ISSN: 2229-6948(ONLINE)
DOI: 10.21917/ijct.2018.0266

AN ENERGY EFFICIENT CLUSTER-HEAD FORMATION AND MEDIUM ACCESS TECHNIQUE IN MULTI-HOP WBAN

Sanchari Saha[1] and Dinesh K Anvekar[2]

[1]Department of Information Science Engineering, MVJ College of Engineering, India

[2]R&D and Product Innovation Cell, Vijaya Vittala Institute of Technology, India

Abstract

In the present era, Wireless Body Area Network (WBAN) has emerged as one of the most desired healthcare technologies. Along with healthcare, its application area includes sports, entertainment, battlefield etc. Any time to time posture and position changes of human beings result in changes in node connectivity of the WBAN associated with them. To cope with this situation, the data cluster heads should be changed and adjusted as per the distance between the various sensor nodes. Also, the cluster head must be accessible to all neighbouring nodes to ensure that each node transfers its data packet to the cluster head. This ultimately increases the reliability of WBAN. Energy efficiency is another most important requirement in WBAN to increase the network lifetime. Selection of cluster head plays a crucial role in improving energy efficiency. In this paper, an energy efficient, integrated cluster formation and cluster head selection method where cluster head can be selected dynamically to achieve high fault tolerance is presented. This work has relevance to multi-hop WBAN environment as cluster-based topology involves minimum two hop communication between sensor node and the coordinator node. The proposed technique involves selection by the cluster head the frames having least interference. Achieving energy efficiency without any data discrimination, considering probabilistic inter-cluster interference as one of the constraints in cluster creation for avoiding collision, elimination of hard clusters, and incorporation of dynamic channel allocation scheme in CH selection for efficient utilization of the bandwidth and reduction in adverse effects of clustering are the main beneficial features of the technique.

Keywords:

Wireless Body Area Network, Cluster-Head Formation, Sensor, Medium Access, Energy Efficiency

1. INTRODUCTION

In this century, Wireless body area network (WBAN) enables pervasive healthcare applications, environment monitoring and many more. It uses radio frequency-based communication between sensors implanted inside the human body as well as in the surface of the body. Due to energy restriction that it can consume, limited operational capability of sensor nodes and interference caused by radio communication between sensor nodes, designing an energy efficient WBAN is a challenging task [1]. WBAN uses diverse types of sensors to gather physiological data from human body and contains a centralized personal server (PS) which acts as a gateway between human body and medical server to transfer data with the help of multi-hop communication. Following Fig.1 explains an example WBAN communication scenario.

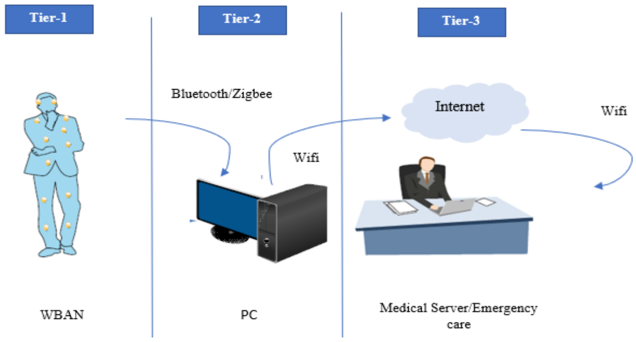


Fig.1. WBAN communication scenario

The Fig.2 presents changes in human body postures depending on time. Tier-1 consists of sensors that sense body temperature, heartbeat, glucose level, pulse rate and other required data and through Bluetooth or Zigbee transfers to personal coordinator in tier-2. Tier-2 is responsible for sending this collected data to medical server in tier-3. Tier-3 consists of medical server or health care provider who are responsible for processing the received data and give medical treatment [2].

To increase network lifetime, WBAN should have energy saving communication among nodes. For this purpose, in this paper we have proposed an energy efficient cluster formation technique for inter-WBAN communication. In inter-WBAN communication, personal server plays the role of an individual node to represent the whole wireless body area network.

