



A Survey on Energy Efficient Biomedical Wireless Sensor Networks

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Abstract: *Sensor nodes can be used for continuous sensing, location sensing and event detection with the help of different types of sensors such as seismic, thermal, visual, infrared, magnetic, and many gaseous sensors. Sensor networks have wide range of applications including medical, military, home, etc. All these applications involve vigorous wireless communication protocol that is good in reduced energy utilization. This paper presents a survey on energy efficiency in Biomedical Wireless Sensor Networks.*

Keywords: *energy efficiency, biomedical wireless sensor networks*

I. Introduction

The progression in wireless communications and electronics has emerged the expansion of low-cost sensor networks. Wireless sensor network is a collection of sensors which are interconnected by means of wireless communication channels. A sensor node in the wireless sensor network is a small device which is capable of collecting data from the surrounding regions [3]. With the collected data, simple computations are carried out and correspond with other sensor nodes and controlling authorities in the network. Sensor networks exploit large number of wireless sensor nodes to collect information from their sensing terrain. The gathered information will undergo in-network process and is send to the remote sink. The network consists of low-cost sensor nodes with limited battery power. The sensor nodes have to use the available energy source with limited computational capabilities.

Now a day, the low cost sensor devices are capable of efficient computation and wireless communication. A network of wireless sensor nodes can be used to collect information from a variety of applications including military, environmental, medical, and scientific applications. The wireless sensor network is deployed with hundreds or thousands of wireless sensor nodes. The wireless sensor nodes are capable of self-organizing a network and the nodes will communicate with each other by the use of wireless interfaces. Every packet transmitted in the wireless sensor networks contains useful information, which can be utilized through packet-based computation and to enhance congestion control. The wireless sensor network packet computation has small packet forwarding rate and the forwarding computation capability is limited [2]. Most of the time the sensor nodes are modeled with limited energy, as a result the sensor nodes lacks recharging issues.

Because of the inherent characteristics of wireless sensor network, the nature of routing is a challenging one. The wireless sensor network design will carry out data communication in order to prolong the node lifetime in the network. This is also used to prevent connectivity degradation by the use of employing aggressive energy management approaches. The following are the routing design issues and routing challenges that affect the routing process in wireless sensor networks.

- Deterministic node deployment
- Energy consumption without losing accuracy
- Node/Link heterogeneity
- Fault tolerance
- Scalability
- Network dynamics
- Transmission media
- Connectivity
- Coverage
- Data aggregation
- Quality of service

The routing protocols in wireless sensor networks can be categorized into the following three types based on the network structure, named; flat-based routing protocol, hierarchical-based routing protocol, and location-based routing protocol [1]. In flat-based routing protocol, all the nodes in the wireless sensor network is assigned with equal functionalities and the sensor nodes pool resources to perform the sensing assignment. In hierarchical-based routing or cluster-based routing protocol, the nodes in the wireless sensor network will have different roles in the network with scalability and efficient communication. In location-based routing protocol, the position of the sensor nodes is exploited based on the signal strength to route data in the wireless sensor network.

Based on the route identification from the source to the destination, the routing protocols in wireless sensor networks are classified into three types, namely; proactive routing protocol, reactive routing protocol, and hybrid routing protocol [4]. In proactive routing protocol, the routes are identified even before the route is actually needed. In reactive routing protocol, the routes are identified when needed. Hybrid routing protocol is the combination of the proactive and reactive routing protocols.

Again, based on the routing operation, the routing protocols are classified into multipath-based routing protocol, query-based routing protocol, negotiation-based routing protocol, Quality of Service (QoS)-based routing protocol, and coherent-based routing protocol. In multipath-based routing protocol, multiple paths are used to improve the network performance like fault tolerance, energy consumption, and reliability. In query-based routing protocol, a query for data is propagated by the destination node. In QoS-based routing protocol, both data quality and energy consumption is given more importance. In coherent-based routing protocol, data aggregation is carried out with minimum data processing before forwarding.

The rest of the paper is organized as follows. Section 2 reviews about the related literature on wireless sensor networks and section 3 describes about diverse work on biomedical wireless sensor networks. Section 4 surveys about the study on energy efficiency in biomedical wireless sensor network. Finally conclusion is given in section 5.

