Research on the WBAN structure based on LEACH Protocol

Jing-Jing Zhang[1,a], Xin Feng[1,b], Yan-Long Wang[1,c,*], Teng Li[1,d] and Wen-Long Yang[1,e]

[1]College of Computer Science and Technology, Changchun University of Science and Technology, Changchun 130022, China

[a]894684039@qq.com, [b]fengxin@cust.edu.cn, [c,*]594741695@qq.com, [d]766049177@qq.com, [e]947882896@qq.com

Keywords: Wireless Body Area Network, Telemedicine, LEACH Protocol, Low Energy Consumption.

Abstract. WBAN, as an important application aspect in the wireless sensor network, has a favourable application prospect in biomedical field, which can provide real time monitoring and health nursing for patients. Therefore, it requires a higher efficiency and better reliability on medical data transmission in Wireless Body Area Network (WBAN). This paper analyses the problems of low energy consumption in data transmission and establishes a networking model based on Low Energy Adaptive Cluster Hierarchy (LEACH) protocol, which is suitable to apply in WBAN. Considering the life cycle of the network and the importance of the nodes in certain environment, we improve the LEACH algorithm in order to adapt to the WBAN. The experiments simulation and analyses results denote that this improved algorithm effectively reduces the consumption energy and prolongs the life cycle of the entire network.

Introduction

With the development of the human society and the technology, the rise of wearable equipment makes it possible to monitor the health situation of human beings in real time. This leads to the quick development of WBAN techniques along with the wireless communication techniques, the embedded computing techniques, and the wearable biosensor technology [1].

Wireless Body Area Network (WBAN), a branch of Wireless Sensor Network (WSN), can be used in collecting physiological parameters of human body. Though real time analyses of the collected data, the potential disease can be predicated and those data will be save and transmitted to certain server via wireless communication techniques for further diagnosis and treatment [2]. Each node around the human body will transmit data to the central node, consuming great energy and shortening the life cycle of the network. Considering this issue, we take the classical LEACH clustering algorithm. This paper first analyses the advantages and disadvantages of LEACH algorithm when applying in WBAN. Based on the analyses, an improved algorithm is proposed that by reducing the energy consumption of the nodes and balancing the energy consumption of the entire network, the life cycle of the network are prolonged.

Research status

There are three levels in the WBAN as illustrated in Fig.1: the wearable WBAN, the handhold intelligent terminals and the remote medical service centers. The wearable WBAN consists of the micro intelligent sensor nodes that are attached on or embedded in human body. Through the communication routes established by those nodes, they collect, process and transmit certain physiological parameters that will be sent to the handhold intelligent terminals later. The terminals, working as a connector between the nodes in the WBAN and the service centers, are responsible to receive, process and upload the physiological parameters to the medical service centers and meanwhile provide real time data to the patients. The medical service centers analyze the received data and offer real-time and individual medical services [3].

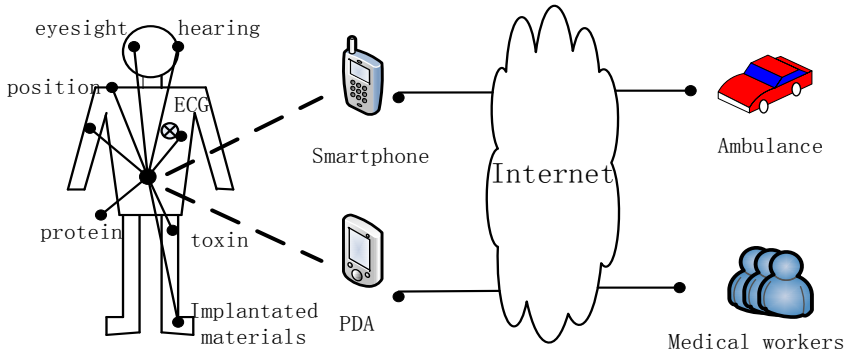


Fig. 1 The structure of WBAN [4]

WBAN becomes a research focus recently because of its favourable application prospect. The design of the wearable sensor nodes in WBAN must consider the requirement on energy consumption, security and reliability. Since its data transmission is quite close to human body, the energy consumption must be under restriction [5]. Kim et al [6] propose a high efficient routing method based on the energy levels of GPS and sensor nodes. [7, 8] evaluate the energy consumption of ZigBee protocol when applying in WBAN and point out that ZigBee protocol is not suitable to apply in WBAN unless being improved. [9] suggests a dynamic schedule solution based on Bluetooth, in which the sensor nodes switch between connection status and sleep through self-adaption and as a result less energy is consumed by the nodes. In conclusion, the above research improves the MAC protocol under Bluetooth technique or ZigBee technique. This paper improves the entire sensor network and reduces the energy consumption by prolonging the life cycle of singe node and further increasing the energy utilization.