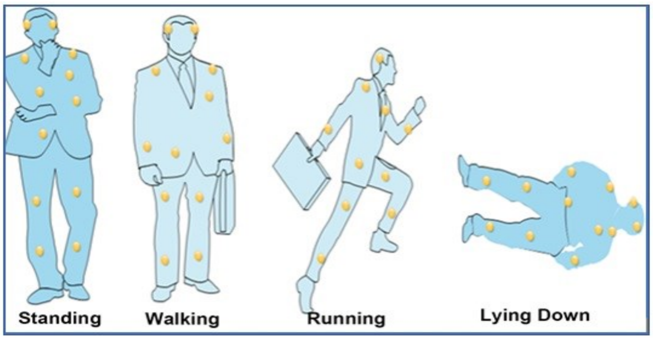


Fig.2. Human body postural mobility

During inter-WBAN communication, personal servers in individual WBAN communicate with each other and among all these communicating personal servers one is chosen as cluster head. Advantages achieved from clustering are: (a) Instead of single data frame, aggregated data is sent to the sink node (b) Node count in data communication is reduced (c) Energy consumption and resource utilization is optimized (d) Scalability for enormous number of nodes can be achieved (e) Reduced communication overhead (f) No more redundant data [3].

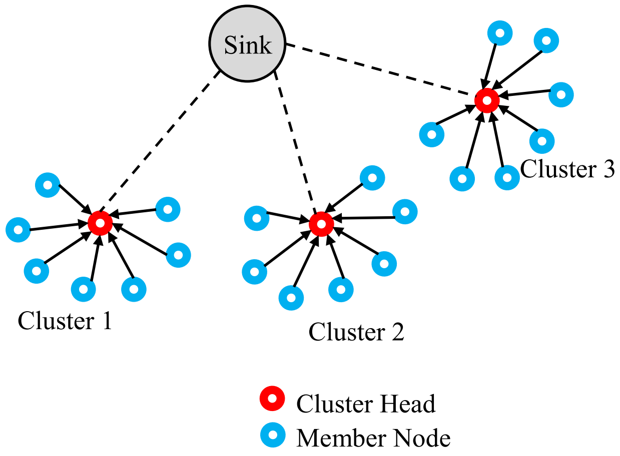


Fig.3. Clustering

As an example, let us consider A, B, C as individual WBAN and PS1, PS2, PS3 as personal server in mentioned WBANs respectively. Then in cluster head-oriented communication, if all these 3 WBANs want to communicate with each other, they will communicate through personal servers only and regular nodes will not take part in the communication.

The paper is organized as: section 1 gives a brief introduction about requirement of cluster head in WBAN communication. Section 2 gives details on cluster head selection. Energy saving mechanism is discussed in section 3. Section 4 explains about cluster formation and maintenance procedure. How cluster head can be selected dynamically is explained in section 5. Section 6 describes creation of listening clusters and finally, concluding remarks are presented in section 7.

2. PROPOSED NETWORK MODEL

In our proposed multi-hop based network model, WBAN users are denoted by U, Wi-Fi gateways are denoted by G. All these WBAN users (U) try to transmit collected sensor data to the medical section via a gateway (G). Every WBAN user consists of either wearable or implanted sensors designated as S, a central coordinator designated as C. The central coordinator can be either a smart phone or a personal digital assistance (PDA). All the sensors (S) send the sensed data to the coordinator (C). This coordinator also can act as a router in transmitting the data to the medical section. The coordinator uses ZigBee communication technology for communicating with the sensors and Wi-Fi or 4G for Inter-network communication.

In our network model, we have considered each WBAN user as a cluster wherein the coordinator is by default the cluster head. The communication is categorized as intra-WBAN and extra-WBAN communication. The intra-WBAN communication is between the sensor nodes and the coordinator, whereas the extra-WBAN communication includes both inter-WBAN communication as well as communication between the gateway and the coordinator.

