# Healthcare Aide: Towards a Virtual Assistant for Doctors Using Pervasive Middleware

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## Abstract

*The advancement of available, portable, low cost handheld devices (PDAs, cell phones, etc.), Bluetooth, and WiFi has resulted in the users' mobility at unprecedented levels. As these devices can communicate with one another, the combined capabilities can be leveraged to form a useful new set of tools. Presently, pervasive computing is being extended into the sophisticated healthcare sector with the promise of providing an easier and more efficient mode of communication among healthcare professionals. In this paper, we present the details of our application 'Healthcare Aide', which has been designed to provide not only more convenience for doctor-doctor, resident doctor-doctor, patient-doctor and nurse-doctor interaction but also a smooth pathway for real-time decision making along with survey results from users' point view and performance analysis. Our pervasive middleware MARKS (Middleware Adaptability for Resource Discovery, Knowledge Usability and Self-healing) provides the underlying support for 'Healthcare Aide' in a completely transparent manner.*

**Keywords**: Healthcare Aide, Pervasive healthcare, and MARKS

## 1. Introduction

Pervasive computing [1] incorporates computing in our working and living environment to enable transparent interaction between humans and computers using wireless, sensor networks, PDAs, mobiles, smart phones, and other small hand-held devices. Pervasive computing is showing its potential in almost every aspect of our life including hospital, emergency and critical situations, industry, education, and hostile battle fields, to name a few. The use of this technology in the field of health has been termed pervasive health care. The goal of pervasive health care is to provide healthcare services to everyone at any time overcoming the constraints of place, time and availability of doctors, nurses and resident doctors. Healthcare professionals need information delivery tools for accessing information at the point of patient care as well as transporting the information to other relevant sites. Hand-held devices demonstrate great promise as point of care information devices. A 1995 study on the use of PDAs at the point of care found that hardware constraints, such as memory capability limited their usefulness [18]. Since this study was completed, over the last 10 years, hand-held computer technology has advanced rapidly, and as of 2001 and 2002, between 26% and 50% of physicians used PDAs [26]. A survey in [13] finds nearly half of U.S. healthcare members use hand-held computers. This use appears higher among residents, with one recent study finding that over two-thirds of family practice residencies use hand-held computers in their training programs [14]. Results of another survey and follow-up interviews on 88 residents in seven programs showed most residents use PDAs daily, regardless of practice or whether their program encourages PDAs. Uses include commercial medical references and personal organization software, such as calendars and address books. The results of another study[15] suggests improvement needed in (a) providing secure clinical data for the current patients of a given resident, and (b) allaying concerns of catastrophic data loss from their PDAs (e.g. by educating residents about procedures to recover information from PDA backup files). However, PDAs have undergone continuous and substantial improvements in hardware and graphics capabilities, making them a compelling platform for novel developments in high space occupying usage including even teleradiology. According to [16], the availability of bedside computer facility helped physicians to access information at the bedside and increased the use of Clinical Practice Guidelines Decision Support Tools, which patients have accepted too. Another study [10] was conducted regarding any potential benefit of wireless communication devices. The results identified a number of significant findings that demonstrate a healthcare benefit from a quantitative and qualitative standpoint. Hence, it has become an integral part to incorporate use of PDAs along with some software tools in healthcare professionals' daily life.

There are a number of research projects [3-12] at various universities and research institutes related to pervasive healthcare. In the WWM (Wireless Wellness Monitoring) project [3] a behavioral feedback system is implemented using some monitors, PDAs and a home server forming a WLAN (Wireless Local Area Network). In the CASCOM project [4], researchers provide real-time solutions in the tele-medicine sector using mobile devices. Several application projects, working to satisfy various concerns or segments of the healthcare sector, are going on in Denmark's 'Centre for Pervasive Health Care' [5]. In their application 'Pervasive Computing for Acute

Medicine', they build a solution for critical and emergency situations involving emergency vehicles, dispatch centers and hospitals through biomedical and other sensors. In the CodeBlue project [12] at Harvard University, the researchers provide an ad-hoc wireless infrastructure using low power sensors (for providing vital data) and PDAs as a solution to a medical emergency situation to communicate and share data more efficiently and also help in decision making.