LEACH algorithm and the improvement

LEACH algorithm. Low Energy Adaptive Cluster Hierarchy (LEACH) [10] is the first clustering routing algorithm in wireless sensor network. Its operations are broken into rounds and each round begins with setup phase and is followed by steady-state phase [11]. It selects different sensor nodes as cluster heads and distributes the energy load among the nodes in the entire network so as to balance the energy consumption and prolong the life cycle of the network.

In the setup phase, the procedure to select the cluster head is that a sensor node chooses a number randomly between 0 and 1, and if the chosen number is less than the pre-set threshold $T(n)$, this node becomes the cluster head in this round. The other nodes decide whether to join this cluster or not according to the signal strength. The equation to calculate $T(n)$ as Eq. 1:

$$T(n) = \begin{cases} \frac{P}{1-P*(r \bmod \frac{1}{P})}, & n \epsilon G \\ 0, & others \end{cases} \quad (1)$$

In the equation, n is the number of the sensor nodes. p is the desired percentage of the cluster nodes in the round. r is the current round. G is the set of nodes that have not been selected as cluster heads in the left rounds.

As long as a cluster head is determined, it will broadcast to the other nodes about this information. Then each node that is not a cluster head decides to join the cluster according to the signal strength and sends the results to the correspondent cluster head.

There are many researches on the improvement of LEACH such as LEACH-MR [12] and TEEN [13]. However, most of them are based on the situation that all the nodes have the same initial energy and importance. Also the improvements like the selection of second–level cluster head and the partitioning of the area are not well adapt to small wireless sensor network like WBAN. Therefore, this paper improves the LEACH algorithm to increase the efficiency of the WBAN.

The improvement on LEACH. Our improvement is based on the consideration of how to make LEACH adaptable to WBAN, which includes the following aspects:

1. In WBAN, sensors deployed on different parts of human body have different functions and therefore have different importance to the health of human body. For example, the data collected by

electro-cardiograph sensor is related to the life of human beings. The data collected by glucose sensor only reflect the health situation of human beings. In this case, the sensors deployed on important parts should be given more focus and protection. In our algorithm, the nodes that monitor important parts of human body will be allocated more energy than those nodes on comparatively less important parts. Through this way, those important nodes are able to continuously collect data.

2. The farther the sensor is from the base station, the more energy will be consumed. Considering this point, we add $\frac{Energy_{max}-Energy}{Energy_{max}}$ to the formula for selecting the cluster head in order to decrease the possibility of the nodes far from the base station to be the head in our algorithm. $Energy_{max}$ denotes the most energy that is consumed in the network when transmitting data to the base station. $Energy$ denotes the energy consumed by the node.

3. The importance of the sensor nodes is also an important indicator for selecting cluster head. So we add the importance denoted as $S(n).proporty$ into the formula. For example, the value of $S(n).proporty$ of electro-cardiograph sensor may be quite small while that of sensor deployed on the ankle may be quite big. In this way, the less important sensor nodes could have greater possibility to be the cluster head and as a result the entire energy consumption of the network can be balanced.

The equation used for selecting the cluster head used in our algorithm as Eq.2:

$$T(n)=\begin{cases}\frac{P}{1-P*(r\ mod\frac{1}{P})}*S(n).proporty*\frac{Energy_{max}-Energy(n)}{Energy_{max}}, & n\epsilon G\\ 0, & others\end{cases} \quad (2)$$

Through the above improvements, the algorithm considers the energy consumed by the nodes and the importance of the nodes when routing to the base station. By this way, the total energy consumption of the WBAN is well balanced among the nodes and as a result the life cycle of the network is prolonged.

Simulation results and analyses

We conduct the simulations on MATLAB R2011b. The experiments parameters are shown in Table 1.

