A Survey on Wireless Body Sensor Networks for Health Care Monitoring

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Abstract: ***With recent advances in wireless sensor networks and embedded computing technologies, miniaturized pervasive health monitoring devices have become practically feasible. Due to advancement in technology a low-power networked systems and medical sensors are merged as wireless sensor networks (WSNs) in healthcare. These WSNs carry the promise of drastically improving and expanding the quality of care across a wide variety of settings and for different segments of the population. This paper explains the important role of body sensor networks in medicine to minimize the need for caregivers and help the chronically ill and elderly people live an independent life, besides providing people with quality care. The purpose of this paper is to provide a snapshot of current developments, survey on wireless body sensor networks and existing work done on body sensor based networks are discussed.***

Keywords: Distance, Energy consumption, Lifetime, Wireless body sensor networks, Health monitoring

1. Introduction

A wireless sensor network is a collection of nodes organized into a cooperative network. The nodes communicate wirelessly and often self-organize after being deployed in an ad hoc fashion. Currently, wireless sensor networks are beginning to be deployed at an accelerated pace. This new technology is exciting with unlimited potential for numerous application areas including environmental, medical, military, transportation, entertainment, crisis management, homeland defense, and smart spaces. In particular, their application to healthcare areas received much attention recently. The design and development of wearable biomedical sensor systems for health monitoring has drawn particular attention from both academia and industry. As an extension to the WSN a body area network (BAN), also referred to as a wireless body area network (WBAN) or a body sensor network (BSN), is a wireless network of wearable computing devices. The development of WBAN technology started around 1995 around the idea of using wireless personal area network (WPAN) technologies to implement communications on, near, and around the human body. The implanted sensors in the human body will collect various physiological changes in order to monitor the patient's health status no matter their location. The information will be transmitted wirelessly to an external processing unit. This device will instantly transmit all information in real time to the doctors throughout the world. If an emergency is detected, the physicians will immediately inform the patient through the computer system by sending appropriate messages or alarms. Currently the level of information provided and energy resources capable of powering the sensors are limiting factors. Hence this paper presents the current state in research and development of wireless sensor networks and related sensors for health monitoring.

2. Survey on Wireless Body Sensor Network

During the last few years there has been a significant increase in the number and variety of wearable health monitoring devices, ranging from simple pulse monitors, activity monitors, and portable Holter monitors, to sophisticated and expensive implantable sensors. Traditionally, personal medical monitoring systems, such as Holter monitors, have been used only to collect data. Data processing and analysis are performed offline, making such devices impractical for continual monitoring and early detection of medical disorders. Systems with multiple sensors for physical rehabilitation often feature unwieldy wires between the sensors and the monitoring system.

These wires may limit the patient's activity and level of comfort and thus negatively influence the measured results [1]. Finally, the existing systems are rarely made affordable. One of the most promising approaches in building wearable health monitoring systems utilizes emerging wireless body area networks [2].

A WBAN consists of multiple sensor nodes, each capable of sampling, processing, and communicating one or more vital signs (heart rate, blood pressure, oxygen saturation, activity) or environmental parameters (location, temperature, humidity, light). Typically, these sensors are placed strategically on the human body as tiny patches or hidden in users' clothes allowing ubiquitous health monitoring in their native environment for extended periods of time.

This section discusses about the existing research work on wireless body sensor network in detail.

In this paper [3] presented hardware and software architecture of a working wireless sensor network system for ambulatory health status monitoring. The system consists of multiple sensor nodes that monitor body motion and heart activity, a network coordinator, and a personal server running on a personal digital assistant or a personal computer.

