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Sensor grid applications in patient monitoring

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ABSTRACT

Wireless Sensor Networks (WSNs) are finding an important role in patient monitoring in diverse environments including hospitals for post-operative patients and nursing homes for elderly patients. Sensor networking devices in WSNs are resource constrained since they have limited processing power and communication bandwidth. However, with a large number of such devices being deployed and aggregated over a wide area, WSNs have substantial data acquisition and processing capability. Thus, WSNs are important distributed computing resources that can be shared by different groups of patients in different environments. The emerging domain of WSNs with the grid extends the grid computing paradigm to the sharing of sensor resources in WSNs. In this perspective, by their very demand requirements and their socioeconomic impact, medical applications are certainly the most pertinent domain for using a wireless sensor grid. In this paper, we propose a wireless sensor grid architecture for monitoring the health status of different groups of patients to provide a platform for physicians and researchers to share information with distributed database and computational resources to facilitate analysis, diagnosis, prognosis and drug delivery.

1. Introduction

A link between Wireless Sensor Networks (WSNs) and grid computing would be an exciting avenue to explore. By integrating the two systems, the WSN would collect large quantities of data which could be processed intensively and stored effectively within the grid system. The combination of the two systems, that is, the wireless sensor grid, would provide a powerful platform for a range of research studies, large-scale military operations, medical applications and commercial organizations [1]. The major obstacles are mainly down to the design goals of the grid when compared to sensor networks. Sensor networks are limited resource systems with limited power and bandwidth. A grid, on the other hand, has huge quantities of bandwidth and processing power; power saving is not a requirement of the system.

Our particular interest is in solving the core technological problems involved in extending the grid by exploring these challenges within the medical domain [2]. This paper proposes a technique for monitoring different groups of patients using a wireless sensor grid. The need to make grid facilities available "in the field" is particularly critical in the case of medical services where much of the day to day work of medicine centers on the patient requiring a number of medical professionals to correlate medical data with patient examination and observation.

The ultimate goal is to increase the availability of medical care in order both to reduce the demands on hospital services and to improve the long-term care and recovery of patients. This system also reduces the time of routine check-ups and its real-time monitoring also allows emergency situations to be handled immediately. The data are published via web servers. Healthcare professionals, researchers and patients can access the long-term physiological data via the Internet. A secure web server allows authenticated users to access real-time patient information to consult with medical specialists located at distant places.

2. Related works

A number of recent research efforts focus on wearable systems for health monitoring. Researchers at the MIT Media Lab have developed MIThril, a wearable computing platform compatible with both custom and off-the-shelf sensors. CodeBlue, a Harvard University research project, is also focused on developing WSNs for medical applications. The sensors, when outfitted on patients in hospitals or disaster environments, use ad hoc networks to transmit vital signs to healthcare givers, facilitating automatic vital sign collection and real-time triage [3].

Recently, research efforts are beginning to study the integration of WSNs and grid computing. Researchers in the UK are studying how sensors can be integrated into e-Science grid computing applications. The Discovery Net project is building a grid-based framework for developing and deploying knowledge discovery services to analyze data collected from distributed

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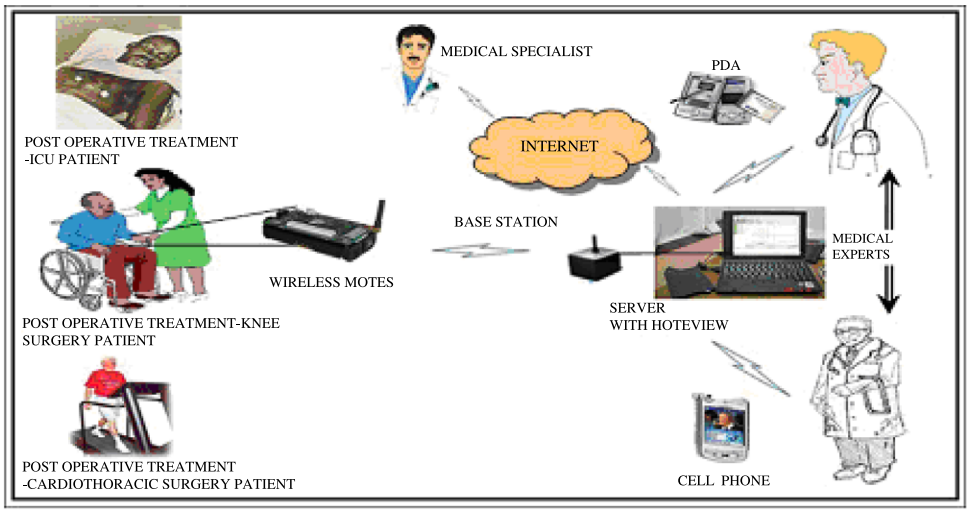

Fig. 1. Architecture for Monitoring Postoperative patients at hospital.

high-throughput sensors. The applications include life sciences, environmental monitoring, geo-hazard modeling and remote patient monitoring.