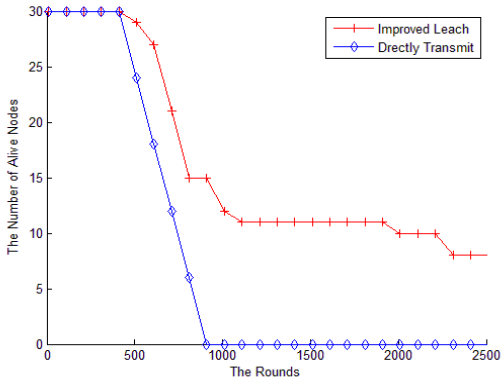
Table 1 Experiments parameters

Parameter	Value
Distribution area	1m*1 m
Number of nodes	30
Coordinates of base station	(25m,25m)
Activity area	50m*50m
Initial energy of ordinary nodes	0.1J
Initial energy of senior nodes	0.5J
Percentage of senior node	10%
Possibility of nodes to be cluster heads	0.05
Rounds	2500
Size of data package	4000bit
Ullage of sender & receiver circuits	50nJ/bit
Energy consumption of free space	0.1pJ/bit/m^2
Energy consumption of multi-route transmitting	0.13pJ/bit/m^4

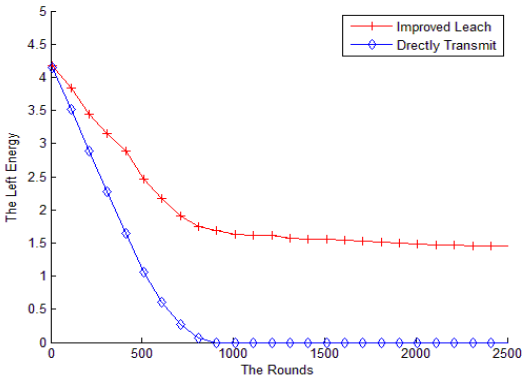
The paper mains focus on the comparison of the improved LEACH and the directly transmit. Suppose the human wearing the sensors is mobile within the area of 50m*50m and the location of the base station is (25m, 25m).

As illustrated in Fig.2 (a), the blue line denotes the nodes surviving in each round after communicating with the base station when transmitting directly to the base station. With the rounds going on, more and more nodes die. All the nodes die when the round is executed less than 1000 times, i.e. the life cycle is short. The red line denotes the surviving nodes when applying our

improved algorithm. With the rounds going on, the number of surviving nodes decrease slowly, which shows that the life cycle of the network is prolonged.



(a) The number of surviving nodes



(b) The left energy

Fig. 2 Life cycle of network

As to the energy consumption, the improved algorithm presents better performance than transmitting directly. As shown in Fig.2 (b), the blue line denotes the energy left in each round after transmitting the data directly to the base station. With the rounds going on, the energy of the nodes is consumed quickly. On the contrary, when applying the improved algorithm, the energy is consumed quite slowly and as a result, the energy is saved.

Table 2 compares the numbers of surviving nodes in each phase when transmitting data directly and applying the improved LEACH algorithm. In the 500th round, there are 23 nodes left in the former while no node dies in the latter. In the 1000th, all the nodes die in the former while there are 12 left in the latter. The life cycle of the network of the latter is longer than that of the former.

Table 2 Comparison on the number of surviving nodes

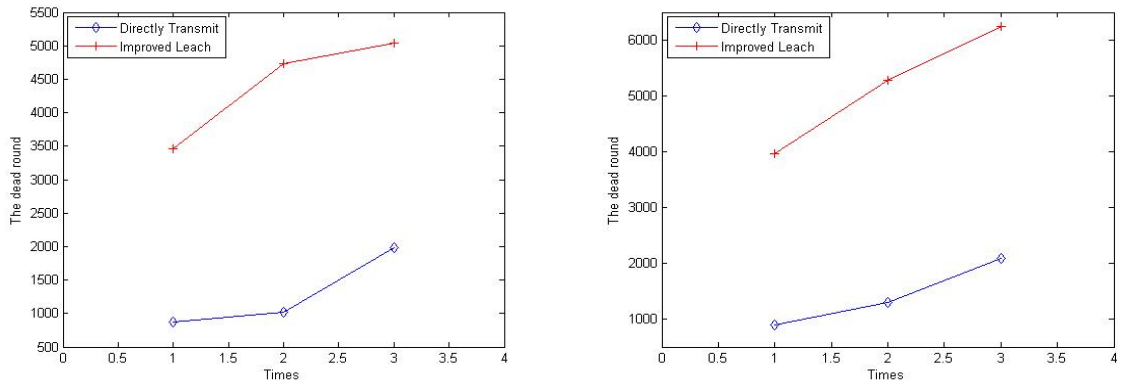
Rounds	0	500	1000	2000	2500
Directly Transmit	30	23	0	0	0
Improved Leach	30	28	12	9	7

Table 3 Comparison on the left energy

Rounds	0	500	1000	2000	2500
Directly Transmit	4.2	1.1	0	0	0
Improved Leach	4.2	2.4	1.7	1.52	1.4

Table 3 compares the energy left in each phase when transmitting data directly and applying the improved LEACH algorithm. In the 500th round, lots of energy is consumed and only 1.1 is left in the former while less than a half is consumed in the latter. In the 1000th, all the energy is consumed over in the former while there are 1.7 left in the latter. The energy is consumed slowly and slowly with the rounds going on, which shows that applying improved LEACH has a better performance on energy consumption and solves the energy problems in WBAN.