Recent technological advances in sensors, low-power integrated circuits, and wireless communications have enabled the design of low cost, miniature, lightweight, and intelligent physiological sensor nodes. These nodes, capable of sensing, processing, and communicating one or more vital signs, can be seamlessly integrated into wireless personal or body networks (WPANs or WBANs) for health monitoring. These networks promise to revolutionize health care by allowing inexpensive, non-invasive, continuous, ambulatory health monitoring with almost real-time updates of medical records via the Internet. Though a number of ongoing research efforts are focusing on various technical, economic, and social issues, many technical hurdles still need to be resolved in order to have flexible, reliable, secure, and power-efficient WBANs suitable for medical applications. This paper [4] discusses implementation issues and describes the authors' prototype sensor network for health monitoring that utilizes off-the-shelf 802.15.4 compliant network nodes and custom-built motion and heart activity sensors. The paper presents system architecture and hardware and software organization, as well as the author's solutions for time synchronization, power management, and on-chip signal processing.

Ijaz et al in their paper [5] provides an overview of the impact of Wireless Sensor Network (WSN) on medical healthcare. Wireless Sensor Networks can be found in various healthcare applications. This paper focuses on the applications of WSN which provides all-time monitoring to the user and either avoids the dangerous situation or is capable to take appropriate actions in case of emergency. They highlighted the major challenges WSN faces when implemented in medical healthcare applications.

Movement between indoor and outdoor environments and physical movements constantly change the wireless channel characteristics. These dynamic application contexts can also have a dramatic impact on data and resource prioritization. Thus, BSNs must simultaneously deal with rapid changes to both top-down application requirements and bottom-up resource availability. This is made all the more challenging by the wearable nature of BSN devices, which necessitates a vanishing small size and, therefore, extremely limited hardware resources and power budget. Current research is being performed to develop new principles and techniques for adaptive operation in highly dynamic physical environments, using miniaturized, energy-constrained devices. This paper [6] describes a holistic cross-layer approach that addresses all aspects of the system, from low-level hardware design to higher level communication and data fusion algorithms, to top-level applications.

The purpose of the paper [7] is to provide an enhanced version of TBCD communication protocol (Time Based Coded Data) for implantable sensor networks in order to guarantee an ultra-low energy consumption in the very tiny battery of the biosensors, and hence increasing the network lifetime for longer periods of time

Hongliang Ren did his first attempt in his paper [8] to investigate the mobility model in WBSN based on the existing mobility models in wireless data networks and ad hoc networks. He first briefly reviewed the existing mobility models in related research areas such as wireless ad hoc network and cellular networks. Further, proposed a dedicated mobility model for wireless body sensor networks by concentrating on the unique characteristics of WBSN and finally study the effects of mobility on the performance of WBSN by simulation experiments

This paper [9] models the periodic characteristics of body sensor network (BSN) wireless channels measured using custom hardware in the 900-MHz and 2.4-GHz bands. The hardware logs received signal strength indication (RSSI) values of both bands simultaneously at a sample rate of 1.3 kS/s. Results from a measurement campaign of BSNs are shown and distilled to reveal characteristics of BSN channels that can be exploited for reducing the power of wireless communication. A new channel model is introduced to add periodicity to existing 802.15.6WBANpath loss equations. New parameters, activity factor and location factor, are introduced to estimate the model parameters. Finally, a strategy for exploiting the periodic characteristics of the BSN channel is presented as an example, along with the power savings from using this strategy

This paper [10] presents an ultra low power wireless insole sensor biofeedback and gait analysis system for rehabilitation of balance control for post stroke patients and gait related rehabilitation. The system integrates ANT wireless protocol, a wireless home E-health care sensor network and open-source mobile device technology. The paper also presents methods to time synchronize the two sole sensors. The system has been evaluated and it shows good performance in power consumption, communication latency, coexistence with Wi-Fi/Bluetooth/GSM.

