A Scheme for On-Site Service Provision in Pervasive Assistive Environments

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ABSTRACT
Remote healthcare monitoring and on demand provision of support attracts a lot of interest due to the ability to provide assistance to elderly and patients when needed; thus on one side the hospitals demand less personnel to be engaged in monitoring patients, whereas on the other side the patient does not need to remain hospitalized unless there is need to. Wireless and wearable devices enable the constant monitoring of vital parameters; with the aid of appropriate infrastructures they can be sent to the hospital and when it is needed help can be sent at home. As the number of remotely monitored patients grows, there is a need for efficient management of emergency messages originating from portable and wearable devices as well as a demand for an efficient management scheme for mobile units, which provide help at home or transfer patients to the hospital. We present an architecture that enables provision of help at home with wearable devices and wireless transmission methods. Our approach also focuses on providing help at home in an efficient manner minimizing the service time while maintaining high availability for the high priority calls. We present an algorithm that enables the management of prioritized messages and manages the mobile units providing assistance at home in an efficient manner.

Categories and Subject Descriptors
H.3. [**Information Storage and Retrieval**]: Systems and Software. H.4. [**Information Systems Applications:** Communications Applications.

General Terms
Design, Reliability, Security, Human Factors.

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Keywords
Medical Information Systems. remote healthcare monitoring, assistance at home, mobile k-server problem

1. INTRODUCTION
Lately there is a paradigm shift towards the provision of advanced health monitoring techniques. Several factors have contributed towards this direction. Among them, the advances in technology that make wireless devices more efficient and powerful, along with the fact that the elderly population is increasing constantly.

Therefore, along with the advancements in ubiquitous technologies there is a need for utilization of advanced technological means to provide efficient healthcare services that demand less intervention from personnel while on the contrary they are mostly based on the use of monitoring devices.

Remote monitoring enables the provision of support for a patient when necessary, while it disengages medical personnel from being constantly on one spot; it also allows the patient or the elderly to reside at home and ask for medical advice or transfer to hospital when necessary. Using IP or 3G network and a wearable device it is possible to record continuously a number of physical parameters and monitor the patient's condition. In case they exceed some certain threshold which shows potential danger for the patient an alert may be sent to the hospital to notify the doctor [13]; a notification may be sent upon the patient's request by pressing a specific button in a portable device (e..g., GSM phone). These messages can be further classified on the basis of their urgency to be served. When the patient keeps pressing a specific button, for example, he/she demands immediate help from the hospital in cases when he/she is not feeling well; by pressing other buttons the patient may ask for on-site help or just for advice [13].

There is a need to provide help at home in response of appropriate requests. There is also a demand for an efficient management scheme that handles appropriate mobile service providing units (MSUs), e.g., ambulances, so as to serve the high priority demands first, having in mind both the minimization of time to serve all the requests and taking care so as to be ready to serve another high rated request at low times.

participating users. However, there is not care for immediate provision of support in case of an emergency.

In [14] the authors describe a prototype that uses wearable devices to record several body parameters such as glucose for patients with diabetes. The transmission is made using mobile phones and the Zigbee protocol. The users have to log on to a web service in order to send the data. a user could easily record various physiological parameters at home and transfer the data to themedical gateway through his or her home gateway in order to establish a personal health file. Beyond collecting uploaded public health data from public gateways and home gateways, the medical gateway also provided a portal site allowing users to both access various community medical and communicatewith their family doctors. Still no emergency monitoring services are provided in case when the monitored values exceed certain thresholds.

