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Research Article
Cluster Based Energy Efficient Routing Protocol for Wireless Body Area Networks

Turki Ali Alghamdi

Department of Computer Science, College of CIS, Umm Al Qura University, Makkah, Saudi Arabia

Abstract
Wireless Sensor Networks (WSNs) are well known due to its multiple application areas. It consists of tiny nodes, which are cheap and easy to deploy in several types of application areas ranging from industrial to health. The Wireless Body Area Sensor Networks (WBANS) are popular in health applications and play an important role for monitoring the critical patients. Among different operations, routing is always recognized as a resource hungry operation. Therefore, it is pertinent to design an energy efficient routing protocol for WBNS. The main aim of this study was to design a Cluster Based Body Area Protocol (CBBAP) in order to enhance the overall energy efficiency by 25% over the existing approaches. The Base Station (BS) is placed far in our routing protocol of CBBAP, while the gateway approach is adopted, which is proposed to be placed in the centre of the sensing area. The current proposed protocol of CBBAP uses the Cluster Head (CH) mechanism as a Low Energy Adaptive Clustering Hierarchy (LEACH). The performance of the proposed CBBAP protocol was compared with LEACH for WBNS efficiency and found more practical for various application areas.

Key words: Leach, energy efficient, WSN, WBSN, CBBAP, routing protocol

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Corresponding Author: Turki Ali Alghamdi, Department of Computer Science, College of CIS, Umm Al Qura University, Makkah, Saudi Arabia

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The Wireless Sensor Networks (WSNs) is becoming more popular and capable to penetrate into several applications areas including heath applications. It consists of small nodes having limited sensing, computation and wireless communication capabilities (Al-Karaki and Kamal, 2004; Noor and Azween, 2010). Normally, the sensor nodes senses the data and forward it to the base station such as temperature, sound, vibration, pressure, motion or pollutants (Akyildiz *et al*., 2002). In WSN, the sensor nodes are highly resource constraint type of network based on tiny size without chargeable and irreplaceable batteries. Whereas, the network life is highly energy dependent (Bhardwaj and Chandrakasan, 2002; Zussman and Segall, 2003). Generally, in WSN type of networks, energy consumption is more during path finding and data transmission operations, which is called as routing. Because, routing is the most challenging and directly related issue of energy consumption in WSN comparable with *ad hoc* and cellular network (Cao *et al*., 2007; Pandana and Liu, 2008). Clustering is one of the most suitable techniques for routing in WSN based on its characteristics such as energy-efficient, scalable, lower latency, etc. In clustering, the WSN is divided into sub networks\clusters where, each cluster has cluster head responsible to collect the sensed data from its cluster and forward it to the base station (Younis and Fahmy, 2004). The cluster heads consume more energy due to collecting and forwarding data from the cluster. While, the remaining nodes in the clusters still have more energy of their initial energy (Lian *et al*., 2006; Olariu and Stojmenovic, 2006; Wadaa *et al*., 2005).

Wireless Body Area Network (WBAN) is one of the most important types of WSN application, which is normally used to monitor human health (Bao *et al*., 2005). Because, the WBAN helps the medical staff to monitor the patients regularly at any time by implanting or positioned sensors with patient body. The WBAN sensors monitor patient's vital sign including pulse rate, blood pressure, glucose level, etc. The measured information is delivered to the main server, where it is accessible to the medical staff at any time. Some researchers reported that health WBANs application operations are affected severely due to energy constraint type network of sensor nodes. Therefore, the energy expenditure of sensor nodes is the critical issue for WSNs. Several protocols based on clustering topology (Ye *et al*., 2005; Ahmad *et al*., 2013; Li *et al*., 2005; Kashaf *et al*., 2012; Shah *et al*., 2012) are available and designed for a variety of applications. The minimum energy routing problem was addressed by Sadek *et al*. (2007). It is well known that if the sensor nodes consume energy more equitably, then they continue to provide connectivity for a longer period of time and the network lifetime increases (Zaman *et al*., 2012; Pantazis *et al*., 2013; Zaman *et al*., 2014).

