ABSTRACT
The number of people over age 65 will almost double by 2030 and as they age, they generally prefer to remain in their home or go to a nursing home. There are a variety of reasons for their decision, such as convenience or a need for security or privacy. So, it is time to break through the physical boundaries of hospitals, and bring the hospital information to the homes of the elderly rather than bringing elderly folks to the hospital. Despite growing requests by people to be able to take a more active part in managing their own health, wireless or internet-based healthcare devices have not been accepted for use in this area. This is probably due to the reluctance of this age group to make use of new technology, as well as the lack of reliable, individualized, or user friendly interfaces. In this paper, we discuss the challenges of developing Wellness Assistant (WA), software which is looking to solve some of these problems. The Assistant will use pervasive computing technologies because of the availability of inexpensive handheld devices such as PDAs, cell phones, and wrist watches with short range wireless capabilities. The WA can also be used by people with obesity, diabetes, or high blood pressure, conditions which need constant monitoring.

Keywords
Pervasive health care, Wellness Assistant, mote, TinyOS, MARKS.

1. INTRODUCTION
Pervasive computing is the concept that incorporates computation in our working and living environment in such a way so that the interaction between human and computers becomes extremely natural and the user can get multiple types of data in a totally transparent manner[1]. The potential for pervasive computing is evident in almost every aspect of our lives including the hospital, emergency and critical situations, industry, education, or the hostile battlefield. The use of this technology in the field of health and wellness has been termed pervasive health care. The goal of pervasive health care is to provide health care services to anyone at anytime, overcoming the constraints of place, time and character. Pervasive health care takes steps to design, develop, and evaluate computer technologies that help citizens participate more closely in their own healthcare, particularly seniors over age 65 whose numbers are expected to hit 70 million by 2030, almost doubling from 35 million in 2000, in the United States alone. In many situations people have medical issues which are known to them but are unwilling or unable to reliably go to a physician. Obesity, high blood pressure, irregular heartbeat, or diabetes are examples of such common health problems. In these cases, people are usually advised to periodically visit their doctors for routine medical check ups. But if we can provide them with a smarter and more personalized means through which they can get medical feedback, it will save their valuable time, satisfy their desire for personal control over their own health, and lower the cost of long term medical care.

Several health care projects are in full swing in different universities and institutions, with the objective of providing more and more assistance to the elderly. CAST (Center for Aging Services Technologies) [16] is organizing multiple projects including: 1. A safe home that will help debilitated elderly by tracking their activities. 2. A sensor-based bed to track the sleep and weight, which will later be used in detecting diseases. In The Center for Future Health [14], a five-room house has been implanted with several infrared sensors, monitoring devices and biosensors. The ultimate goal of the project is to provide a unified solution for the seniors in the home, enabling them to closely participate in disease detection and health management by themselves. A similar type of project named ‘AHRI’ (Aware Home Research Initiative) [15] is going on at GeorgiaTech University. MobiHealth project [23, 24, 25] is going on to build a system for collecting vital body signals and manipulating those in distant health care institutes. Citizen Health System (CHS) [26, 27, 28, 29] is aimed to develop a call center to give real time support to patients at home. Several other projects like TERVA, IST VIVAGO®, WWM (Wireless Wellness Monitor) [9, 10, 11, 12] have been described in the related work section.

We are implementing a smart software system called WA, which will integrate sensing, communication, and event/information management. The research challenges include: to understand, analyze, structure and control the complex interactions, computing, communication and sensing along the dimensions of robustness, reliability, quality of service, device co-existence, interoperability, security, trust and privacy. Several sensors will be needed to collect data from several aspects of the body. These sensor devices will pass the data to a mote running TinyOS which is a small wearable device. The combination of all these sensors will form a body network. This information is then passed and displayed to a hand held device such as PDA or cell phone. The patient or a caretaker can make a decision based on the display...
data. The WA will also include the capability to send this information to medical personnel for evaluation. In this paper, we present the overview of WA, its design and architecture, and the implementation of the scheduler part of WA.

The outline of this paper is as follows: We provide the characteristics of WA in Section 2. Functionalities are described in Section 3 followed by our design in Section 4. Current state of the art is presented in Section 5. Section 6 presents an illustrative example of our model. How to use WA is depicted in Section 7. The evaluation of our proposed WA is presented in Section 8. Our future research direction and concluding remarks are in Section 9.

