C5) Ad-hoc wireless infrastructure expertise

UA does not need to have any fixed infrastructure, though it willo work with the aid of fixed infrastructure as well. Since any user can join or leave a group at any time, it should have the expertise to utilize the ad-hoc wireless infrastructure.

C6) Miniature footprint

The software for pervasive computing technology should be miniature software [2]. Since presumably UA would be used mainly in tiny devices which do not have large memory space, a small footprint is a primary requirement for this service.

C7) Free availability

Unlike other services (internet, or phone service), one should not need to pay for UA. UA will be freely available to facilitate communications ubiquitously.

C8) Persistent connectivity

The connection between two devices should be persistent so that the user feels that he is always "ON".

C9) Coupling the physical and mobile information world

UA should provide functionality for the user to transparently couple the physical world to the mobile information world.

5. FUNCTIONAL REQUIREMENTS OF UA

The role of a person is context dependent. The user interface and functionality should automatically be updated according to the role of a person (instructor, student, surveyor, etc.).

Requirements from Instructors' point of view

1) They can enter as many question (Multiple choice, True/false, Fill blanks) as they want.
2) They are able to create the answer key.
3) The distribution of the entire exam should take place when the instructor selects the designated action.

4) Due to the limited memory capacity, Data (exams, answers, etc.) should be saved in an efficient way.
5) They would be able to get some feedback from the students.
6) They can append any new questions to the existing exams.
7) While creating questions, they can skip any answer.

Requirements from Students' point of view

1) They are able to submit answers within a specified time.
2) The system should be very reliable and secured.
3) They can post the comments or question to the instructor.
4) They should be able to skip any question if they want.
5) They should be able to take notes in PDA.

The above requirements are described in detail in [12].

Requirements from Surveyors' point of view

The requirements are similar to the instructors' requirements.

Requirements from Survey attendees' point of view

While these requirements are similar to the requirements of a student, it should have some extra requirements too.

1) No one can force any UA user to participate in a survey
2) They can cancel the survey at any time.
3) They can respond to as many questions as they want.

Requirements from Conferences attendees' point of view

1) They can communicate with others (chat, files sharing etc.).
2) They can post any comment/question to the presenter at any time without interrupting the session.
3) If the presenter agrees, then he can download the necessary files residing in the presenter's mobile device.
4) They can take any note, edit it, and send it to other people.

Requirements from Fun lovers' point of view

1) A fun lover should have the list of his buddies (also using UA) available in his UA service who remain in the vicinity.
2) The list of the anonymous but trusted fun lovers residing in the same wireless region is also be available in his UA.
3) Besides chat, one can send/receive any files (text/binary) to and from anyone, provided the sender has given permission.

Requirements from Resident doctors' point of view

1) They can securely keep and transfer the patient record.
2) They can append new information to the existing database.
3) The service should be scalable. Same information can easily be sent to as many people as necessary.
4) Only authenticated doctor can access the patient database.

6. DEVELOPMENT OF UA USING MARKS

We have developed the first prototype of the MARKS. The system architecture of MARKS has been shown in figure 1.

6.1 UA is a third tier service

MARKS provides three tiered services:

a) First tier services or core services. They ensure the transparency over ad-hoc communication.

b) Second tier services: They may use the first tier services as a component. They include RD (Resource Discovery), KU (Knowledge Usability), SH (Self-healing), and CP (Context Processing). Each service incorporates an agent along with it.

c) Third tier services: They may use both the first and second tier services. It contains Security, PerAd, and UAsService

After converting and classifying the request taken from the application developer, the IDL (Interface Definition Language) and the classifier of MARKS send it to the agent which drives it to the appropriate unit. For example, if an application developer wants to find the nearby people who are using UA, he will invoke UA through IDL. Then the classifier will determine the appropriate agent (here RD agent) with the specific parameters. The RD unit will then perform those functions by using core services and will return the result to UA via the RD agent. Finally UA will propagate the same result to the application developer. The communication mechanism and network environment for UA as well as MARKS are based on the ad-hoc mode of 802.11. Though it does not require any fixed infrastructure, it is capable of communicating with the devices of fixed infrastructure.