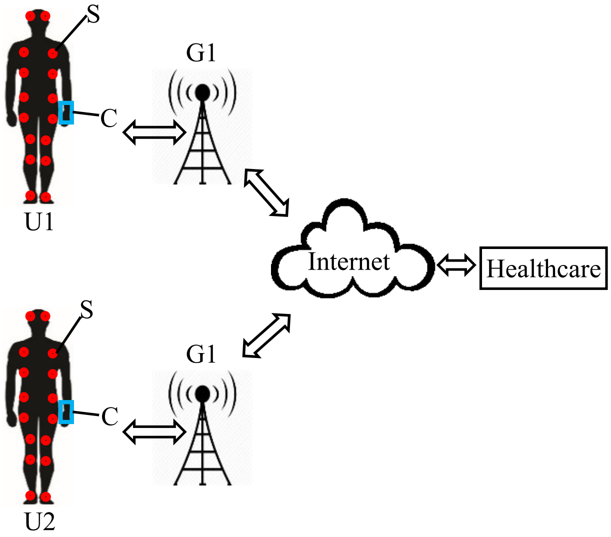


Fig.4. Proposed Network Model

3. CLUSTERING AND MEDIUM ACCESS

The Fig.5 shows clustering snapshot in distributed WBAN nodes. To select an appropriate cluster head, the WBAN needs to be organized into overlapped clusters [5]. For medium access, time is distributed for super frames with duration of $T_{SF.}$ It is matched to the cyclic rate of data frames where each individual super frame contains N_F frames. Each individual data frame contains two sub-frames: (i) control sub-frame which contains beacon slot, cluster-head announcement slot, header slot, contention slot and an information summarization slot (ii) data sub- frame which contains the actual data.

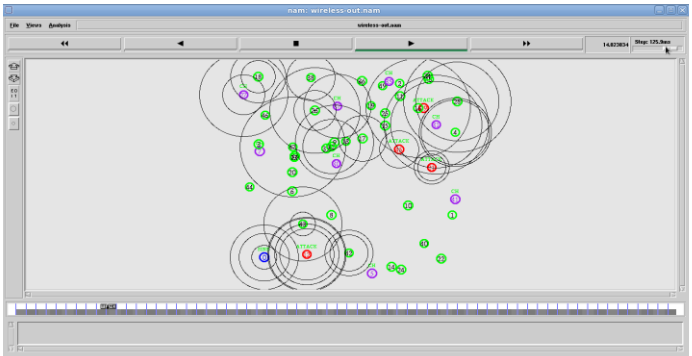


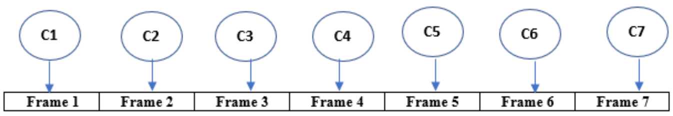
Fig.5. Clustering snapshot

In the beginning of allocated and occupied frame, the cluster head sends a beacon message to announce existence and continuation of cluster to all the cluster members and also to other regular nodes that are in the transmission range of the cluster head. After listening the beacon and cluster head announcement, all the nodes residing in the carrier sense range of the cluster head update their interference level. The cluster head chooses the lowest noisy frame slot to work on and according to the interference level, it dynamically changes the frame slot. By selecting cluster heads of the minimal interference frame, collisions with the members in other cluster heads are reduced.

The contention slot consists of total N_c sub-slots. After hearing the beacon, each individual node which didn't reserve any data slot in previous cycle but has data to send, randomly selects some sub-slot and transmits its data. Without any collision if the contention is successful, a data slot will be granted to the contending node. Following the contention sub-slot, a data transmission schedule of the current frame will be sent by the cluster head.

