SMART MONITORING OF ELECTRICAL PARAMETERS USING CLUSTERING MECHANISM BASED ON BATTERY THRESHOLD AND FUZZY LOGIC

Ms. G. Anitha[1,*]   **Dr. V. Vijayakumari[2]**   **Dr. G. Suchitra[3]**

[1]Department of Electronics and Communication Engineering, Sri Krishna College of Technology, Coimbatore, India.
[2]Department of Electronics and Communication Engineering, Er.Perumal Manimekalai College of Engineering, Hosur, India.
[3]Department of Electronics and Communication Engineering, Government College of Technology, Coimbatore, India.
[*]Corresponding Author Email: anitha1.thangavelu@gmail.com

Abstract: *Wireless Sensor Networks (WSNs) is one of the key and rapidly emerging technology which has a wide range of applications. One of the application is the Electrical System Automation where sensor network place a vital role in monitoring the real time operating conditions of the electrical systems. The Wireless Automatic Meter reading is the key area where sensor networks can be used to gather the energy consumption data for billing without human intervention and for remote deactivation of the service provided to the customer. In order for the proper functioning of the WSNs for a long period of time the sensor networks energy has to be used efficiently. Clustering is one of the key approaches to conserve energy. The proposed novel clustering algorithm, Clustering based on Battery Threshold and Fuzzy Logic (CBTFL) selects the cluster head (CH) in such a way that the energy consumption of the network reduces there by increasing the network life time. The simulation results prove that the CBTFL outperforms LEACH with respect to network life time.*

Keywords: *Wireless Sensor Networks, Electrical System Automation, Wireless Automatic Meter Reading, Clustering, Fuzzy Logic, Network Life Time.*

1. Introduction

Wireless Sensor Network consists of large number of sensor nodes deployed in the area of interest. The sensor nodes are equipped with data sensing, data processing and communication capabilities [1, 2, 3]. They are battery operated and hence it is mandatory that the available energy of the nodes should be efficiently utilized. WSNs have wide applications which include climate monitoring, healthcare monitoring, forest fire detection etc. Nowadays the upcoming applications of WSNs are bringing revolution in human lifestyle which makes things easier. This network has the capability to monitor real time operating conditions and the performance of electric systems. One of the main and upcoming applications is Electrical System Automation. Usually the meter reading is done manually, monthly once. The utility personnel has to go from one house to other and note down the meter readings. In the modern world, this can be automated using WSNs which leads to the Wireless Automatic Meter Reading (WAMR).

The process of collecting the data in wireless manner is cost effective in nature for gathering the billing data of the customers. And few other services along with this also can be provided such that the complete process of meter reading becomes flexible. The meters fitted with the sensor nodes collects the information and the billing information is sent to the electric utility centre and as well as the monitoring personnel of that area. Apart from sending the billing information, suppose if the meter is tampered, the information like an alarm notification is sent to the utility centre. In few cases, the failure of equipment occurs due to nature calamities and this can be easily detected with the help of sensor nodes. So the fault detection can be done easily within a short duration of time and the electric supply can resume soon.

The WSNs advantages prove that it will be beneficial for automation. The benefits are the operation of WSNs in harsh i.e. hostile environment is uninterrupted. It can cover a large area when compared to the human personnel coverage. The accuracy is enhanced because there may be human errors in the traditional method.

So WSNs prove to be very useful in implementing the Wireless Automatic Meter Reading system. The nodes are battery operated which poses to be one of the biggest resource constraints. So as to overcome this, a suitable routing protocol has to be designed such that the network lifetime of the WSN is improved [23].

Hence in this paper, the clustering method is employed for routing. A novel clustering algorithm, Clustering based on Battery Threshold and Fuzzy Logic (CBTFL) is employed where the cluster heads are chosen having the battery threshold in mind and the priority of the nodes becoming CH is provided by the Fuzzy Logic

algorithm. The proposed algorithm proves to be energy efficient when compared to the traditional clustering protocol named LEACH.

2. Literature Survey

Jin Wang et al. have introduced an energy efficient routing algorithm for heterogeneous wireless sensor network with mobile sink. It is a modified SEP protocol that employs mobile sink. The common problem encountered while using fixed sink is the hotspot issue arising near the sink due to multi hop transmission. In this paper, it is proved that by introducing mobile sink the network lifetime of the proposed work is better when compared to LEACH and the number of packets received by sink node is also high [14].