Fig.3 illustrates the rounds that all the nodes die under two different scenarios. In Fig.3 (a), the activity area is 50m*50m and there are three ordinary nodes with energy of 4.2, 8.4 and 12.6 respectively. It can be seen that on average more than 2000 rounds are executed till the node dies when applying improved LEACH. This shows that the improved algorithm increases the utilization of energy. In Fig.3 (b), the activity area is 25m*25m. It can be seen that the smaller the area is, the more times the round is executed when applying improved LEACH, i.e. there are about 1000 more rounds to be executed compared with the situation in Fig.3 (a). On the contrary, there are no big changes when transmitting the data directly compared with the situation in Fig.3 (a). Therefore, our improved algorithm is suitable to apply in different network scenarios of different activity areas while increasing the energy utilization and prolonging the life cycle.



(a) 50m*50m (b) 25m*25m

Fig. 3 Life cycle of network under different scenarios

Summary

This paper conducted a deep analysis on WBAN and LEACH algorithm and proposed an improved LEACH algorithm applicable in WBAN. Firstly, we took into account this energy consumption issue and the importance of nodes when defining the formula to select the cluster head. Take electro-cardiograph sensor nodes for example. Its collected data is related to the life of human beings. More energy is needed for this type of sensors in order to maintain the activity of data collection. Then, according to the different monitoring parts of the nodes, different possibilities to be chosen as the cluster heads are required for those nodes. In this way, the sensor nodes monitoring importance parts have a low possibility to be chosen as cluster heads and as a result the energy of those nodes are saved for sending more data. In conclusion, our improved algorithm can reduce the energy consumption and prolong effectively the life cycle of the entire network.

References

[1] LIU Yi and SONG Yu-qing, Study on Wireless Body Area Networks, Journal of Chinese Computer Systems. 8 (2013) 1757-1762.

[2] KONG Ling-shu and YAO Xiang-hua, Low Power Consumption and Rapid Networking Algorithm for WBAN, MICROELECTRONICS & COMPUTER 30(12) (2013) 10-17.

[3] DONG Yunpeng and WANG Yinglong et al, Implementation of Data Transmission Scheme for BSN's Intelligent Client, Electronic Sci. & Tech. 27(1) (2014) 125-127.

[4] Gyselinckx, B. and Van Hoof, C. et al, Human++: Emerging Technology for Body Area Networks, 2006 IFIP Int'l. Conf. Very Large Scale Integration, 10 (2006) 175-180.

[5] DENG Shi-zhou and GAO Wei-dong et al, Research status and prospects of WBAN technologies, Transducer and Microsystem Technologies 33(11) (2014) 1-8.

[6] Tehranipoor M and Koushanfar F, A survey of hardware Trojan taxonomy and detection, IEEE Design & Test of Computers 27(1) (2010) 10-25.

[7] Golmie N and Cypher D et al, Performance analysis of low rate wireless technologies for medical applications, Computer Communications 28(10) (2005) 1266-1275.

[8] Cavalcanti D and Schmitt R et al, Performance analysis of 802.15.4 and 802.11e for body sensor network applications, 4th International Workshop on Wearable and Implantable Body Sensor Networks (2007) 9-14.

[9] Rebeiz E. and Caire G et al, Energy-delay tradeoff and dynamic sleep switching for Bluetooth-Like body-area sensor networks, IEEE Transactions on Communications 60(9) (2012) 2733-2746.

[10] Heinzelman W R and Chandrakasan A et al, An application specific protocol architecture for wireless microsensor networks, IEEE Transactions on Wireless Communications 1(4) (2002) 660-670.

[11] SUN Liming and LI Jianzhong et al, Wireless Sensor Networks, in: Tsinghua University Press, Beijing, 2005, pp. 96.

[12] LIU Tieliu and WU Yongqun, A New Energy-Saving Multi-Hop Routing Protocol Based on Clustering for Wireless Sensor Network, Information and Control 41(1) (2012) 27-32.

[13] Handy MJ and Haase M et al, Low energy adaptive clustering hierarchy with deterministic cluster-head selection, Proc. of the 4th IEEE Conf. on Mobile and Wireless Communications Networks (2002) 368-372.