In the transmission schedule, list of nodes having granted data slots along with their data slot numbers will be included. If any contending nodes does not hear its ID in the given schedule considers that either a collision might have occurred, or all the data slots are occupied. In this case, during next super frame the node again contends. A threshold value T_{drop} is set for waiting time. During contention, if the waiting time for channel access cross the threshold, then the packet is dropped. After the header slot information summarization (*IS*) slot starts. The information summarization slot consists of N_D sub-slots. Before sending the actual data, each scheduled data transmission node first sends a small IS packet which consists of ID of the transmitting node followed by end-of-stream bit. If the bit is set to one, then the node has no data to send.

Depending on this information summarization packet, neighbouring nodes decide whether to stay awake to receive the data or to enter in sleep mode and avoid data reception of unwanted, collided data packets. The IS table acts as a proximity metric for communicating nodes. Top N_{max} closest transmitters are selected by every communicating node to create its own virtual cluster. Here we have proposed to partition the data into enormous count of virtual clusters based on the receivers.



C1= Cluster Head 1; C2= Cluster Head 2; C3= Cluster Head 3; C4= Cluster Head 4;

C5= Cluster Head 5; C6= Cluster Head 6; C7= Cluster Head 7;

Fig.6. Frame allocation to multiple cluster heads

The Fig.6 shows the frame allocation to multiple cluster heads. The data subframe is broken to produce fixed length data slots, which is shown in Fig.7. During reserved data slots only, scheduled nodes in the header transmits data. A node always keeps a scheduled transmission slot as long as it has data to transmit. It enables transmission of uninterrupted real-time data streams. In the IS packet, if a node sets its end-of-stream bit to one, will not be granted next super frame channel access as it has indicated that no more data is there to send.

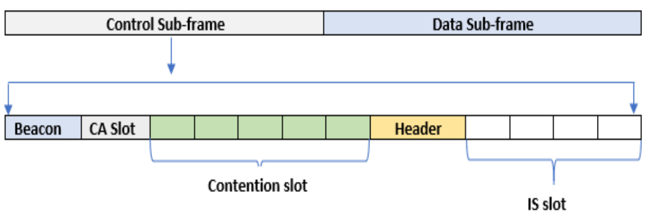


Fig.7. Frame format

4. OPTIMIZATION OF ENERGY CONSUMPTION

Nodes in multi-hop wireless body area network are extremely power constrained. It is not only enough to reduce the overall energy consumption but maximizing network lifetime is also important [5] [6].

In this paper, 3 techniques are proposed to optimize energy consumption.

a) First proposal is to let idle nodes to go in sleep mode whenever possible to reduce energy dissipation in MAC layer. Through this technique, energy dissipation in idle state can be avoided and also chances of reception of collided packets will be reduced.

Any particular node first needs to reach a steady-state mode to enter in sleep mode. If a cluster head transmitted a header packet or any regular node received a header packet within $2T_{SF}$ super frame duration, then it is in steady-state mode otherwise, in start-up mode.

To execute successful cluster head selection process, all the nodes should stay awake and gather control information from all the frames within the super-frame in beacon, IS and CA slot. To receive heard slot of own cluster head, regular nodes may stay awake and cluster heads may stay awake to receive contention requests through their contention slot in their own frame.

b) Second proposal is to avoid the reception of packets in the beginning itself at the MAC layer which has the chances of getting discarded at the higher layers in the protocol stack.

Based on the content of information summarization slot, MAC layer will decide whether to accept or reject the data packets. If no collision is there among the packets and all the packets need to be received, then every node will be awake for all the transmissions in its range and will be in sleep mode in empty data slots. In this way, energy efficiency will be achieved without any data discrimination.

c) Third proposal is to employ data discrimination through virtual cluster creation for further energy saving.

5. CLUSTER FORMATION AND MAINTENANCE

Most of the existing clustering algorithms are deterministic. For a given node distribution, they create fixed clustering and, they do not consider interference as constraint for cluster creation [4].