RECAD [16] is a real-time continuous arrhythmias detection system based on the wireless sensor network technology. It uses ECG sensor (AWES) to provide all time cardiac monitoring services. The RECAD platform consists of four sub-systems: sensors, local access server, remote access server, remote surveillance server. The patient is provided with light weight, un-obstructive AWES sensors which locally communicate with local access server. The remote access server communicates with remote surveillance server. It adopts a lossless signal compression algorithm in order to reduce network traffics and provides an application layer protocol to guarantee real-time reliable on-line ECG analysis.
Glucose level monitoring system [17] consists of sensors and actuators. An actuator is a device that takes action as commanded by sensor. A biosensor, implanted in the patient body, continuously monitor glucose level and transmits readings to local wireless PDA or other fixed terminal. When the sensed reading approaches a defined threshold, the insulin is automatically injected through actuator

The survey in [18] discusses few routing protocols for sensor networks (24 in total) and classifies them into data-centric, hierarchical and location-based (2005). Although it presents routing protocols for WSNs it does not concentrate on the energy efficient policies. On the contrary, we focus mainly on the energy-efficient routing protocols discussing the strengths and weaknesses of each protocol in such a way as to provide directions to the readers on how to choose the most appropriate energy-efficient routing protocol for their network.

In [19], authors provide a systematical investigation of current state-of-the-art algorithms (2007). They are classified in two classes that take into consideration the energy-aware broadcast/multicast problem in recent research. The authors classify the algorithms in the MEB/MEM (minimum energy broadcast/multicast) problem and the MLB/MLM (maximum lifetime broadcast/multicast) problem in wireless ad hoc networks.

Typically, the two main energy-aware metrics that are considered are: minimizing the total transmission power consumption of all nodes involved in the multicast session and maximizing the operation time until the battery depletion of the first node involved in the multicast session. Moreover, each node in the networks is considered to be equipped with an Omni-directional antenna which is responsible for sending and receiving signals.

Low-energy adaptive clustering hierarchy (LEACH) is a typical cluster-based routing protocol that uses a distributed clustering approach [20]. In LEACH, the large number of sensor nodes will be divided into several clusters. For each cluster, a sensor node is selected as a CH. The selection of CH nodes is based on a predetermined probability. Other non-CH nodes choose the nearest cluster to join by receiving the strength of the advertisement message from the CH nodes. In [21], the authors modify the CH selection approach of LEACH (LEACH-E) to improve the network lifetime by accounting for the available remaining energy level of each sensor node. In [22], the authors propose the HEED (Hybrid, Energy- Efficient, Distributed) clustering protocol to prolong the network lifetime and support scalable data aggregation. In this protocol, the CHs are probabilistically selected based on their residual energy, and the sensor nodes join the clusters according to their power level. A new clustering algorithm with cluster member (NCACM) bounds for energy dissipation avoidance in wireless sensor networks [23] is proposed to reduce the energy consumption and to extend the network lifetime. The authors determine a confidence value for any sensor node that might become a CH by using parameters such as the nodes' remaining energy, the distances between the nodes, and the distances between the CHs in each round. However, a random selection of a CH node could obtain a poor clustering setup in these previously developed schemes, and the CH nodes can be redundant for some rounds of operation. The distribution of CH nodes is not uniform; thus, a cluster can consist of a large number of sensor nodes, and some sensor nodes must transfer data through a longer distance. Additionally, a CH node consumes too much energy to receive and to aggregate data from its non-CH nodes and to transmit data to the BS. It is clear that the CH node will die quickly. Thus, a reasonable energy consumption is not obtained in the wireless sensor networks. LEACH-centralized (LEACH-C) is proposes as an improvement of LEACH that uses a centralized approach to create the clusters [24]. In LEACH-C, the BS collects the information of the position and energy level from all of the sensor nodes in the networks. On the basis of this information, the BS calculates the number of CH nodes and configures the network into the clusters. LEACH-C uses a simulated annealing algorithm to create the routing structure. The average energy consumption of LEACH-C is lower than that of the distributed clustering schemes, such as LEACH, LEACH-E, HEED, and NCACM. In [25], we propose a saving energy clustering algorithm (SECA) to provide efficient energy consumption for the sensor nodes and to prolong the lifetime of the wireless sensor networks. In accordance with the centralized operation, the uniform cluster location can be obtained by using SECA. The data transmission distance from each sensor node to the CH node is suitable. Hence, the energy consumption is reduced, and the network lifetime is extended .