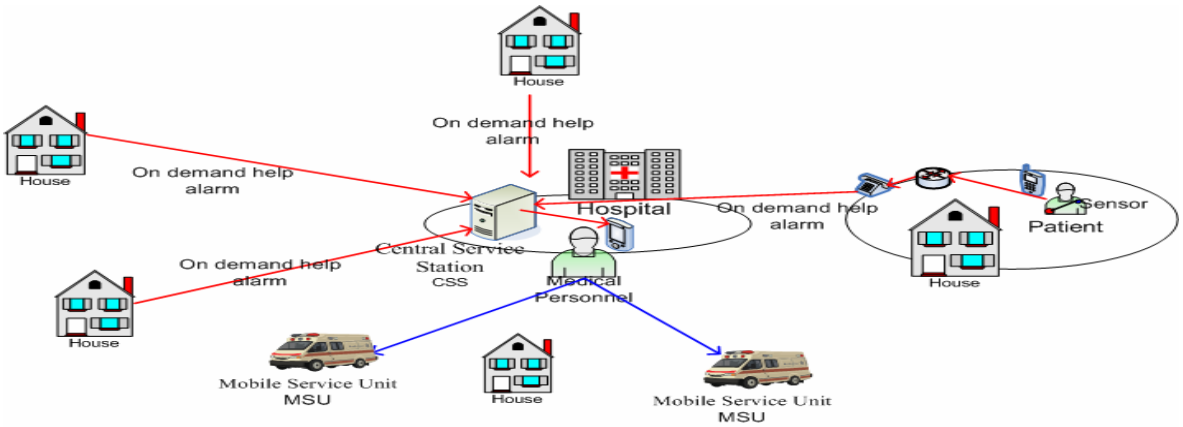

Figure 1: Overall system architecture

2. RELATED WORK

There has been a long of ongoing research in the relevant literature lately with respect to the adoption of different wireless technologies supporting the provision of remote healthcare services. Several international projects lately focus on the advances in remote health care [3][4][5][6].

The advanced care and alert portable telemedical monitor (AMON) project [6] focuses on the development of wearable devices that monitor vital function parameters of patients with chronic cardiac and respiratory illnesses. It focuses on the acquisition of several patient indications which are sent to authorized medical personnel. Transmission of medical data is enabled using GPRS technologies. The MobiCare [7] project is a system for both in-house and open areas patient monitoring that allows remote monitoring of patients vital parameters using wearable devices and transmits the data using GPRS technology. In [5] a campus wide Mobile Information Management System is described that allows incident reporting and retrieval of medical information in a university campus, using a wireless LAN that spans the campus area.

Various mobile communication network technologies such as Bluetooth [17], mobile phones (GSM) [18], wireless application protocol (WAP) [16], wireless local area network (WLAN) [15], have been utilized for this purpose. Other approaches propose a hybrid approach that uses both wired and wireless infrastructures, while uses wearable devices in order to record a patient's physical parameters [12][13].

In [12] a prototype that uses wearable devices that measure levels of glucose and other blood parameters is described. In order to transmit the data several access points have been set up in a wide area, which collect and transmit the data so as to monitor the patient's condition continuously. Initial testing and an evaluation questionnaire have showed an adequate acceptance from the

3. A HEURISTIC FOR ON SITE SERVICE PROVISION

We assume an assistive system with the following components:

- a Central Service Station (CSS),
- a set of Mobile Service providing Units (MSUs), which are located in appropriate service stations (e.g. hospitals) and
- a set of patients, elderly or disabled people connected to the system which may need health related services at home.

People provide to the system requests for services. These requests are gathered to the Central Service Station, where each request is evaluated and it is decided whether it needs to be served by sending an MSU at the patient/elderly's home.

The requests that require service by an MSU may be of two types: *high priority requests* that should be immediately served and *low priority requests* that may wait before they are served. In both cases we consider that MSUs are sent from their stations (hospitals or other service stations) to the patients/elderly sites, they offer on-site care and return back to their stations. Note that in the case that the MSUs are ambulances sent from hospitals, they may return back to the hospitals together with the patients if they actually need hospital care. Given a specific number of MSUs and their locations as well as the locations of the patients we seek for an on-line algorithm which for a sequence of requests constructs a service schedule so that the total waiting time of all requests is minimized. Note that the algorithm needs to handle the requests as they are coming to the system and is not aware of the entire sequence of the requests that will come.

Our problem is formulated as a mobile *k*-server problem, where the *k* MSUs correspond to the *k* mobile servers that travel on a network to serve a set of requests ([9],[10],[11]). We assume that we have an *n*-node network *N* with positive edge lengths d_{ij} (corresponding to the distance between node *i* and *j*) obeying the triangle inequality and the servers (MSUs) as well as the users' homes occupy nodes of *N*. More than one server may reside to a node of the network as each service station of the system may keep more than one MSUs. Given a sequence of requests r_i, $i=1,\dots,m$, where each r_i specifies a node (user) that requires service, as well as the priority of the request, the release time t_i and the service time st_i that r_i requires, the *k*-server problem is to decide which server to move in response to each request so that the total waiting time of all requests is minimized. Given a request from a user in the network, if there are available servers, the scheduler decides which server to send to the user's site to serve the request. If no server is available, the scheduler lets the request wait until one becomes available. When a server is moved to another location in the network, it provides on-site care and returns back to its location.