But in our proposed approach to form a cluster, only interference level in different time frames is required to know which comparatively reduces the overhead. Also, our proposed clustering scheme is not based on connectivity information where some amount of bandwidth needs to be used to collect multi-hop connection information.

In our proposed scheme same frequency and time division among the clusters is used to avoid inter-cluster interference. It enables every single node present in the network not only to receive the data packets from same cluster nodes but also to receive all the desired data packets in its reception range. As the clusters themselves only assigns time slots to nodes for data transmission therefore, our proposed clustering scheme does not create hard clusters.

In the beginning phase, to create interference table for every individual frame within a super frame, nodes will listen to the medium for detecting any ongoing transmission for at least 1T super frame duration.

If any cluster head is detected within its receiving range, then the nodes will start their regular operation. While doing so, if more than one beacon is heard then the node which is closest with higher received power will be chosen as cluster head. If no beacon is heard, then the least noisy frame with random time is chosen to transmit own beacon signal and listens to the channel till the expiry of contention timer. During this if any beacon is heard, then timer is stopped, and normal operation is started. When the timer expires, the node assumes cluster head position and sends a beacon. If any beacon collision happens, then no colliding node will be aware of it except other regular nodes which will only hear the collision and therefore initial startup will continue. Only the cluster heads can measure the received power level from other cluster heads and can measure distance from other cluster heads. Cluster formation process is presented as a flow chart in Fig.8.