2. CHARACTERISTICS OF WELLNESS ASSISTANT

c1. Security, Reliability and energy efficiency:
This is the most discussed and prioritized topic in sensor networks and has gotten even more import with the entrance of biosensors in pervasive health care. While looking for a medical suggestion based on the data collected by biosensors, an obvious question that arises is how reliable is the data. Due to the memory constraints the use of data backups is not feasible. The secure communication of data from mote to a base station (which is actually a PC or from mote directly to PDA) is one of the most important required criteria. But the techniques like encryption that can implement the well-known Hopper-Blum [17,18] algorithm the mote as the RFID and the PDA as the RFID reader. Now we consider that the mote is misguided to collect information from an unauthenticated sensor, a judgment based on the false data can instruct the patient incorrectly, thus placing the patient in danger. We can think of the sensors as RFID tags and the mote as the RFID reader. At the next level of hierarchy, we can think of the mote as the RFID and the PDA as the RFID reader. Now we can implement the well-known Hopper-Blum [17,18] algorithm that can be utilized efficiently for RFID tag identification to the RFID reader while restricting passive intruders as described in [19].

c2. Authentication
Authentication can play a vital role in the long discussed security and reliability features. Though the issue of authentication of biosensors is very crucial, it has not been discussed with proper priority. Security and reliability of the data provided by the biosensors are highly dependant on the authentication mechanism of the biosensors. If the mote is misguided to collect information from an unauthenticated sensor, a judgment based on the false data can instruct the patient incorrectly, thus placing the patient in danger. We can think of the sensors as RFID tags and the mote as the RFID reader. At the next level of hierarchy, we can think of the mote as the RFID and the PDA as the RFID reader. Now we can implement the well-known Hopper-Blum [17,18] algorithm that can be utilized efficiently for RFID tag identification to the RFID reader while restricting passive intruders as described in [19].

c3. Role based information representation:
WA should have the capability to represent the collected data about the person in different ways based on the identity of the role. When representing information to the patient based on the collected data, it should focus mainly on suggestions for what to do rather than depicting the pros and cons of the situation. But when WA represents the data to the doctor, it should show everything in detail, to ease the decision making process for the medical personnel.

c4. Problem based information representation:
WA should be able to distinguish among various levels of importance of the data based on the criticality of the problem. For example, if it is collecting data for a person who has been suffering from obesity and irregular heartbeat problems four times a day, it may represent all this information to that person. But when this information is sent to a doctor he actually doesn’t need to observe the weight four times a day; however, he certainly needs to observe all detailed information about the heartbeat. Depending on the priority of the problem, WA has to decide which information can be discarded before sending it to the doctor.

c5. Meaningful information representation:
The representation style of the collected data is very important. The representation should be visually packed with meaning. It has to enable the users to overcome their problems. The collected data has to be refined and depicted to the user in such a manner that motivates and encourages the user to lead a healthier lifestyle rather than seeing merely numbers or tables. In research [13] it has been shown that people are not benefiting properly from medical data, not due to lack of information but instead due to lack of personalized feedback of information.

c6. User friendly interface:
Many aging people have never used PDAs, let alone mote, sensors etc. Many of them have reluctance to try something new. Some hold the false notion that they will not be able to use the advanced devices. As a result, in order to make this application a fruitful one, a PDA with WA must be made simple in every sense. Representations of the data, suggestions, and all the user interfaces have to be extremely simple, self explanatory and easy to use.

c7. Minimal interaction:
While collecting or representing the data, the interaction with the user has to be minimal. This way, the user will not be bothered with the foreign computing aspects.

c8. Ceaseless connectivity:
The entire system must provide ceaseless connectivity between the hand held device of the user and the wearable device responsible for collecting data.

c9. Non-negative impact:
Running of the application WA should not have any type of negative impact on the performance of other currently running applications. An unnoticed operation style would be optimal for minimal user impact.

c10. Miniature memory footprint:
Considering the memory storage restriction of handheld devices, any application running on a PDA has to be in miniature form. A minimal interface and a minimal memory usage will keep the application quick enough for a wide variety of resource-restricted devices.

3. FUNCTIONALITIES OF WA

1) WA has to be adaptable to multiple situations requiring periodic monitoring like diabetes, obesity, irregular heartbeat, hypertension (and anything that can be considered for a periodic check-up) etc. with equal efficiency. If someone suffers from one
supported condition but no others, there has to be some mechanism through which the unused part of the sensing network can be disabled. For example, if an overweight person suffering from hypertension uses this application, it has to be able to switch off the sensing portion that is responsible for collecting data for other features. This will reduce the pressure on the mote – which is the initial storage of data and at the same time it assists with overcoming the memory constraint in PDAs. At the same time we have to ensure that if the application is used simultaneously for all the available features, the overall performance will not deteriorate.