II. Wireless Sensor Networks

In this section, we review the prior work on the various routing algorithms implemented for the wireless sensor networks. A gateway-selection level for a home network, in which the sensors collect various home environment data is proposed [7]. The sensor nodes are equipped with limited power capacity batteries and are essential to make the network be energy-efficient for maximizing the life time. The technique will increase the life time of the sensor network with the integrated gateway node. To pursue energy conservation through balanced clustering Equalized Cluster Head Election Routing Protocol (ECHERP) is proposed [12]. This protocol models the network as a linear system and uses Gaussian elimination algorithm to calculate the combinations of nodes to be chosen as cluster heads in order to extend the network lifetime. When wireless sensor network is deployed in natural environment large number of security issues will arise. To protect the data in WSN from the attackers an approach called Detection based path hopping to make WSN more secure from intruders and attacks is proposed [13].

Low Energy Adaptive Clustering Hierarchy (LEACH) protocol is an architecture for microsensor networks that combines the concepts of energy-efficient cluster-based routing and media access together with application-specific data aggregation to achieve good performance in terms of system lifetime, latency, and application-perceived quality [10]. The data aggregation technique reduces the amount of data need to be transmitted from the cluster to the base station. The nodes in the network forms clusters by organizing themselves and one node act as a cluster head. Nodes other than the cluster head node send their data to the cluster head node. The cluster head node receives data from all the members of the respective cluster. The cluster head node performs data aggregation or process the data and transmits the information to the base station located remotely.

If the energy level of the cluster head node is reduced then the cluster head node cannot act as the cluster head and all the nodes belonging to that cluster are not able to communicate the information to the base station. LEACH avoids this problem by rotating the cluster head to a node with high energy to avoid draining the battery level of wireless sensor node in the network. In this way an energetic cluster head node is chosen as a cluster head for the cluster in the wireless sensor network. The operation of LEACH protocol is split into two phases: set-up phase and the steady phase. In the set-up phase the entire wireless sensor node in the network chooses a random number between 0 and 1. Each wireless sensor node elects itself to be a cluster head in the beginning with a threshold value for node 'n', as $T(n)$. The threshold value is chosen such that the expected number of cluster head nodes for the current round is 'K'. For a network with 'N' number of wireless sensor nodes, the expected number of cluster head is,

$$E_{[\#CH]} = \sum_{n=1}^N T(n) * 1 = K \quad (1)$$

The threshold value $T_{(n)}$ is expressed as,

$$T_{(n)} = \begin{cases} \frac{P}{1 - P \lfloor r \times \text{mod}(\frac{1}{P}) \rfloor} \\ 0 \end{cases} \quad (2)$$

where, ' P ' is the percentage of wireless sensor nodes which are cluster-heads, and ' r ' is the current round. After the cluster head selection, the cluster head nodes will advertise their selection as cluster head to all the wireless sensor nodes by broadcasting an advertisement message (ADV) using a non-persistent Carrier-Sense Multiple Access (CSMA) MAC protocol. The advertisement message contains the node ID and a header to distinguish this message as an announcement message. All the other nodes which are not cluster head choose a nearest cluster-head when they receive advertisement message based on the received signal strength.

The wireless sensor nodes are assigned with a TDMA schedule by the cluster head node. Then the steady phase exists for a long period to reduce the overhead created in the formation of cluster head. In the steady phase, data transmission is carried out based on the TDMA schedule. For the data transmission the cluster heads perform data aggregation and fusion through local computation. The base station receives only the aggregated data from the cluster heads. This process is repeated after a certain period of time, and cluster heads are selected again through the set-up phase. Table 1 shows a comparison of three recipes of LEACH routing protocols for wireless sensor networks. Various LEACH protocol has been developed to overcome the drawbacks in the flat-architecture protocols that consume more energy [11]. LEACH uses a hierarchical structure, which divides the nodes into clusters.

