ISSN: 2321-7782 (Online)
Volume 3, Issue 12, December 2015
International Journal of Advance Research in Computer Science and Management Studies
Research Article / Survey Paper / Case Study
Available online at: www.ijarcsms.com

A Survey on Network Longevity and Energy Efficiency in Wireless Body Area Networks

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Abstract: Wireless Body Area Network plays a major role in the field of medicine for monitoring the patients. This monitoring helps the patients to recover soon from the illness. Even it can provide precautionary actions to prevent them from diseases. Network Longevity and nodes energy are the major challenges in the Wireless Body Area Network. Mainly, due to limited supply of energy in the nodes, network longevity is becoming a major challenge. This paper presents the effective techniques and approaches such as energy efficient adaptive routing for WBAN, HEED Approach and Body node coordinator placement algorithms for wireless body area networks to improve the lifetime of the network. To provide a efficient energy to the nodes, Energy efficient MAC protocol for WBAN is provided by using the bandwidth allocation mechanisms and the concept of sleep mode. Thus the network longevity and the nodes energy can be improved by the above mentioned techniques.

Keywords: WBAN, adaptive routing, HEED (Hybrid Energy Efficient Distributed), BNC (Body Node Coordinator), Network lifetime, EAR-BAN (Energy Efficient Adaptive Routing-Body Area Networks).

I. INTRODUCTION

Wireless body area network, an emerging technology consists of small and intelligent sensors which are attached in the patients to monitor physiological activities and actions. It can continuously monitor to prevent and early risk detection by sharing the information with care takers and physicians. Broadly divided into two types wearable body area network which is operated on the surface of body and another is implantable body area network which is operated inside the human body. WBAN sensors are capable of sampling, monitoring, processing and communicating various vital signs. Continuous monitoring can benefit patients as a part of optimal chronic conditions. Physiological sensors can be integrated into a wearable wireless body area network, which can be used for computer-assisted rehabilitation or early detection of medical conditions. This area relies on the feasibility of implanting very small biosensors inside the human body that are comfortable and that don't impair normal activities. These sensors in the human body will collect various physiological changes in order to monitor the patient's health status. The collected information will be transmitted wirelessly to an external processing unit. This is the actual process taken place in the wireless body area network. To have better working performance, lifetime of the network and energy efficiency of the nodes should be properly maintained. But in WBAN, network longevity is the major challenge. Network longevity is mainly due to the limited availability of energy supply.So, it has been improved by means various techniques.

Based upon the quality of data received in WBAN, the quality of health monitoring systems could be recognized [1] .The virtual Group Environment plays a major role in the quality of health monitoring systems.

II. TECHNIQUES AND APPROACHES TO IMPROVE NETWORK LIFETIME AND ENERGY EFFICIENCY

A. Energy Efficient Adaptive Routing for Body Area Networks

Energy efficient adaptive routing which is a cluster based routing .Depending on the energy level and spatial information of the body node; it combines the benefits of direct and multichip transmissions. From this energy efficient adaptive routing [2], the features are more advantageous such as centralized coordination among the cluster set up, less computational processing and also prolongs the network lifetime which is the main consideration in the WBAN.The energy consumption model is used to perform energy efficient adaptive routing.

In EAR-BAN [2], the cluster is formed .A cluster head is selected based on the availability of the nodes energy and even also the type of the node. The considerations are being defined in the setup model and the functionalities are performed in the operational model. Synchronization phase, cluster setup phase, gateway selection phase and centralized cluster formation phase are some of the phases involved in the operational model. These operations are performed in the system model [2], here in this model, body area network of 175 × 175 cm is considered. Both weibull distributions are used for the allocation of the body nodes and the body node coordinator. Log distance path loss model is considered to estimate the path loss between two transceivers of the nodes. Here, for estimation of path loss, on-Line-Of-Sight (NLOS) communication is used since the surface of the human body is uneven. Each node consists of a transceiver and a sensor. Energy limited transceiver, NORDIC nRF24L01 [3], where the operating frequency is 2.4 GHz at −85 dBm (0.1% BER) sensitivity and its maximum data rate is 1 Mbps. Gaussian frequency-shift keying (GFSK) modulation is used by the NORDIC Nrf24l01.Time Division Multiple Access MAC protocol is used where each node is divided into number of timeslots. Each time slot is divided into number of sub slots which is used for data message transmission and reception. Based upon EAR-BAN,it was estimated that network lifetime was prolonged by using the uniform distribution of nodes.Thus,EAR-BAN plays a major role in prolonging of network lifetime.