2) **WA** has to provide several scheduled reports. This scheduling will vary depending on the problem. It may have to generate daily or weekly reports showing some vital statistics of the specific problem. At the same time, it has to generate analyzed reports with graphical representations for the physicians. Also, if a specific criterion crosses the programmed threshold, an instant emergency report will be generated as notification of the situation.

3) All of the above mentioned problems have intimate relationship with eating habits. The idea of providing a personalized nutrition chart based on the present condition of health problems and the condition of the person would be really attractive. For example, a person with diabetes has to consume a specific amount of calories each day while avoiding particular foods that may be injurious to his/her health. This feature, including periodic updates on a regular basis, can be provided by WA.

4) One common observation about elderly people is they too often forget things that might be of crucial importance. For example he/she can forget to take medicine. Our application will notify the user through a voice message, while at the same time a pop-up window will show a corresponding message.

5) While transferring the patient’s 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) The base station will store all the information and send the summary at the request of the medical personnel. Doctors can request specific data. Except for the designated authenticated doctor, no one can access the database of the base station for a patient’s information. Before accessing the information, the device of the doctor has to authenticate itself to the system. Note that no multi-user database of authentications needs to be kept, since the units run in a distributed manner.

4. OUR APPROACH

Figure1 gives a schematic diagram of our approach. First the sensors will prove their authentication to the mote through LPN (Learning parity with noise) authentication. A miniature version of MARKS (Middleware Adaptability for Resource Discovery, Knowledge Usability and Self-healing) named µ-MARKS will be running in the mote which will conduct the timely data collection and sending procedures. We have already developed our middleware MARKS that provides some of the required core services. **LPN authenticator** is responsible for the authentication mechanism of the sensors to the mote. **Threshold value comparator** generates a special data packet – ‘threshold data packet’ if the collected data value crosses the pre-specified threshold value.

![Figure 1. Overview of Wellness Assistant.](image)

A schematic diagram of µ-MARKS has been depicted in the following figure:

![Figure 2. µ-MARKS Architecture.](image)

All the data packets are sent to the PDA and base station through **Data sender**. Collection of several types of data is handled by...
**Data collector. Data collection** scheduler passes the appropriate timing information for the collection of several types of data.

From the mote, collected data will be sent to the base station (a laptop or PC) and PDA of the patient. The version of Wellness Assistant running on the PDA (WAPDA) will deal with the representation of the received data and suggestion about medication. The details of WAPDA are as follows: The **Data receiver** is responsible for receiving data from the mote and the base station. The **Report generator** will provide several types of reports based on the problem of the patient and data. **Visual representor** deals with visual representation of the data like charts, curves etc. **Context processor** is burdened with the manipulation and processing of the received data in order to adhere to the characteristics of ‘role based information representation’, ‘problem based information representation’, and ‘meaningful information representation’. The **Visual representor** component also plays an important role in adhering ‘meaningful information representation’. A personalized nutrition chart is generated by **Nutrition chart generator** with the help of the database stored in the base station. It also provides information about physical exercise, calorie content of different foods, etc. **Alarm generator** generates an instant voice warning along with a pop-up menu containing some relevant message about the warning. This component comes into play during times when medication is needed or when the PDA receives a ‘threshold data packet’. **Query sender** is used to send a query to the base station from the PDA.

The version of WA running in base station (WABS) will mainly handle a large database which will store all the collected information for a longer period of time. WABS will also take the responsibility for periodically sending a summary report to the medical personnel. Both medical personnel and the patient can place specific queries to the base station for data. As the information representation will be based on the role of the user, the first step is to choose a role. **LPN authenticator** will be responsible for all types of authentication mechanism and serve the required characteristics of authentication mentioned in section 2-c2. ‘Ceaseless connectivity’ will be provided by MARKS as one of its core services.

### 5. RELATED WORK

The ‘Terva’ [11] monitoring system had been introduced to collect data related to health condition like blood pressure, temperature, sleep conditions, weight, etc., over quite a long time. Here data has been collected four times a day -- morning, noon, evening and night -- and saved in the form a TOD (time-of-day) matrix and analyzed later. The whole system has been housed in a suitcase that includes a laptop, blood pressure monitor and several other monitoring devices. As a result, this system loses its mobility and becomes feasible to be used in a static manner in the home. A remote activity monitor and social alarm generator has been combined in IST VIVAGO® [9] system. The system is comprised of a wearable wrist unit, a base station and a specially developed software named ‘Vista’ which is actually responsible for managing the alarms and accessing data remotely. The wrist unit can be used to generate an alarm both manually and automatically in times of danger. The alarms will be sent to the base station which incorporates several protocols to forward the alarm to several predefined recipients. A feedback-based self monitoring system for managing obesity named ‘Wireless Wellness Monitor’ [10,12] has been devised using Bluetooth and Jini network technology that supports Java dynamic networking. The system consists of measuring devices, a home server as the base station, mobile terminals (e.g., PDA or smart phone) and databases which are connected through the internet. The measuring devices collect data and place that in the home server. Mobile terminals can access information wirelessly from the home server or can collect data from the external databases through the home server. Our focus is on building a wellness assistant using the existing technologies addressing the challenges mentioned in Section 2 and makes it affordable to users.