The current trend towards Telemedicine and Telecare evident in the UK [4] has seen an explosion in the range of locations where advanced medical care needs to be delivered. E-medicine initiatives such as NHS Direct have illustrated the need to maximize the flexibility of delivery of health care. Existing trials in Telemedicine and Telecare such as those carried out by the Oxford centre for e-health [4], the Biomedical Informatics group at Nottingham University [5] and the Glasgow Royal Infirmary and Glasgow University [6] have demonstrated the feasibility of remotely monitoring patients as part of an overall care programme or as part of a clinical trial. However, these efforts have tended to be small scale in nature and have typically required the development of bespoke sensors and purpose-built infrastructure for the logging of data for analysis.

3. Wireless sensor networks in patient monitoring

Recent advances in electronic circuit miniaturization and micro-electromechanical systems (MEMSs) have led to the creation of small wireless sensor nodes which integrate several kinds of sensor, a central processing unit (CPU), memory and a wireless transceiver. These nodes are capable of sensing and communicating one or more vital physiological signals from the patients and integrating them into wireless personal or body networks for health monitoring [7]. These networks promise to revolutionize healthcare by allowing inexpensive, non-invasive, continuous health monitoring of post-operative patients at hospital and elderly patients in home environments with almost real-time updates of medical records. Physiological sensors are attached in the human body to monitor disorders in the heart and brain during normal activities and to help patients maintain their health even after surgery. The integration of sensing and communication technologies has allowed monitoring of elderly patients in home environments and post-operative patients in hospitals for early detection of adverse conditions and diseases, definitely saving more lives [8].

3.1. Monitoring post-operative patients using wireless sensor networks

Patients recovering from surgery are at risk of complications due to reduced mobility as a result of post-operative pain. The ability to pervasively monitor the recovery of this group of patients and identify those at risk of developing complications is therefore clinically desirable; it may result in an early intervention to prevent adverse outcomes [9]. The limitations of current settings, such as limited patient mobility, have encouraged research on wireless medical monitoring solutions, realizing the vision of the wireless hospital. Such a WSN system for monitoring post-operative patients at hospital environment as shown in Fig. 1 consists of the following components. (i) A front end, composed of the different sensors for the recording of the vital signals that are demanded by the application (ECG, respiration and activity level). (ii) A patient station, which consists of a mote device that receives information from the sensors and is responsible for the first stage of data processing in the data communication [9]. The received signal is sent to a central server for analysis. (iii) A central server, which is the core processing element, receives the patient's data from the patient station for analysis. The analysis is done using moteView software and generates alerts to the medical professionals, caretakers and emergency medical department personnel.

3.2. Monitoring elderly patients using wireless sensor networks

Recently, many research groups have shown interest in applying body sensor networks for remote monitoring of elderly patients [10]. Today, elderly patient monitoring at home is performed via wired sensors that transmit vital signs of the patient to a bedside monitor. The limitations of current settings, such as limited patient mobility, have encouraged research on wireless medical monitoring solutions, realizing the vision of wireless homecare. A wireless system could be set up throughout the home to sense physiological parameters such as ECG, heart rate, body temperature, etc., motion patterns and visual detection of elderly patients [11]. However, a wireless home application could provide the freedom and ease of use necessary to make home health monitoring beneficial for continuous long-term monitoring as part of a diagnostic procedure for elderly patients. This system consists of the front end, patient station, and server. The overview of the system architecture for monitoring elderly patients in a home environment using WSNs is shown in Fig. 2.

The front end is composed of different types of sensor for monitoring continuous physiological parameters as well as motion pattern and visual monitoring of the elderly patients at home. We have used ECG sensors, heart rate sensors and temperature sensors for physiological monitoring, accelerometer sensors attached to the human arm to determine patients' movements and 3D cameras for visual monitoring of elderly patients [12]. The patient station is