In teleradiology, a new technology has emerged to interface Picture archiving and communication systems (PACS) and PDA. PDA-based teleradiology has the potential to increase the efficiency of the radiologic work flow, increasing productivity and improving communication with referring physicians and patients [9]. For its new acute care hospital, the University of California at Los Angeles is evaluating innovative technology involving high-resolution flat panel display devices configured as "network appliances" that can be wall mounted for use wirelessly by PDAs of the healthcare professional in the retrieval and display of medical images and patient data and record [7]. For physicians, wireless connected hand-held computers are gaining popularity as point of care reference tools. Physicians in virtually every medical specialty have begun using these devices in various ways [6]. Healthcare for the Homeless--Houston (HHH) began a case study under the assumption that tracking patient information with a personal digital assistant (PDA) would greatly simplify the process. Preliminary evidence suggests that PDAs free clinicians to focus on building relationships instead of recreating documentation during patient encounters [22]. In a workplace study at IMSS General Hospital in Ensenada, Mexico, researchers developed a context aware mobile system for the hospital environment [8] using IM (Instant Messaging) server and a corresponding XMPP (Extensible Messaging and Presence Protocol). In [11], privacy issues of the public displays were discussed, as well as persons involved in the day-to-day hospital work like doctors, supervisors, or medical interns.

In this background, a lot of work is going on in researching to make PDA and wireless network more efficient in meeting the ever increasing need of the healthcare professionals. All the existing and ongoing projects try to build a bridge between service providers (doctors, nurses, or paramedics) and some kind of external events (like a patient at home, emergency situations at some place, etc). In this way, technology is used to increase the interaction between patients and doctors, assisting service providers by giving them needed information. In our work, we have tried to use pervasive computing technologies for situations that occur at the medical center. We have incorporated this technology using PDAs for information sharing in emergency decision making situations. This also provides a means for patients to fully participate with their physicians in managing their own healthcare. Our project will also provide a smooth pathway for better continuity of care for the patient, as well as a smarter doctor-doctor interaction. These benefits will, in turn, create a safer health care delivery system with reduced chances of medical error. A more efficient learning environment for the trainee physicians or medical students will be created. Our main focus areas are the sign out, endorsement, consultation or other patient related communications that go on constantly among the physicians and other healthcare professionals such as nurses, resident doctors working in-house. Our work tries to adopt this promising technology in such a way that it maximizes the use of limited hospital resources, while at the same time creates a faster 21st century communication portal among the in-house healthcare professionals.

To provide support for our application, a middleware named MARKS (Middleware Adaptability for Resource Discovery, Knowledge Usability and Self-healing) [2, 20] has been developed. Along with several core services, it ensures the services of Knowledge Usability [19], SAFE-RD [21], Ubicomp Assistant Service [25], and GETS Self-healing [23]. From a user's perspective, MARKS provides these services in a ubiquitous and transparent manner. In this paper, we have presented the details of our application 'Healthcare Aide' along with survey results and performance evaluation.

Characteristics and challenges are discussed in Section 2, and functional requirements of 'Healthcare Aide' are described in section 3. How 'Healthcare Aide' adheres to the required characteristics is presented in section 4. Graphical representations showing the placement of MARKS and 'Healthcare Aide' and some screen shots of the prototype have been added as supplements. The evaluation details have been portrayed in section 5, which is followed by conclusions in section 6.

## 2. Characteristics of the Healthcare Aide

**c1) Privacy aware seamless service capability**

It will not only present itself as an omnipresent service to the user in any situation at any time but also ensure privacy of information through its security mechanism.

**c2) Continuous connectivity**

The system has to ensure persistent communication between the connected devices.

**c3) Energy efficient**

Battery power consumption places a real constraint on mobile applications.

**c4) Zero negative impact**

One primary goal of any application is to ensure that it doesn't have any negative impact on the performance of other applications running on the specific device.

**c5) Tiny memory footprint**

This application perfectly incorporates the well-known characteristic for pervasive software: miniature form.

**c6) Cost effectiveness through mobility**

As our system is working on ad-hoc devices without the help of any fixed infrastructure (such as a PC, a mainframe, or a central server), the cost has been significantly minimized.

**c6) Concurrent applications**

One user can run more than one feature at the same time.

**c7) Secure service discovery**

Each PDA has to be able to discover neighbors who are 'secured' and be able to communicate only with these 'trusted' friends to get services.

**c8) Secure Communication**

As file transfer and information sharing are the two most important features of this system, this communication procedure has to be absolutely sealed from intruders.

**c9) Authentication**

There has to be some kind of authentication procedure, which can identify the right user and protect the system from being used by any intruder.