MobiHealth project [23, 24, 25] can monitor crucial health signals through tiny medical sensors and transmit them to health care professionals through highly powerful and cheaply available wireless system. Body Area Network (BAN) has been used in signal monitoring and GPRS and UMTS have been used for transmitting signal on the fly. The project Citizen Health System (CHS) [26, 27, 28, 29] has been undertaken with the goal of developing a generic contact center that can provide better health care services to home bound patients. Generic contact center has been developed in modular fashion. **WAP** has been used for providing wireless communication. In [30] researchers have depicted several required characteristics of wearable health care system along with the design, implementation and communication issues of a plug-and-play system but it is not affordable and needs special hardware.

### 6. AN ILLUSTRATIVE EXAMPLE

Mr. Ahmed lives at his own home alone at the age of 51. He is suffering from diabetes, high blood pressure and obesity. He is scheduled to take some medicines three times a day and others twice a day. He is a new user of WA. He chooses his role as normal user/patient. Then he chooses the problems for which he wants to get information such as diabetes, high blood pressure, and obesity. As part of initialization, µ-MARKS uses the ‘LPN authenticator’ to authenticate the sensors attached to the body of Mr. Ahmed. ‘Data collection scheduler’ schedules the number of times it has to collect data along with specific time for collection. Let us assume that the ‘Data collector’ has collected the following data as per schedule for a specific day.

Based on the above data Mr. Ahmed gets a report containing graphs and curves. Using a voice message, WA also reminds him to take medication on time. In addition, WA generates an instant alarm at 4:15 pm mentioning that “The blood pressure is extremely high” as it finds that the blood pressure at this moment (165/85) has crossed a specified threshold for upper limit. Based on this warning, Mr. Ahmed changes his plan for going out and instead rests. At night Mr. Ahmed receives a personalized nutrition chart upon request. Mr. Ahmed is highly motivated now and very mindful of taking medicine due to regular reminders and feedback of personal information.

### 7. EVALUATION

To evaluate the effectiveness of our WA we have used: prototype implementation and cognitive walkthrough.

#### 7.1 Prototype implementation

We are using Dell Axim X50v PDAs, VC++ .NET Compact framework, 802.11b, MIB 510 as gateway, MPR400 CB MICA2 as sensor board and bio sensors for the implementation.

1. Main Screen
2. Setting time for an event
3. Choose recurrence type
4. Detailed recurrence intervals
5. A new event to save
6. Viewing the listing

Figure 3: Some screenshots of the implemented prototype.

In order to provide the core services like ceaseless connectivity, context processing a middleware named MARKS [21] has been developed. A prototype application, particularly the scheduler part (shown in Figure 3) has been developed which illustrates the reminder and data display features of the Wellness Assistant before full network functionality is available. This application exhibits the required abilities to alert the user to time-sensitive events.

7.2 Cognitive Walkthrough

We have adopted the cognitive walkthrough strategy to collect valuable feedback and measure the performance of the scheduler part of the WA the application. In cognitive walkthrough strategy we have interviewed several people based on a questionnaire. Figure 4 shows overall usability of the scheduler part of the WA the application.

Figure 4: Rating of usability issues by users

8. DISCUSSIONS AND FUTURE WORK

In this paper, we describe the details of a smart software system WA which will integrate sensing, communication, and event/information management for healthcare. We have implemented the scheduler part of the WA. Now, we are working on other research challenges which include: understand, analyze, structure and control the complex interactions, computing, and communication and sensing along the dimensions of robustness, reliability, quality of service, device co-existence, interoperability, security, trust and privacy. We are building the prototype using sensors, motes, TinyOS, PDAs and short range wireless network. We are also currently implementing the WA as a dynamic, customizable application that will able to incorporate any new category of disease for measuring purposes. The whole system of pervasive health care using sensor network places forward some future works such as finding the most effective mechanism for ensuring security in biosensors considering the severe restrictions of memory and energy, representing the collected data in the most informative manner with minimal storage and user interaction, modeling of data so that the system will not represent all the data but only relevant information thus saving memory.

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10. REFERENCES


http://www.cc.gatech.edu/fce/ahri/