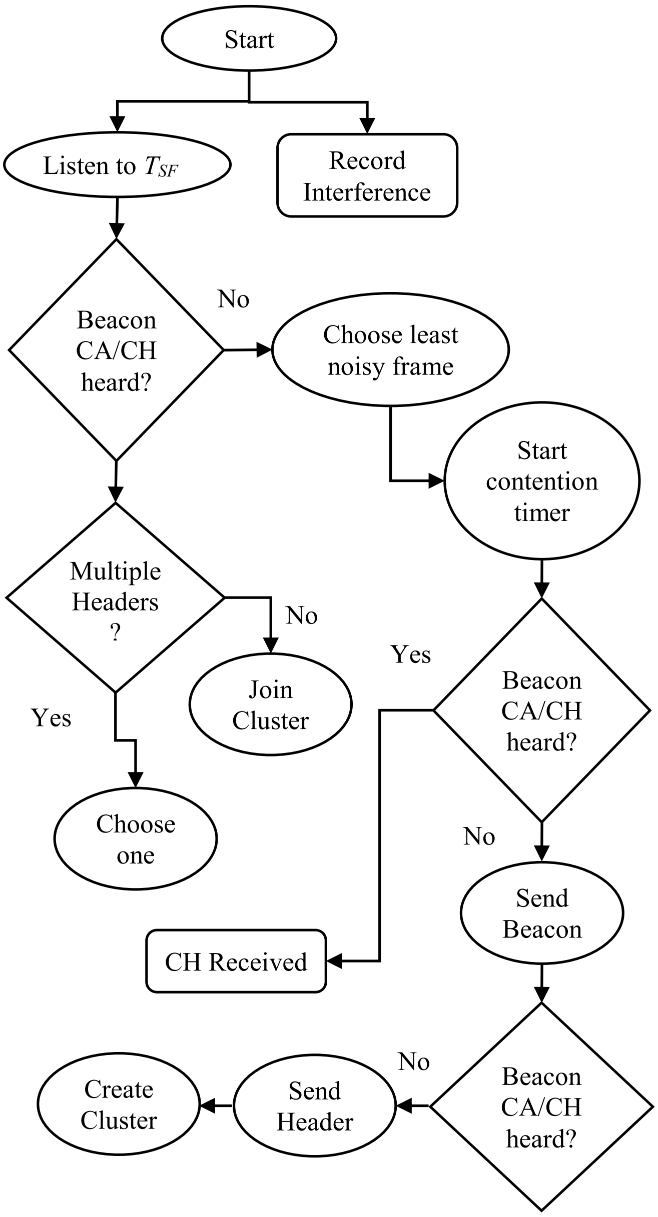


Fig.8. Cluster formation Flowchart

Until and unless another different cluster head enters in the same receive range, cluster heads operate in steady state only. When two cluster heads collide i.e. enters in each other's receive range, the one which receives the other cluster head's beacon leaves first. Cluster maintenance is presented as a flow chart in Fig.9. If for $2T_{SF}$ duration any node does not receive a beacon from its cluster head, then the node enters the initial startup procedure. It happens either due to mobility of the node or cluster head or due to the failure of the cluster head.

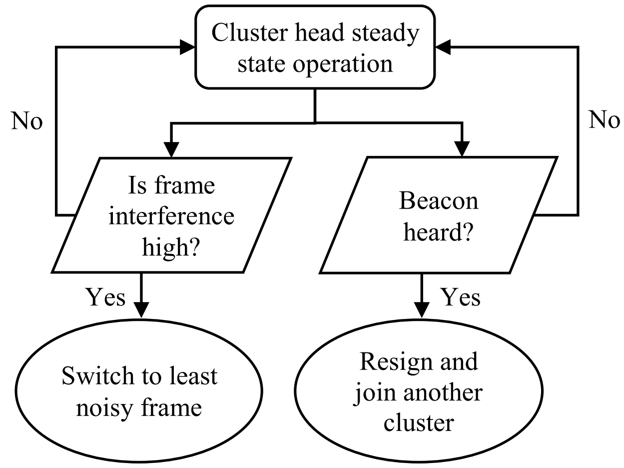


Fig.9. Cluster maintenance flowchart

6. DYNAMIC CLUSTER HEAD SELECTION

Most of the time, network traffic is not uniformly distributed. Some part of network will have higher traffic then the other part. Due to this, some clusters which can support more channel allocations will get only few requests which will lead to underutilization of resource. In another side some clusters which can support only limited channel allocation can get more requests and thereby resulting in call blocking [7]. Enormous number of nodes in WBAN will be having more than one cluster head within their transmit range and for channel access always they prefer to request the nearest cluster head. But if the nearest cluster head's data slot is busy and the second nearest cluster head's data slot is free, then the WBAN node contend for the second nearest cluster head's data slot rather than waiting for the first cluster head's data slot.

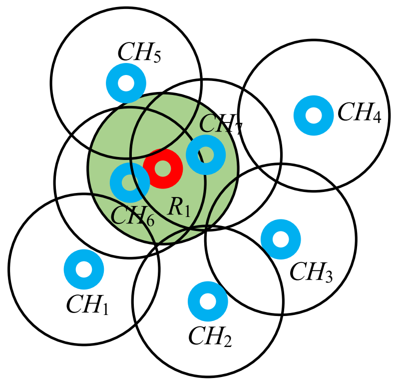


Fig.10. Cluster Partitioning

The Fig.10 shows network partitioning into clusters in WBAN. In Fig.10 nodes CH_1 to CH_7 are cluster heads and their transmission range is represented by circle around them. Node R_1

is a regular or ordinary node and it's receive range is shaded in the Fig.10. It is seen that node R_1 is having three cluster heads CH_5, CH_6 and CH_7 within its receiving range. The most nearby cluster head for R_1 is CH_7 but if the data slot of CH_7 is busy then R_1 can request available data slot either from CH_5 or CH_6. Through our proposed dynamic channel allocation scheme efficient utilization of bandwidth can be achieved and also adverse effects of clustering can be reduced.