## 3. Functional Requirements of Healthcare Aide

### 3.1 Requirements from the resident doctor/doctor's point of view

1) There is a pre-specified form so that the resident doctor can easily keep all the necessary information about the patient.
2) The doctor can take any additional notes on a patient if he/she wants.
3) A doctor can easily send all the information (or some selected information) to as many people as he/she wishes.
4) Except for the designated authenticated doctors, no one can access the database containing patient data.
5) During transfer of the patients' information, it is compulsory to communicate wirelessly in such a way that any intruder will not be able to get the information (e.g. encrypt the file).
6) Normally the doctor writes down the information on paper. The doctor may enter that data in the database later. This two step system should be merged in such an efficient way that if the doctor writes to his/her device (similar to writing on paper), it would automatically be saved in the database.
7) There should be a way to save all the sign-out transactions over the past one year or more in a stable storage device like a desktop or other server. This information can be used for future patient care needs, for research or billing purposes, or medico-legal reasons.
8) A doctor may want to chat with other doctors.

### 3.2 Requirements from the medical student's point of view

9) Medical students will be able to download files from the instructor/doctor, provided the instructor/doctor agrees to share each file. The file might be of any type (docs, images, pdf, voice files, video files, etc.).
10) They will able to share interesting rare cases with other students in the medical center.
11) Communicate with other students about any change in their lecture schedule, by broadcasting a message to all the students scattered throughout the hospital.

Nurses can have some of the similar functionalities of doctors described in section 3.1

## 4. Development of Healthcare Aide using MARKS

'Healthcare Aide' encapsulates all of the characteristics mentioned in section 2. Some of the characteristics are supported by 'Healthcare Aide' itself, whereas the rest are provided by the core services of middleware MARKS [2].

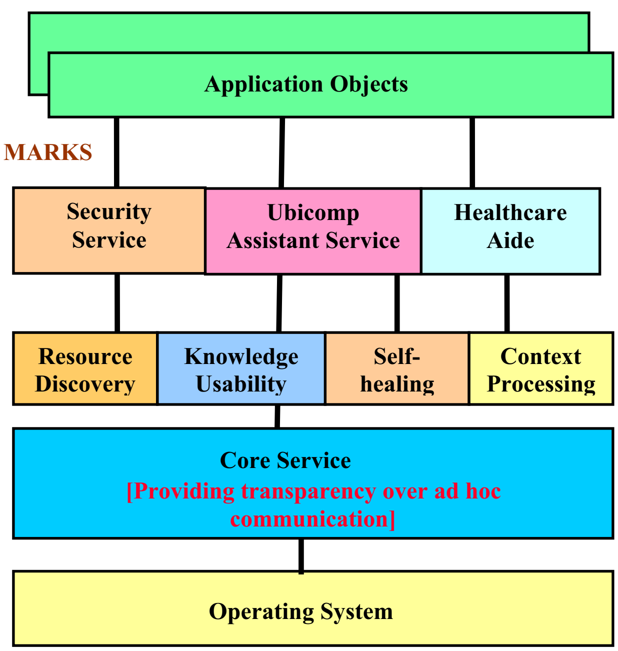


**Figure 1. MARKS architecture [2]**

‘Healthcare Aide’ incorporates the characteristic ‘privacy aware seamless service capability’ (c1). Provided that the wireless connectivity is available, it places itself in an ‘all-time ready’ service state that is available to serve whenever the user wants.

The core services of our middleware (MARKS) support the characteristics ‘continuous connectivity’ (c2), ‘concurrent applications’ (c6) and ‘secure service discovery’ (c7). In accordance with (c6) someone can give the command for transferring a file while he/she is chatting. A special ‘key’ feature has been introduced to achieve ‘secure service discovery’ (c7). When a PDA will try to discover its neighbors, it will broadcast a special packet, and this will be recognized and responded to only by those trusted devices that have that predefined ‘key’.

In section 5.3 we provided a detailed graphical representation in order to prove that this tool is really ‘energy efficient’ (c3) and complies with the ‘zero negative impact’ (c4). In order to comply with the memory storage constraints of PDAs, ‘Healthcare Aide’ captures only a small portion of memory. This fact – ‘tiny memory footprint’ (c5) is illustrated in the following table:

**Table 1. Code size of Healthcare Aide**

| | Lines of code | Executable file size (KB) |
|---|---|---|
| Healthcare Aide | 2111 | 29 |

Our tool doesn’t use any costly and comparatively heavy fixed infrastructure, and rewards itself with cost minimization (c6). Since several devices can join and leave arbitrarily at any time, an ad-hoc wireless infrastructure is very crucial and is conveniently supported by MARKS.