Sensor networks are popular due to ease of deployment and variety of applications. The role of sensor network is to sense the data at the source and forward to its destination. Sensor network works in different topologies and normally changes more than once during data transmission rounds due to energy constraints issue. In case, if any full\partial segment dies due to its energy drain during routing operation it may disable any segment of sensor network for transferring sensed data to the destination. As such, this issue requires more attention to design an energy efficient routing protocol for WBAN to address the above mentioned issue and enhances energy efficiency of WBAN.

Recently, several protocols were developed to address the energy efficiency issue in WSN with a few focusing specially to WBAN. It is described that energy utilization, energy efficiency and life span of sensor networks have highest priority in WSN. In WSN, a great number of clustering protocol approach is presented already while, only a few protocols focused to WBAN. A large number of the clustering protocols are homogeneous. For example; LEACH (Wadaa *et al*., 2005; Heinzelman *et al*., 2000), Power-Efficient Gathering in Sensor Information Systems [PEGASIS] (Lindsey and Raghavendra, 2002) and Hybrid Efficient-Energy Distribution [HEED] (Younis and Fahmy, 2004), ACH (Ahmad *et al*., 2014). The CHs are responsible for collecting data from its cluster and then forward to BS. The LEACH works fine with homogenous networks while, its performance lowers with heterogeneous networks (Smaragdakis *et al*., 2004). Another clustering protocol two-levels hierarchy for low-energy adaptive clustering hierarchy [TL-LEACH] (Loscri *et al*., 2005), it works on two level clustering scheme, which can perform well in terms of minimum energy consumption of network. The PEGASIS arranges nodes to form a chain. In chain formation process, each node computes to connect with next node or BS assist nodes to form chain. In HEED clustering protocol, CHs are selected on the basis of probability. The probability value for becoming CHs is based on the remaining energy of sensor nodes. An Energy Efficient Unequal Clustering (EEUC) protocol works on the basis to equalize the network energy utilization. It divides sensor networks into unequal clusters. The main disadvantage with EEUC is all nodes are not connected with CHs (Heinzelman *et al*., 1999).

The protocols related specifically to WBAN are presented in this study. In thermal aware routing protocol, where each node selects the minimum hop rout to the sink is based on thermal heat nodes, which can change another optimal route. The Cascading Information retrieval by Controlling Access with Distributed slot Assignment (CICADA) routing protocol employs a spanning tree structure (Latre *et al.*, 2007). The CICADA uses Time Division Multiple Access (TDMA) technique to schedule transmission for sensor nodes. Another clustering based routing protocol known as Anybody (Watteyne *et al.*, 2007) has features to restrict the sensor nodes to transmit directly to the sink, which affects the CHs selection mechanism (Tsouri *et al.*, 2011; Sapio and Tsouri, 2010), use creeping waves to relay data packet and to minimize energy use to keep nodes reliable on body link. Also Quwaider and Biswas (2009) proposed a delay tolerant protocol. Even though a number of routing protocols are designed for WSN and WBAN, yet, there is still a gap to design an energy efficient routing protocol such as CBBAP which can enhance energy efficiency, throughput and life time of WBAN.

MATERIAL AND METHODS

System model: The proposed routing protocol CBBAP mainly focused to human body and worked for class of WBAN applications. In CBBAP, the researcher deployed eight sensors nodes on human body as shown in Fig. 1. At initial stage, all the nodes contained the same power, sensing and computational capabilities and were distributed on different body parts. Sink was placed in the center of the human body at waist. The close nodes can directly transmit their data to the sink as node-1 and node-2, where each node was responsible to get electrical cardiography (ECG) and glucose readings, respectively.