3. Existing challenges in Wireless Body Sensor Network

3.1 Energy Conservation

Typically sensor nodes are equipped with small batteries which cannot be changed or recharged and a node destroys when its battery exhausts. The experimental evaluations highlights that data communication consumes more energy as compare to data processing. The energy cost of receiving or transmitting a single bit of information is approximately the same as that required by processing executing a thousand operations [12] [13]. The continual operation of sensors is vital for healthcare applications.

Two major techniques, duty cycling and in-network processing are used in WSN to reduce power consumption. The power reservation algorithms in medical healthcare must be able to reduce power consumption without compromising on system reliability.

3.2 Vulnerability

Vulnerability is an important part of any system and it is a major area of research in general WSN. Wireless media is always more vulnerable than wired media for attackers [14]. This is more important in healthcare applications since a security breach can result in life threatening situations.

We can define security at several levels in healthcare applications. The security threats can occur during routing the data where intruders may change the destination, can make routing inconsistent or even steal the data by eavesdropping the wireless communication media [14]. The attackers can steal or modify the data routing through GPRS or similar networks [14]. The criminal-minded attackers can track the user location or can keep an eye on user's activity. The attackers can fiddle with the data by forging alarms [15]. They can also wage the Denial of Service (DoS) and Jamming attacks on the networks.

Data Encryption and Authentication are major security techniques used for security provision. Data encryption techniques must be used for secured data transfer and legitimate devices must be allowed to create or inject data into the system [15]. One of the solutions against security threats is to implement different encryption techniques

3.3 Power Sources

No matter how intelligent the routing mechanism or how adaptive the network, if the sensor loses power the sensor is simply non functional. Significantly more work is needed on alternative low cost power techniques such as solar, fuel cells and RF coupling.

3.4 Usability

Much of the work in this space has stopped at lab type ‘prototype solutions. More commercial devices are needed and more studies needed on performance in real world applications .

3.5 Autonomic Networks

Substantive effort is needed in the self- organizing properties of sensor networks. Also end-to-end pilots are needed that demonstrate the autonomic properties of sensor networks. In healthcare the Reliability Dilemma is particularly important, i.e. data needs to be secure and reliable, but this brings high overheads in terms of data size, power consumption and scalability. This dilemma needs attention through appropriate studies. Body Sensor Networks need to be recognized as a special category of sensor networks as the requirements can be quite different from general wireless sensor networks.

3.6 Privacy

In parallel with the technical research, research in to the societal, ethnographic and demographic effects of wireless sensor networks need to be performed. This encompasses the privacy debate also. Concerns such as profiling, 'big brother', 'one big database' etc need to be addressed up front and policies developed and agreed ahead of the technology becoming mature. Issues around data ownership when data travel across multiples boundaries arise. Also the legal aspects need to be reviewed, who is liable etc.

3.7 Design Challenge

Also one should accept that Wireless devices are slower than wired because of traffic congestion and hence increases the challenge to create the devices that could reach to better performance. This creates a big challenge for developers in programming and designing a secure sensor network. Ensuring patients information security can be a major issue when deploying these applications. Privacy of user data over wireless channels can be another major issue. Wireless network based medical devices can be very limited in terms of power availability and processing strength. Thus ensuring privacy without using complex encryption algorithms can be a big issue for developers of medical devices[11].

4. Conclusion

From the survey considering the existing drawbacks and issues in wireless body sensor network we have planned to propose a novel approach on increasing efficiently the lifetime of sensor nodes, energy consumption and routing design issues must be accounted for. Energy saving becomes one of the most important features for the sensor nodes to prolong their lifetime. In the wireless body sensor networks, the main power supply of a sensor node is a battery, and a sensor node consumes most of its energy in transmitting and receiving packets. However, the battery energy is finite in a sensor node, and a sensor node that has its battery drained could make the sensing area uncovered. Hence, energy conservation becomes a critical concern in wireless body sensor networks. To reduce the energy consumption and to prolong the network lifetime, new and efficient energy saving routing architectures must be developed.

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