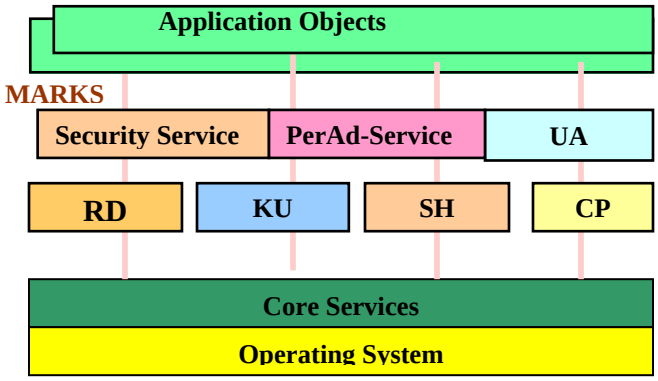

Figure 1. MARKS Architecture [7]

6.2 How UA adheres all the characteristics

The heterogeneous platform flexibility (C3), ad-hoc wireless infrastructure (C5), and persistent connectivity (C8) are supported by the core services of MARKS.

UA itself provides the customization facility (C1). Currently UA supports several types of users such as instructors, students, surveyors, fun lovers, conference attendee, and residence doctor. One can easily add a new role. The features and the interface will be changed according to the user type. The role selection principle depends on the user needs. UA provides a model for the users to select the role and associated functionality dynamically. For example, a user can easily append a new role named "Manufacturer" for work coordination and can also select corresponding functionalities like employee database, chat with factory workers, file transfer, note taking facility, etc. It supports multi dimensional utility functions (C2) like chat with nearby people, secured data (text, video, audio) transfer, assessment on the fly, survey on the fly, patient tracking, note taking facility by using both keyboard and transcriber of PDAs etc. It also maintains different types of databases for different types of users. The database for a residence doctor would be different than the database of an instructor and a surveyor. UA has the omnipresent seamless service capability (C4). It can be used anytime anywhere, if wireless facility is available. To prevent any kind of tantrums during the entire process, it takes the help from the first and second tier services. Table 1 shows the tiny footprint (C6) of UA.

Table 1. Miniature footprint of UA

	LOC	Executable file size (KB)
MARKS-ORB	868	16
UA	14556	236

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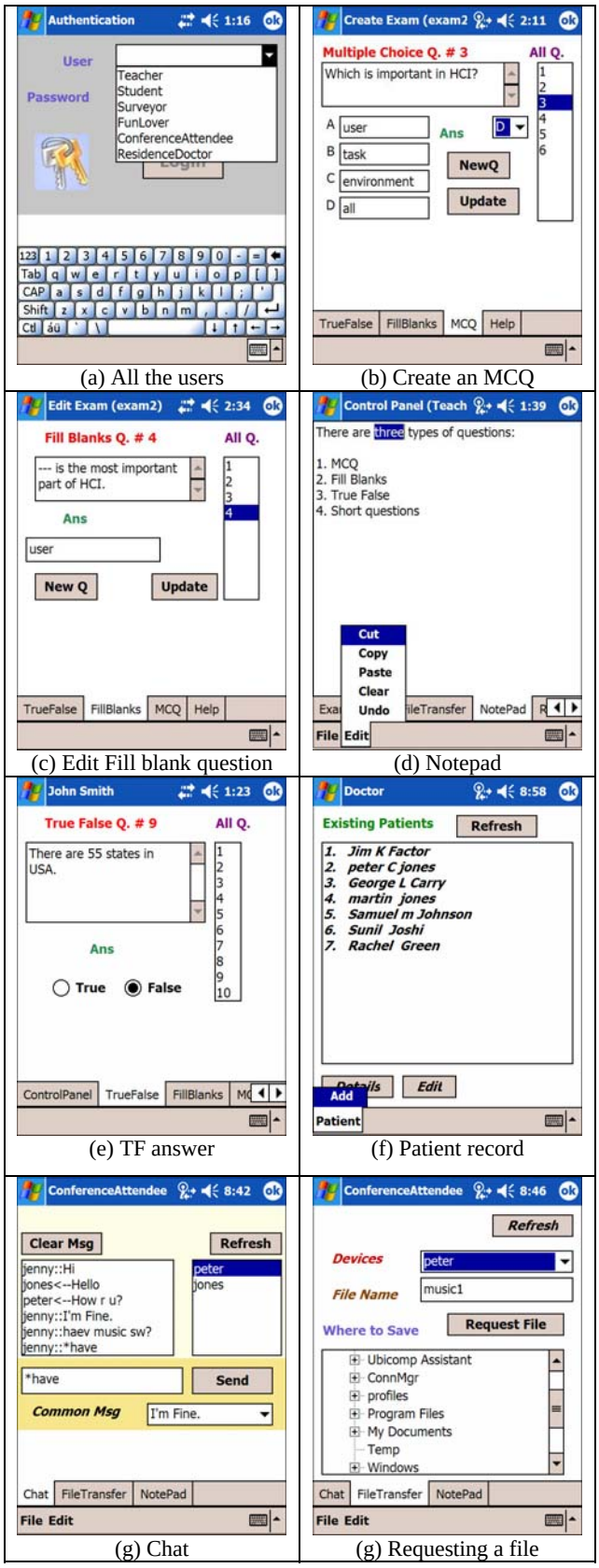