Table 1 Comparison of LEACH, LEACH-C, and DEEAC protocols

	LEACH	LEACH-C	DEEAC
Centralized Approach	NO	YES	NO
Distributed Approach	YES	NO	YES
Hotness-based	NO	NO	YES
System Lifetime	High	Very High	High
Energy Efficiency	Medium	High	Medium
System Efficiency	Medium	High	Very High
Cluster Formation	Self Organizing	Centralized	Centralized

III. Biomedical Wireless Sensor Networks

In this section, we review the prior work on biomedical wireless sensor networks. The performance statics of event based data delivery model for a Biomedical Sensor Networks is designed in accordance with IEEE 802.15.4/ZigBee wireless communication technology is examined [5]. All the sensor nodes in the model share the same medium with different traffic characteristics and different QoS requirements. A congestion control and service prioritization protocol for real time monitoring of patients vital signs using wireless biomedical sensor networks is proposed [8]. The system is able to discriminate between different physiological signs and assign them different priorities. The congestion control is performed by considering both the congestion situation in the parent node and the priority of the child nodes in assigning network bandwidth to signals from different patients. A mobile tele-healthcare system is presented [9], in which the tiny sensors can achieve long-distance bio-signal monitoring through self-healing multi-hop communication architecture. The system uses an interface to pre-process different medical signals before assembling into RF transmission packets. The interface uses wavelet-based signal decomposition to obtain the signal feature parameters. The signal is classified into normal/abnormal signals, and the normal signals are not transmitted. Biomedical wireless sensor networks with high quality of service need to be integrated on the existing network infrastructure and information systems [14]. The quality of service is addressed during the development stages and monitored during the network operation. The QoS requirements must be identified on the development state and ensures its accomplishment during the network operation to evaluate the performance and manage the admission of new nodes.

IV. Energy Efficiency in Biomedical Sensor Networks

In this section, we review the prior work on the various energy efficient methods implemented for the biomedical wireless sensor networks. A near-optimal chain-based protocol for minimizing energy named Power-Efficient GAttering in Sensor Information Systems (PEGASIS) is proposed [6]. A node will communicate with its close neighbor, and turns transmitting to the base station to reduce the energy usage. The delay incurred in gathering sensed data is minimized by using Code Division Multiple Access (CDMA) capable

sensor nodes, which will transmit data simultaneously with less interference. By using CDMA capable sensor nodes, a chain-based method performs well for energy $\times$ delay. Wireless biomedical network is a breakthrough technology used in telemedicine for monitoring the physiological condition of an individual [18]. This network is very sensitive and must provide security and patient privacy as it is an important issue in the design of such system. The security is provided to the physiological data, which is being transmitted from the sensor node to the sink device. The security is achieved by authenticating the data using patients biometric, encrypting the data using |Quasi Group cryptography after compressing the image data using an energy efficient number theory based technique.

To improve high quality of life expectations to provide affordable healthcare solutions the optimization of Medium Access Control (MAC) protocols for biomedical wireless sensor networks [15]. The scheme has efficient management of channel resources and the overall minimization of sensors energy consumption in order to prolong sensors battery life. The standards mentioned serves as a link for the introduction and initial description of the proposed system. This framework has an extensive Distributed Queuing MAC energy-consumption analysis in saturation conditions to evaluate the performance in relation to IEEE 802.5.4 MAC in highly dense BWSNs. Minimization of energy consumption by applying optimization techniques enables pervasive computing especially in the field of biomedical engineering [16]. The system framework for energy consumption measurement and analysis combines a theoretical approach based on software simulator and validation by means of a high sensitivity measurement setup. Tiny, cheap and low-power biomedical nodes are dedicated for healthcare monitoring applications [17]. This application ensures a continuous monitoring of vital parameter of patients while giving them the freedom of motion and thereby better quality of healthcare. Table 2 lists few differences between the wireless sensor networks and body area networks.

Table 2 Differences between wireless sensor networks and body area networks

Parameter	Wireless Sensor Networks	Body Area Networks
Scale	Wire Coverage	Limited to human body
No. of Nodes	Huge number	Limited number
Accuracy	Compensated by the redundancy	Accurate measurements
Failure	Nodes are disposable	Difficult replacement of implanted nodes
Energy Scavenging	Solar or wind power	Motion or body heat

V. Conclusion

This paper surveys the prior work on various wireless sensor networks related to biomedical applications. Also study is made to see the work carried out through energy efficient applications in the field of biomedical wireless sensor network. From this survey new energy efficient protocols should be designed in the field of biomedical wireless sensor network to maximize the life-time of the system.

VI. References

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