7. VIRTUAL CLUSTER FORMATION

Based on the information received from information summarization slot, WBAN nodes decide which data transmission to receive. Every node gets knowledge in advance about transmitting nodes within the range of reception through *IS* packets even if they are not in the receive range of the cluster heads of those transmitting nodes. As an example, node R_1 is able to receive data from the nodes which are members of seven distinct clusters. In this, four cluster heads are not in the receive range of R_1.

The Fig.10, the network is partitioned into clusters. Nodes CH_1-CH_7 are cluster head nodes, and the circles around them show their transmission radius. Node R_1 is an ordinary node with its reception range shown with the shaded disk.

Through this flexible cluster head selection, following advantages can be achieved: First, only when data slots are available nodes can be awake and during other time they can go into sleep mode. Second, in advance itself all the data collisions will be known because when *IS* packets collided, the data packets also will collide.

Table.1. CH Selection acronyms, descriptions

Acronym	Description
CH	Cluster Head
CA	Cluster Head announcement
IS	Information Summarization
T_{SF}	Super Frame duration
T_F	Frame Duration
R1	Regular node 1
PS	Personal Server
MAC	Medium Access Control
Nc	Count of contention slot
N_F	Number of frames within super frames

8. SIMULATION RESULT AND COMPARISON OF LEACH ALGORITHM AND WBAN_CHSM TECHNIQUE

LEACH [8] is the first invented clustering routing algorithm in wireless sensor network. Entire working phase of LEACH algorithm is divided into rounds and each round begins with a setup phase and followed by a steady-state phase. It selects variety of sensor nodes as cluster heads and distributes the energy load among multiple nodes in the whole network so that energy consumption can be balanced and the network life cycle can be prolonged.

Many researches have been done on the improvement of LEACH such as LEACH-MR and TEEN. However, most of them considers the situation that all the nodes have the same initial energy and importance. Also the selection of second–level cluster head is not well adapt to small wireless sensor network like WBAN. Therefore, our paper proposed an efficient cluster head formation and maintenance technique to optimize the energy consumption of the WBAN. In this regard two parameters are compared: count of surviving nodes and left energy.

Table.2. Simulation Parameters

Parameters	Value
Distribution Area	1m×1m
Number of nodes	30
Initial energy of nodes	100mJ
Possibility of nodes becoming Cluster Heads	5%
Rounds	2000
Size of data packet	4000 bit

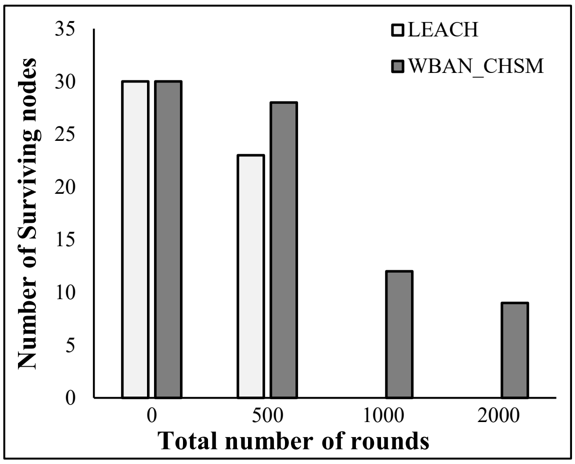


Fig.11. Comparison on count of surviving nodes

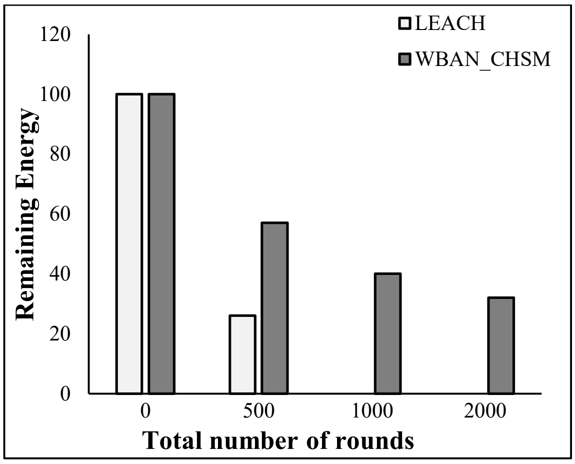


Fig.12. Comparison on left energy (mJ)