(a) All the users (b) Create an MCQ

(c) Edit Fill blank question (d) Notepad

(e) TF answer (f) Patient record

(g) Chat (g) Requesting a file

Figure 2. Some Screen shots of UA

We are also planning to make this service and the middleware freely available (C7) via the internet. UA has the capability of transparent coupling of the physical world to the mobile information world (C8). Different types of services of physical world like finding the friends, chatting with them, etc. are provided to the users but from mobile information perspective.

7. EVALUATION

To evaluate UA, we have used a three fold approach.

1. Implement a prototype of an application which uses UA
2. Cognitive walkthrough strategy
3. Performance measurement

7.1 Prototype Implementation

To implement a prototype of an application by using UA, a platform consisting of WinCE running on a set of Dell Axim X30 pocket PCs (Processor: Intel@PXA270, speed: 624 MHz, and weight: 4.8 oz) has been used. As an implementation language, we have used C# in Compact Dot Net Framework. As the underlying wireless protocol, we have used the mobile ad hoc mode of IEEE 802.11b. Databases have been maintained through SQLCE. Figure 2(a) shows the existing user list. 2(b) and 2(c) illustrate scenarios how instructors create and edit questions. How to use the Notepad is pictured in 2(d). A student is answering a question TF question is shown in 2(e). 2(f) shows the patient record in the resident doctor's PDA. A conference attendee is chatting with another conference attendee is shown in 2(g). A fun-lover is requesting a music file is shown in 2(h).

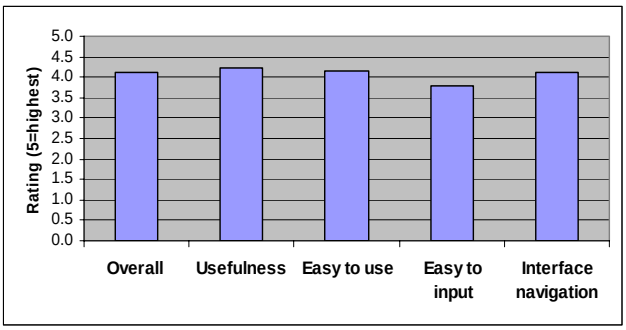
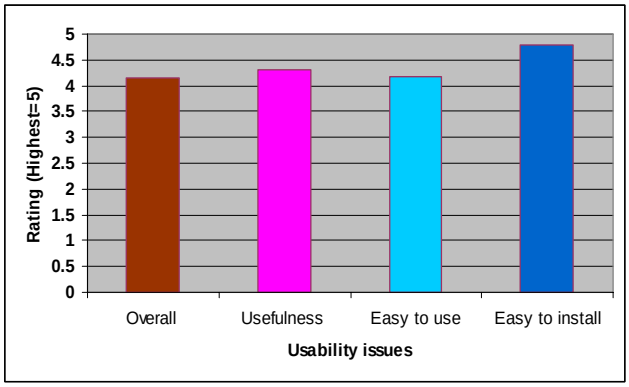


Figure 3. Rating by users



. **Figure 4. Rating by application developer**

7.2 Cognitive walkthrough strategy

Cognitive Walkthrough Strategy [13] encompasses one or a group of evaluators who inspect a user interface by going through

a set of tasks and assess its understandability and ease of learning. To evaluate our application, we followed this strategy.