When we transfer a file containing secure and sophisticated information, that file is transferred in encrypted form. At the destination end, receivers only with the decryption mechanism can read the file. Again MARKS has a vital role in merging this characteristic (c8).

At present we are providing a heavily used password based authentication system to ensure this characteristic (c9). But we hope to give more time and effort in the future to this field, which is discussed in section 6.

## 5. Evaluation

### 5.1 Prototype implementation

We have designed and implemented the prototype of Healthcare Aide. We have used WINCE as the operating system, a Dell Axim X50v as PDA hardware platform (processor type is Intel PXA270, speed is 624 MHz, display is 3.5" Transflective TFT color, and weight is 4.8 oz), VC#.Net Compact Framework as programming language, mobile ad-hoc mode of IEEE 802.11b as underlying wireless protocol, and SQLCE for database support. The screen shots of the prototype are shown in figure 2.

### 5.2 Cognitive walkthrough strategy

To get the proper assessment of our application, we have followed the cognitive walkthrough strategy [24], which encompasses one or a group of evaluators to inspect a user interface by going through a set of tasks to evaluate its understandability and learning curves. We have used the following characteristics of cognitive walkthrough strategy (shown in Table 2) for Healthcare Aide:

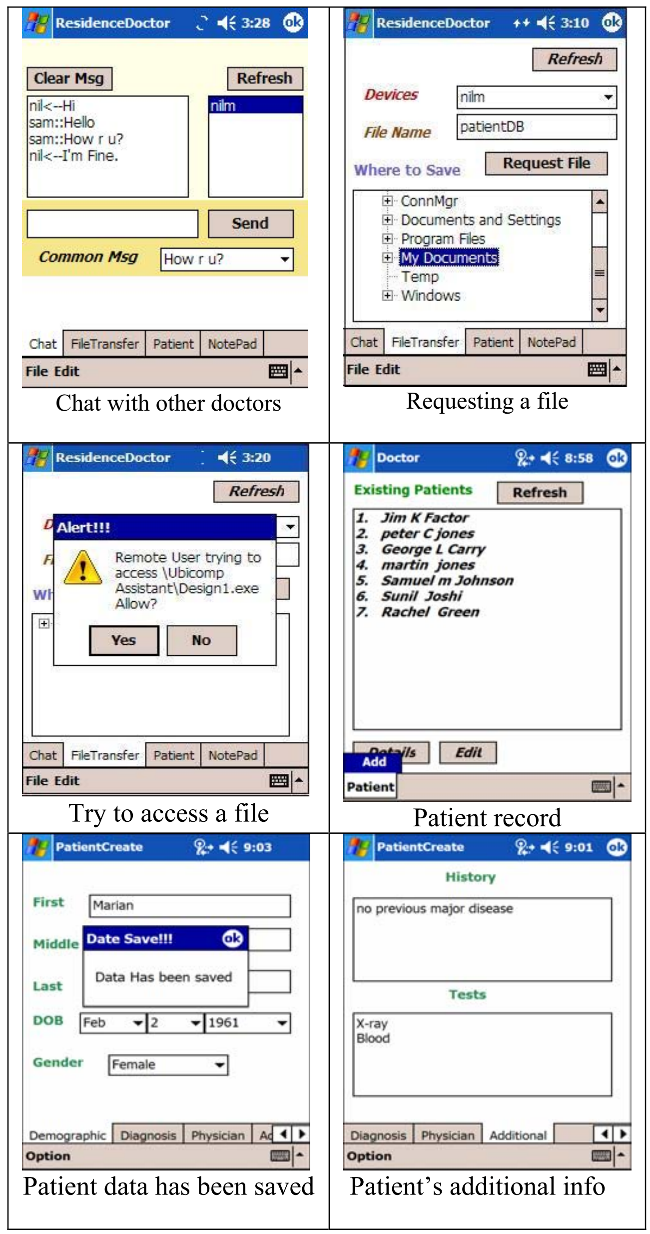


**Figure 2. Some screenshots of Healthcare Aide application**

**Table 2. Characteristics of cognitive walkthrough strategy**

<table>
<tr><td colspan="2">Applicable stages: design, test, and deployment</td></tr>
<tr><td>Personnel needed for the evaluation<br>Users: Some resident doctors and medical professionals</td><td>Usability issues covered<br>Effectiveness: YES<br>Efficiency: YES<br>Satisfaction: YES</td></tr>
<tr><td>Can be conducted remotely: NO</td><td>Can obtain quantitative data: YES</td></tr>
</table>