9. CONCLUSIONS

In a multi-hop data forwarding scheme, during different data gathering rounds, distance between the forwarding cluster head and intermediate cluster head needs to be maintained almost same, so that equal amount of energy consumption due to their data forwarding towards the base station can be ensured. In a concluding note, our proposed cluster head formation and maintenance technique provides following advantages: First, without any data discrimination, energy efficiency is achieved. Second, our proposed clustering technique is probabilistic. For avoiding collision, inter-cluster interference is considered as one of the constraints in cluster creation. Third, our proposed clustering technique does not create hard clusters. And finally, dynamic channel allocation scheme is incorporated into CH selection and thereby adding one more degree of freedom to achieve the network dynamics to enable efficient utilization of the bandwidth and reduction in adverse effects of clustering.

REFERENCES

[1] Sanchari Saha and Dinesh K Anvekar, "A Poly_Hop Message Routing Approach through Node and Data Classification for Optimizing Energy Consumption and Enhanced Reliability in WBAN", *Proceedings of IEEE International Conference on Smart Nation*, pp. 17-19, 2017.

[2] Marko Kompara, "Survey on Security in Intra-Body Area Network Communication", *Ad Hoc Networks*, Vol. 70, pp. 23-43, 2018.

[3] Mustafa Shakir, Obaidur Ur Rehman, Majeed Ahmed and Mahmood Ashraf Khandata, "Data Collection through Adaptive Cluster Head Selection Scheme in Wireless Body Area Networks", *Proceedings of Research for an International Conference*, pp. 1-6, 2017.

[4] K. Ramesh and K. Somasundaram, "A Comparative Study of Cluster Head Selection Algorithms in Wireless Sensor Networks", *International Journal of Computer Science and Engineering Survey*, Vol. 2, No. 4, pp. 153-164, 2011.

[5] Aftab Ali and Farrukh Aslam Khan, "Energy-Efficient Cluster-Based Security Mechanism for Intra-WBAN and Inter-WBAN Communications for Healthcare Applications", *EURASIP Journal on Wireless Communications and Networking*, Vol. 216, pp. 1-16, 2013.

[6] Bulent Tavli and Wendi B. Heinzelman, "MH-TRACE: Multihop Time Reservation Using Adaptive Control for Energy Efficiency", *Proceedings of IEEE Military Communications Conference*, pp. 1-6, 2004.

[7] K. Vijayalakshmi, S. Jayalakshmi, S. Abinaya, S. Indhumathi and J. Hemavathi, "Dynamic Cluster Head Selection Method for Wireless Sensor Networks", *The SIJ Transactions on Computer Networks and Communication Engineering*, Vol. 5, No. 5, pp. 74-77, 2017.

[8] Jing-Jing Zhang et al., "Research on the WBAN structure based on LEACH Protocol", *Proceedings of International Conference on Advances in Mechanical Engineering and Industrial Informatics*, pp. 1287-1292, 2015.

[9] M.A. Kafi, J.B. Othman and N. Badache, "A Survey on Reliability Protocols in Wireless Sensor Networks", *ACM Computing Surveys*, Vol. 50, No. 2, pp. 31-36, 2017.

[10] Sarah Irum and Aftab Ali, "A Hybrid Security Mechanism for Intra-WBAN and Inter-WBAN Communications", *International Journal of Distributed Sensor Networks*, Vol. 3, pp. 1-11, 2013.

[11] S. Movassaghi, M. Abolhasan, D. Smith and A. Jamalipour, "Wireless Body Area Networks: A Survey", *IEEE Communications Surveys and Tutorials*, Vol. 16, No. 3, pp. 1658-1686, 2014.