Who will be the users of the system? 4 graduate students (3 computer science, 1 mechanical eng.), 1 undergrad student, 1 college teacher, 9 professors as well as conference attendees (2 computer science, 1 communication science, and 6 chemistry), 1 English teacher, and 1 resident doctor were chosen as the users to cover all types of end users In this paper, we have described in details that application as well as the UA

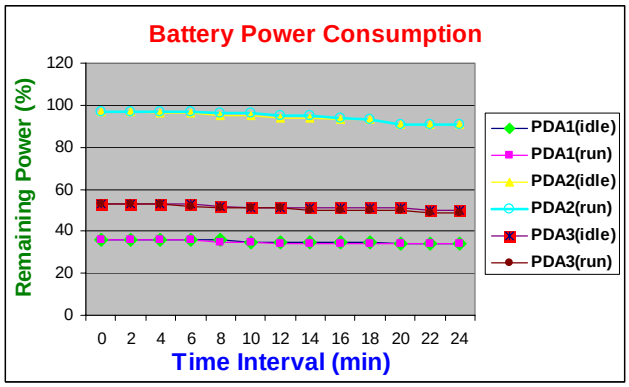


Figure 5. Power consumption

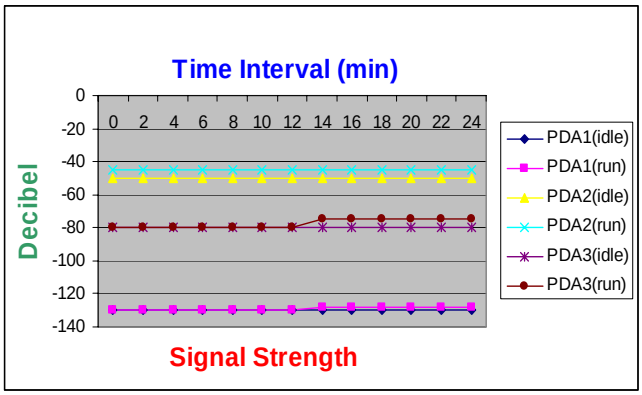


Figure 6. Signal strength

What tasks will be analyzed? Some tasks are user specific (e.g. maintaining patient database). Some tasks are common for some users. For example, file transfer can be used by both fun lover, and conference attendee. We have tried to select the tasks to be analyzed in such a way that no major task has been overlooked.

What is the correct action sequence for each task? First, we briefly explained the task sequences and process to get result. We recommended them to use "HELP" section if needed.

A questionnaire was given to the users. We modified our design based on their responses and implemented our second prototype. Figure 3 shows the users' satisfaction rating and figure 6 shows the application developers' satisfaction rating.

7.3 Performance Measurement

From the power consumption perspective, it is very efficient. In figure 5, the power consumption of 3 PDAs where the application based on UA is running, has been shown. To make the comparison crystal clear, we have shown two cases for each PDA. The idle case (UA is not running) and the run case (UA is running). Similar measurement but based on signal strength, has been shown in figure 6.

8. CONCLUSIONS AND FUTURE WORKS

An important emerging requirement in ubiquitous computing is to have an omnipresent customizable middleware service which can be used by different users of diverse fields. To accomplish that, we have developed UA, a third tier middleware service of MARKS. Moreover, to show the efficiency of that service, we have implemented an application by using UA service.

Currently, to the use UA, all devices should have MARKS on it. However, in future, we will make this service more flexible so that one device with UA can talk to another device whether MARKS is present or not. Also, we will incorporate:

- Voice enabled UA
- User Authentication by using signature or finger print
- Drawing facility inside the notepad

9. ACKNOWLEDGEMENT

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