B. Body Node Coordinator Placement Algorithms

Network longevity is the major challenge due to the limitation of availability of energy supply in the nodes. Therefore routing protocols along with the effective body node coordinator placement algorithms can influence the network lifetime eminently. The body node coordinator placement algorithms are as follows Distance aware BNC placement algorithm-iterative, Distance aware BNC placement algorithm-fixed and Position-aware BNC placement algorithm. These effective body node coordinator placement algorithms has less computation processing when compared to the other node placement algorithms of wireless sensor nodes.

Body node coordinator plays a major role in coordinating the functionalities of all the other nodes. Usually, BNC could be mobile phones and the laptops [4][5]. The recent research [6] has improved the energy efficiency of the network. This will lead to improve the lifetime of the network.

BNC placement in WBAN is similar to the node placement of wireless sensor networks. WBAN differs from WSN by means of path loss model, energy consumption and other hardware architecture. So, it becomes incompatible for the BNC placement. The major requirements for the node placement in WBAN is as follows i) the computational and message exchanging complexity should be less ii)the operation involved should be a centralized one.

1) Distance Aware BNC Placement Algorithm-Iterative:

This is an effective BNC placement algorithm which makes the WBAN to be more energy efficient which in turn improves the lifetime of the network. The BNC placement is performed along with some routing protocols.

The assumptions for the Distance Aware BNC Placement Algorithm-Iterative are as follows: The BNC should be placed either at the border or outside the WBAN and all the other sensor nodes should be placed within the transmission coverage of the WBAN. The BNC, which coordinates the functionalities of all the other nodes, should be aware of the relative transmission distance of all the other nodes from it.

The Procedure followed for this algorithm is as follows: BNC should be placed according to the above mentioned assumptions.BNC calculates the relative distance of all the nodes and finds the D_{min}, D_{max} (min=closest node, ax=farthest node).Then, based upon the minimum and maximum distance calculated, D_{avg} is calculated.D_{avg} gives the intermediate distance between the D_{min} and D_{max}.All the sensor nodes which are assumed should be divided into two subsets such as U_L and U_R. Then the BNC node is now being moved to the location of D_{avg} . Again from the particular location, relative distance of all the nodes is calculated. Finally, the utility factor all the nodes are calculated. Since the two subsets has been made, the utility factor could be easily calculated by summing up the values of U_L and U_R.The certain condition for the process of iteration

If $\frac{sumU_L}{number\ of\ node\ in\ U_L(\#U_L)} \geq \frac{sumU_R}{number\ of\ node\ in\ U_R(\#U_R)}$ Eqn – (1)

U_L>1, then the assumption made by the BNC is considering the subset U_L for the entire process.

If $\frac{sumU_L}{number\ of\ node\ in\ U_L(\#U_L)}$ ⍰ $\frac{sumU_R}{number\ of\ node\ in\ U_R(\#U_R)}$ Eqn – (2)

U_R>1, then the assumption made by the BNC is considering the subset U_R for the entire process.

2) Distance Aware BNC Placement Algorithm-Fixed:

The Distance Aware BNC placement algorithm –fixed is also an effective one for the placement of BNC in WBAN.The requirements and assumptions are similar to the distance aware BNC placement algorithm –Iterative. The computational complexity exhibited by this algorithm is linear complexity where as above mentioned exhibits iterative computation.

The assumptions for the Distance Aware BNC Placement Algorithm-Fixed are as follows: The BNC should be placed either at the border or outside the WBAN and the other entire sensor nodes should be placed within the transmission coverage of the WBAN.The BNC, which coordinates the functionalities of all the other nodes should be aware of the relative transmission distance of all the other nodes from it.

The Procedure followed for this algorithm is as follows: The BNC should be placed same as the distance aware BNC placement algorithm-iterative i.e. it should be place either at the boundary or outside the WBAN. BNC calculates the relative distance of all the nodes and finds the D_{min} ,D_{max} (min=closest node, max=farthest node).Then, based upon the minimum and maximum distance calculated,D_{avg} is calculated.D_{avg} gives the intermediate distance between the D_{min} and D_{max}.All the sensor nodes which are assumed should be divided into two subset such as U_L and U_R. Then the BNC node is now being moved to the location of D_{avg} . Again from the particular location, relative distance of all the nodes is calculated. The utility factor all the nodes are calculated by the BNC.Then it sums up the relative distance and the available energy of each nodes of both the subsets.Correlation(X) is estimated by the BNC based upon the utility factor of all the nodes, which in turn helps us to find the discrimination distance. The discrimination distance determines the optimal location of the BNC.Finally; the BNC is placed in the optimal location. The user defined constant is used which determines the tolerance limit of the estimated value.