Network model: The protocol for CBBAP network model is shown in Fig. 2. The sensor nodes were distributed in homogenous mode assuming that the total energy level of all the nodes was the same at initial stage. The Base Station (BS) was placed outside the network as shown in Fig. 2. The gateway was placed in the center of network to receive information from the nodes and forward it to BS. It was assumed in the study that BS, gateway and sensors are in stationary mood, while each node has its unique ID.

Energy model: The power control model used in this research consumed the energy during the transmission and depends on the transmission distance (Heinzelman *et al.*, 2002). The energy consumed by a node (E_{Tx}) during transmission of k bits to another node at a distance of d (meters) and the energy consumed (E_{Rx}) to receive k bits were calculated as in Eq. 1 and 2:

$$E_{Tx} = kE_{elec} + k\,E_{amp}d^2 \quad (1)$$

$$E_{Rx} = kE_{elec} \quad (2)$$

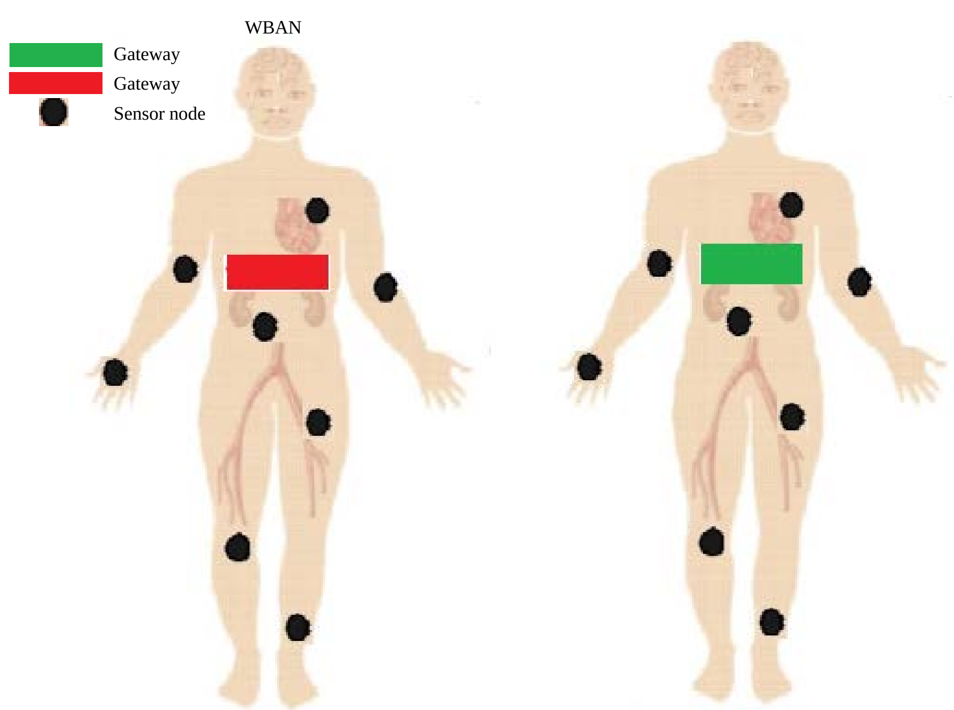

Fig. 1: System model

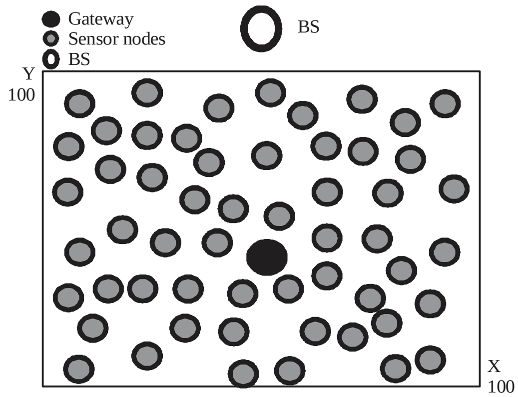

Fig. 2: Network model

Table 1: Radio parameters

Parameters	nRF 2401A	CC2420	Units
DC current (Tx)	10.5	17.4	mA
DC current (Rx)	18	19.7	mA
Supply voltage (min)	1.9	2.1	V
Etx elec	16.7	96.9	nJ/bit
Erx elec	36.1	172.8	nJ/bit
Eamp	1.97e-9	2.71e-7	j/b