Our statement of the mobile *k*-server problem closely follows [11] with the following two exceptions. First, we assume that the requests have priorities. Second, we assume that at each node of the network corresponds to a service station where more than one server may reside.

The on-line version of the mobile *k*-server problem which decides which server to move to satisfy a given request without knowing what the future requests will be, is NP-complete [11]. The off-line version of the mobile *k*-server problem where the request sequence is known is related to a job scheduling problem where *m* jobs are to be scheduled on *k* different machines in such a way that the total completion time of all jobs is minimized [11]. Therefore, the off-line mobile *k*-server problem is solvable in polynomial time.

In the following we give a heuristic for our on-line version of the mobile k-server problem. We suppose that the algorithm is centralized and it runs on the Central Service Station where all requests for on-site help are gathered by the system, are evaluated and it is decided whether they need to be served by sending MSUs at users' homes or not. The requests that need to be served on-site or need an MSU to transfer a patient to the hospital, are classified either as high priority requests or as low priority ones.

High priority requests should be immediately served. Therefore, such requests are served in a first come first served basis by our heuristic algorithm as follows:

- When a high priority request r_i arrives, an MSU M_j is sent to r_i*'s* site from the service station that has available MSUs and minimizes the quantity d_{ij}/ v_j, where v_j is the speed of M_j. If no MSU is available, then the request is waiting for the first available MSU in the network.

The low priority requests are treated in a different way. Let t_i be the release time of a request r_i and st_i the service time that r_i requires either to be served on-site or for the transferring of a patient to the hospital. The service time st_i of a request r_i is computed by the Central Service Station based on the type of the request and the kind of help alarm that was received. Note that request r_i requires $st_i + 2d_{ij}/ v_j$ time to be completed from the time its service starts by server (MSU) M_j, where d_{ij} is the distance between the node of r_i and M_j and v_j is the speed of M_j, i.e., the request's completion time includes the time that M_j needs to travel from its station to r_i and back. Note also that the total completion time of all requests is minimized if and only if the total waiting time of all requests is minimized [11].

Our heuristic algorithm for scheduling low priority requests to MSUs is as follows:

- If a request r_i arrives and there are no other waiting requests then MSU M_j which minimizes $st_i + 2d_{ij}/ v_j$ is sent to serve r_i. If there is no available MSU then r_i is added to the list of the waiting requests.
- If a request r_i arrives and there are other waiting requests then r_i is added to the list of the waiting requests. If there are available MSUs, then from the cartesian product of the set of available MSUs and the set of waiting requests, the pair (M_j, r_k) is chosen which minimizes $st_k + 2d_{kj} / v_j$. M_j is sent to serve r_k and r_k is deleted from the waiting list. While there are no available MSUs, the requests remain in the waiting list.

The above algorithm suggests that only high priority requests are served in a first come first served basis, immediately after they are released by MSUs that can reach the sites of the requests earliest than others (given that there are available MSUs). Low priority requests are not necessarily served in a first come first served basis immediately after they are released but they may wait in the waiting list until other more appropriate according to our cost criterion requests are served. That is, shortest (smaller service time) requests may be given priority and be assigned to MSUs that can earliest reach them.

In the case of low priority requests, although the above server–to–request assignment criterion seems to perform well in practice, it is not easy to prove that there is a non-trivial upper bound for its behavior with respect to the behavior of the optimal off-line algorithm. In other words, we do not have upper bounds for the total waiting times of the service schedules constructed by the above heuristic with respect to the schedules provided by the optimal algorithm which knows before it decides its schedule the whole sequence of requests. In [11] only lower bounds are given for the behavior of their Shortest Request Closest Server heuristic with respect to the optimal algorithm.

Our scheme may be easily modified so that a small number of MSUs of the system are not assigned to low priority requests but are kept only for high priority requests. For example, it could be proposed that for large service stations that occupy a large number of MSUs one of these MSUs should be always available for the emergency cases that a high priority request needs immediate service.

4. CONCLUSIONS

In this article we presented a scheme for constructing service schedules with small total waiting time for all requests for the on-line k-server problem in a pervasive assistive environment. People provide to the system requests for services which are gathered to a Central Service Station where they are classified as high priority requests that should be immediately served and low priority ones that may wait before they are served. In both cases we consider that mobile service units should move to the user's site. High priority requests are served in a first come first served basis, immediately after they are released, while in the case of low priority requests shortest (smaller service time) requests are given priority and they are assigned to mobile service units that can earliest reach them.

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