3) Position Aware BNC Placement Algorithm:

Position Aware BNC placement algorithm exhibits linear computational complexity. When compared to Distance Aware BNC Placement Algorithm-Iterative and Distance Aware BNC Placement Algorithm-Fixed, it has less computational complexity. Instead of relative distance, here in this algorithm it assumes spatial coordinate information of the node.

The assumptions for the Position Aware BNC Placement Algorithm- are as follows :The sensor nodes should be placed within the transmission coverage of the WBAN.The BNC should be aware of the spatial coordinates of all the nodes.

The Procedure followed for this algorithm is as follows: The BNC should be placed within the transmission coverage of the WBAN.BNC measures the relative distance of all the nodes only based upon the coordinate space of the nodes. Then the utility factor of the available nodes is calculated. The utility factor is calculated based on the available energy of the node and the relative distances.UF denotes the utility factor of all the available nodes and where as the uf denotes the utility factor of each node. Among the estimated utility factor of all the available nodes i.e. (UF), the maximum UF should be determined .From the determined UF, the utility factor of each node (uf) is found.

For node i, $$uf_i = \frac{\max_{j:N_j \in U_j} UF - U_j}{maximum\ value\ of\ UF\ among\ all\ UF\ (\max_{j:N_j \in U_j} UF)}$$ Eqn – (3)

From this, the maximum value of utility factor (uf) is determined and it is normalized to each node. This in turn produces X.Each node possess their own X.Then all the available nodes multiply their X with their respective coordinates. Finally, the obtained result is divided by the number of nodes available in the WBAN.

Thus these effective BNC placement algorithms along with multi hop routing protocols has increased the lifetime of the network.

C. *Heed: Hybrid Energy Efficient Distributed Clustering Approach*

In sensor networking, controlling of topology balances the load on sensor nodes. This makes the network lifetime to be scalable and efficient. HEED approach that periodically selects the cluster head according to the hybrid of the nodes residual energy. It provides guarantee for the connectivity of the clustered network based upon the density of the node and also transmission range such as intra cluster and inter cluster.

The two parameters have been made. One is to select the initial set of cluster heads and another is to provide break ties. The break tie is nothing but the node that falls within the range of more than one cluster i.e. transmission power level used for clustering. The cluster power level determines the amount of cluster formation. The intra cluster communication could also be considered as the parameter. Here the function of the cluster size and verifying the power level variable for intra cluster communication. Node degree is one of the parameter used to distribute among the cluster heads. If dense cluster is to be formed, 1/Node degree [9] is used.

Make a assumption that 1000 nodes are uniformly distributed in the field of dimension 2000mx2000m.Minimum number of probability for the cluster head formation is considered to be 0.0005[9].

Based on their residual energy, the tentative cluster heads are randomly selected. When compared to generic clustering, the number of cluster heads selected in HEED is having more number of residual energy. This can be used for constructing energy-efficient hierarchies for routing protocols. More residual energy should be there for higher tier nodes. Mainly for sensor applications which need efficient data aggregation, to prolong network lifetime, HEED Approach plays an effective role.

In the HEED operation, single hop communication among cluster heads is assumed. This is most suitable for the source-driven networks in which reports are periodically transmitted by the sensor nodes. A TDM frame is constructed at each cluster head. This helps to eliminate interference within a cluster. This construction requires node Synchronization. Multihop routing to the cluster head can increase network capacity. To address the issue of single-hop versus multihop routing in clustered networks [10][11],the mentioned papers are referred. The importance of this approach is to exploit the availability of multiple transmissions of power levels at the sensor nodes. The HEED protocol terminates in a constant number of iterations which is independent of network diameter. HEED parameters, [9] such as the minimum selection probability and interval of network operation, makes to easily to optimize resource usage .This is mainly according to the network density. A multihop intercluster network is achieved when a specified density model and a specified relation between cluster range and transmission range is held. Thus, HEED approach is effective in prolonging the network lifetime and it supports scalable data aggregation.