where, E_{elec} is the electronics energy, E_{amp} is the amplifier energy. The E_{elec} representing the electronics energy was determined by several factors such as digital coding, modulation, filtering and spreading of the signal. On the other hand, E_{amp} is the amplifier energy. The radio parameters used in this study are presented in Table 1. Mainly the energy parameters are hardware dependent. However in simulation, both the transceivers such as nordic nRF 2410A single chip and chipcon CC2420 were considered having low power and frequently for use in WBAN applications.

Data analysis: The study data was analysed by following appropriate statistical techniques as described in SAS (2010).

RESULTS AND DISCUSSION

A comparison was made between the proposed protocol of CBBAP in this study with LEACH. Also, different parameters such as network throughput, network life time and energy efficiency were compared with each other. The simulation results of CBBAP protocol were better than LEACH for all the parameters. In CBBAP, the network was divided in different regions. In each region the cluster head was responsible for collecting the information of sensed data from sensor nodes. However, the clusters and cluster heads were proposed to reduce the transmission distance to enhance throughput of the network and the energy efficiency of sensor network, which directly influence the life time of sensor nodes. The CBBAP is cluster based routing protocol where, clusters heads are placed in each cluster and a rechargeable gateway is placed in the center of the network. The Base Station (BS) is placed far from the sensor field. The study results agree with those of Younis and Fahmy (2004), who stated that clustering technique is a suitable technique for routing in WSN depending upon its different characteristics such as energy efficiency, scalable and low latency.

Comparison analysis network lifetime: The sensor network life time analysis is presented in Fig. 3. The simulation result showed significant improvement in sensor network life of CBBAP compared to LEACH due to many factors. In CBBAP, the network was divided into different clusters where, nodes were homogenous. Also, at the same time, the Cluster Heads (CHs) were selected on the basis of neighboring nodes while, in LEACH, the cluster heads were selected randomly. Because, there are chance that some of the nodes are far from the CH and causes energy loss due to transmission distance. In few cases, the CHs were surrounded with more nodes thus resulting in rapid energy loss of CHs. In addition to that, the gateway was placed in the center of the network in static condition thus causing further reduction of transmission distance. In CBBAP, BS is placed far from the sensor network, which receives data through gateway. As such, all these aspects seem to be the main cause to enhance sensor nodes life over LEACH as shown in simulation results. The simulation result also showed the initiation of death of nodes after LEACH protocol. Many researchers have reported similar results for comparison of different network systems with respect to their performance (Kashaf *et al*., 2012; Sadek *et al*., 2007; Heinzelman *et al*., 1999).

Throughput: The analysis of results for network throughput showed much improvement with the proposed CBBAP protocol in this study. In CBBAP, throughput analysis was performed on the basis of average packets received by BS. However, the extensive simulation results showed that network throughput remains constant at the initial stage, but increased later with time due to efficient routing maintenance and reduction of transmission distance. Because, these factors have direct impact on network lifetime and network good put as shown in Fig. 4. The results also showed that throughput decreased in LEACH with respect to the time, but it remained constant and then increased with CBBAP. Based on the study assumptions in CBBAP, the nodes close to the gateway and BS can transmit data directly, which seems to be a source of