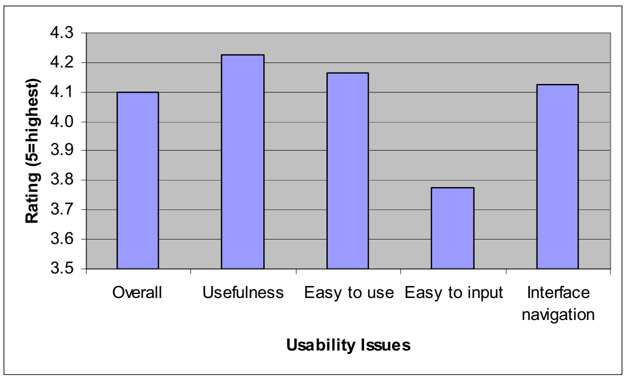


**Figure 3. Rating of Healthcare Aide by users as a whole**

*Input Definition:*

*Who will be the users of the system?* We selected several resident doctors and medical professionals to get the first hand feedback about this application.

*What tasks will be analyzed?* All the major tasks like maintaining a patient database, updating or deleting any patient information if needed, file transfer among doctors, chatting among doctors or patients, etc. have been analyzed.

*What is the correct action sequence for each task?* First of all, we have briefly explained to each user about the sequence of tasks and what they should finally get. Also, we recommended them to use the "HELP" section when necessary.

We have followed the cognitive walkthrough strategy on our first prototype of Healthcare Aide. We collected the feedback from the users (doctors, patients, and medical professions) by giving a questionnaire. Modifications were made based on their responses, and we have implemented a second prototype. Healthcare Aide has also been rated from the users' perspective. Figure 3 shows the users' overall rating. It also shows usefulness, simplicity of use, and ease with which to input data as well as navigate from one screen to another.

### 5.3 Performance measurement

Power consumption is one of the most important performance metrics of pervasive computing applications and services, and Healthcare Aide seems to be very power-conservative. It consumes the minimal amount of battery power possible. Figure 4 establishes this as a true statement. Here we have shown two cases for each PDA: the idle case (when the PDA is ON but not doing anything) and the active case (when the application is running on the PDA).

## 6. Conclusions

In this paper we have presented the details of our application 'Healthcare Aide'. It has been designed to facilitate doctor-doctor, resident doctor-doctor, patient-doctor and nurse-doctor communication for real-time decision making and provide a convenient environment for better healthcare. In our first prototype of 'Healthcare Aide,' we have tried to address some frequently occurring situations between patients and physicians that are of immense importance. This tool has been designed to create a healthier environment in the hospital through the creation of a secure passage for two-way interactions and flow of information. At the same time, this tool has proved the effectiveness and utility of our developed middleware MARKS. Our future work includes addition of note taking, inclusion of voice command, and extension of security features, bridging the existing fixed infrastructure and wireless approach, and additional functions for nurses.

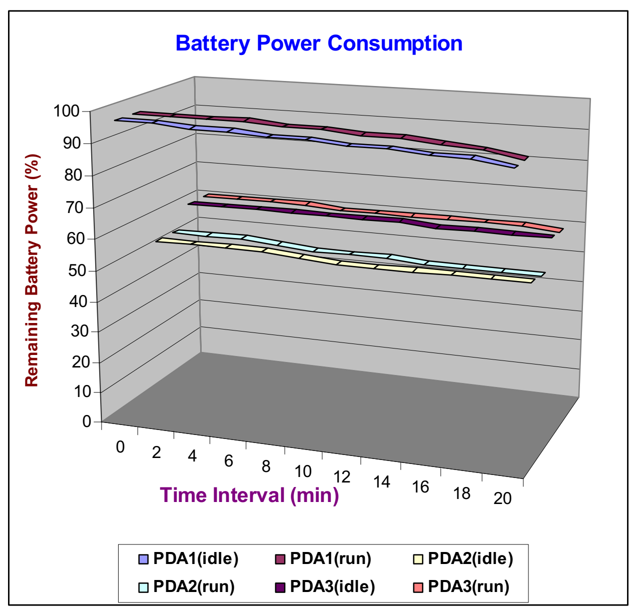


**Figure 4. Power consumption by all PDAs before and after running the Healthcare Aide**

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