D. Energy Efficient TDMA Based MAC Protocol for WBAN

An energy efficient MAC protocol (Body MAC) which uses flexible bandwidth allocation mechanisms to improve node energy efficiency by reducing the possibility of packet collisions and by reducing radio transmission times and control packets overhead. Mainly to reduce the idle listening, an efficient sleep mode is introduced.

1) Burst Bandwidth:

Based upon the characteristic of the data traffic from the nodes to the gateway, the resource allocation algorithm in the gateway can have different types of resources [12] such as Burst bandwidth, Periodic bandwidth and adjust bandwidth.

For several MAC Frames, Burst bandwidth provides a temporary period of bandwidth which can be recycled only by the gateway. The initial bandwidth is denoted by the BURST LENGTH where the request is made by the node from the gateway. The Burst length becomes half of the previous one if the gateway couldn't able to find the burst bandwidth. To represent the burst bandwidth is not currently used in the MAC frame, an acknowledgement message is being sent to the node. In such a scenario, the burst length will be reduced to both the node and the gateway.

2) Periodic Bandwidth:

Based on the QOS requirement and the present availability of the bandwidth, periodic bandwidth is used. Normally, the periodic bandwidth is allocated by the interface and it allows nodes to have access with the channel within the MAC Frame. For example, if a node requests the gateway to release its particular periodic bandwidth, the periodic bandwidth has to be recycled by the respective gateway. The data transmission used in periodic bandwidth is the data packet or control packet.

3) Adjust Bandwidth:

This bandwidth determines the required amount of bandwidth to be added or removed from the previously generated periodic bandwidth same as the burst and the periodic bandwidth, the request is made. The gateway will generate a response message i.e. bandwidth adjustment result. If necessary when gateway is in need to reduce the bandwidth it informs the node about the recent periodic bandwidth.

3) Sleep Mode:

When there is no data transmission, the sleep mode helps the nodes to move on to sleep state by switching off their radios. The node which is in sleep state cannot able to perform any reception operations. Even they could not be aware about the information which is broadcasted. Since the wireless body area network possess [12] low duty cycle application and also no downlink data to the node has mainly motivated for the design of the sleep mode for body MAC.

The sleep mode is processed in three steps such as sleep mode request, sleep mode grant and sleep mode wakeup. The sleep mode process begins by sending the sleep mode parameters such as start frame num and sleep duration to the gateway. In turn, the gateway sends the acknowledgement message to the node indicating that the sleep mode request has reached them. Based upon the QoS requirements and the traffic characteristics, the nodes decide their respective parameters. The gateway sends the sleep mode grant to the node which indicates whether sleep mode request has been accepted or not .The sleep mode parameters are mainly decided by the gateways.

If GTS resources have been allocated, the node can transmit the data packets to the gateway even during the sleep duration. In this case the GTS could be used as a synchronization procedure. The acknowledgement message such as frame number and slot number has been sent by the gateway. Then adjustments are made according to the information obtained.

The major advantage is that the end to end delay has been reduced by the burst bandwidth allocation mechanism. Thus the TDMA based MAC protocol has provided better performance in terms of energy saving .Thus in turn leads to improve the energy efficiency of the node.

III. Discussion

We have discussed about the existing approaches and techniques to improve the lifetime of the network and energy efficiency of the node in the Wireless Body Area Network.Mainly, the network longevity is one of the major issue in the Wireless Body Area Network.The techniques which have discussed above have both advantage and disadvantage. Among them, the Body Node Coordinator Placement Algorithms Which has been designed especially for Wireless Body Networks has improved the lifetime of the network.

IV. Conclusion

Thus, in this paper, to provide an efficient energy to the node and also to improve the network lifetime, various techniques have been discussed. The various techniques such as HEED,BNC placement algorithms includes Distance Aware BNC Placement Algorithm-Iterative, Distance Aware BNC Placement Algorithm-Fixed and Position Aware BNC Placement Algorithm has improved the network lifetime efficiently with less computational processing rather than the node placement algorithms of Wireless sensor network.

Acknowledgement

I would like to express my sense of profound gratitude to all the People who have helped me to gain more knowledge about research papers .I also wish to thank my guide who has helped me to complete the survey paper successfully and also extend my thanks to many of the journals and the websites which has helped to refer many research papers and make it to publish successfully.

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