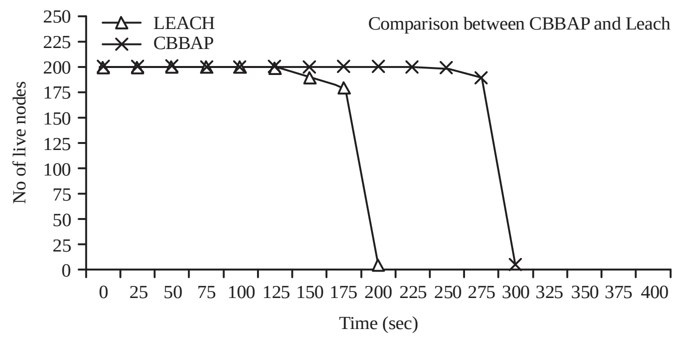

Fig. 3: Network life time analysis

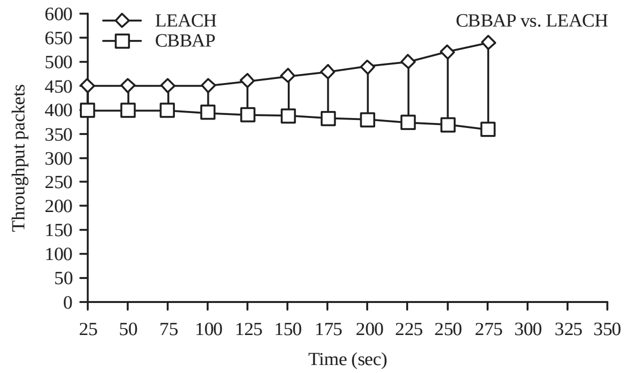

Fig. 4: Network throughput analysis

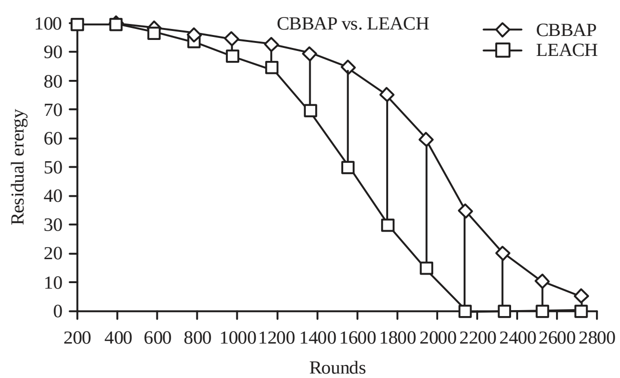

Fig. 5: Network residual energy analysis

throughput enhancement. The study findings are identical to those reported by Li *et al*. (2005) and Latre *et al*. (2007), who concluded that energy constraint type of network and thermal aware routing are important for system efficiency.

Residual energy: The residual energy of sensor network for LEACH and CBBAP was compared with different rounds as shown in Fig. 5. The result of 200 nodes in the network showed a total energy of 100 J with each node having 0.5 J the as initial energy. The proposed CBBAP protocol in this study showed better performance than LEACH protocol and the survival time was maximum by retaining residual energy for a longer period of time. However, the residual energy increased due to efficient routing management by reducing the transmission distance for routing thus having better impact over network lifetime, throughput and residual energy.

Overall, the Cluster Heads (CHs) and the gateway mechanism showed improved performance for the proposed CBBAP protocol in the present study. The results of this study are in line with the findings of Cao *et al.* (2007), Zussman and Segall (2003) and Ahmad *et al.* (2013), who stated that the life of network depends on energy consumption in WSN. They also reported that clustering protocols are homogeneous such as LEACH and ACH.

CONCLUSION

The study showed that Wireless Sensor Network (WSN) has important role and use due to its diversified approach and range of applications. The WBAN is the main WSN application and is directly linked with health. It was noticed that routing is the main expensive operation for nodes energy consumption. This paper proposed a new routing protocol known as Cluster Based Body Area Protocol (CBBAP). The proposed CBBAP protocol addressed the energy efficiency, network life time, data throughput and network residual energy under certain controlled conditions. Also, the proposed CBBAP protocol works on the basis of cluster formation, cluster heads (CHs), gateway and static BS outside the network. Furthermore, the simulation based research showed significant improvement than LEACH protocol for WBAN such as energy efficiency improvement between 25-35% in WBANs by increasing overall energy efficiency, life time, throughput and residual energy.

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