The network is considered to be heterogeneous in nature. Here out of 'n' nodes, a fraction of 'm' nodes have an additional energy 'α'. Using the initial energy level of the normal and advanced nodes the weighted probability is calculated. Using the weighted probability, the threshold for election of CH for a normal node and advanced node is derived. Once the CHs are selected, it sends the information along with its id. The non-CH members get associated with the nearest CH based on the strongest RSS. Now the members of the cluster send data to its CH following the TDMA schedule. Normally the CH sends the aggregated data to the sink. But here the mobile sink collects the data. The mobile sink moves up and down along the centre line. The normal CH checks the distance between itself and the sink trajectory (dt) with the distance from itself to advanced CH (da) and from the advanced CH to the trajectory (dat). If dt is less when compared to da+dat then the normal CH sends the aggregated data to the mobile sink directly or else it forwards the aggregated data to the advanced CH and then the data is sent to the sink. The mobile sink data collection is done as follows. When it moves forward it receives the data from the cluster heads which lies to its left and when it moves backward the collection is from the CHs which lies to its right and this avoids collision. Suppose if an advanced CH dies, then at times data might not be transmitted to the sink and complete reclustering might have to be done. So as to overcome this , the residual energy of the advanced CH is computed.If the residual energy drops below a certain value, then the advanced CH sends a message that it will stop receiving messages. Now the normal CH will get attached to the next nearest advanced CH or it by itself transmits data to the mobile sink.

This paper provides energy balancing and improves the network lifetime. But the constraint over here is the static mobile sink trajectory. It might not be suitable at all times particularly when few node dies or when topology changes.
Peyman Neamatollahi et al. employs Fuzzy based Hyper round policy technique which is distributed, energy aware and scalable. The main aim of this paper is to improve the network lifetime by reducing the clustering overhead.

Initially a node decides its status whether it is a CH or not based on the local information. The information's that are required are the energy of the node and whether a node is its neighbor or not. Each node calculates its waiting time based on its energy level. The waiting time is inversely proportional to the energy level. If the energy level of a node is high then it has to wait for a smaller time period and if the energy level is low then it waits for a longer period. During the waiting time it may receive CH messages from the neighboring nodes. The node which has the highest energy is chosen to be its CH. If it does not receive any CH messages from the neighboring nodes within the waiting time, the node sends a CH message to the neighboring nodes. Based on this it can be said that, node with higher residual energy has higher probability of being elected as a CH and node with low residual energy becomes a normal node [29,15,21,30].

Moreover, CHs will not be in close range with each other because the node in the neighbourhood with highest energy alone is chosen as CH. Here the process is being split into Hyper rounds. Each Hyper round is divided into many rounds. Usually each round will have a set up phase but in this work each hyper round will have a single set up phase thereby reducing the clustering overhead. The Hyper round length is not fixed and it varies based on the sensor node. To determine the length of hyper round, fuzzy based approach is used. Before deciding the HR length, the sink broadcasts the maximum value of HRlength to the entire network. The HR length is calculated based on Relative distance and Relative energy of a particular CH. Now all the CHs calculate its HR length and the shortest computed HR length is the global HR length which will be broadcasted by the sink to all CHs. For the Fuzzy system, Relative distance and Relative energy forms the input and HR length is the output. This methodology of dynamic clustering reduces the clustering overhead which improves the network lifetime and scalability also [4, 5, 11, 12, 13].

Mohammad Shokouhifar et al. have introduced a centralized Fuzzy based clustering algorithm to enhance the network lifetime according to the applications. In this clustering algorithm, there are two phases namely the set up and the steady state phase. In the set up phase, the clusters are formed and then CH is elected in a centralized fashion by the sink. Once the cluster heads are selected, sink broadcasts the message to its non CH members intimating its leadership. It sends the TDMA schedule to its members. Once it is completed, steady state phase begins where the non CH members transmits data to its CH and then CH aggregates the data and sends it to the sink via single hop communication. Initially the clusters are formed using Fuzzy Clustering algorithm (FCA). This ensures that there are balanced clusters. Fuzzy C means algorithm is employed which ensures to reduce the sum of distances between each node and the cluster centroid. Once the clusters are formed, cluster heads are selected using Sugeno Fuzzy Clustering Algorithm. For this fuzzy

system, residual energy, distance from sink and the distance from centroid of the cluster are considered as the inputs. These inputs are selected so as to prevent the nodes having low energy to be elected as cluster head. Distance from sink input ensures that the energy of the CH is minimized and the distance from the centroid of the cluster focuses to reduce the total energy consumed by the members. The output of the Fuzzy system is known as the Impact Factor IF(n). The value of the IF is in the range [0,1]. It is the parameter used for the selection of CH. The node with a larger IF, has higher probability to be the cluster head. The Sugeno Fuzzy rules are optimized automatically using the Artificial Bee Colony Algorithm. This optimization algorithm is executed only once initially and is not executed during every set up phase. The fitness function is calculated using the First Node Dies, Half Node dies and Last Node Dies. Based on the application, weights are assigned for the fitness function. Hence this algorithm when compared with LEACH, LEACH DT, LEACH FL, ASLPR proves to perform better by having balanced clusters and ensures to increase the network lifetime. This algorithm cannot be employed for mobile applications, because it is designed for stationary nodes. For a large coverage area, the overall energy consumption is high because here single hop communication alone is considered [26].

3. CBTFL Protocol

In the proposed protocol, the assumptions made in the network model are as follows:
   a.   Consider "N" number of nodes which are deployed in the region of interest.
   b.   The sensor nodes and the base station are static in nature.
   c.   All the nodes are homogeneous in nature which indicates that the nodes have same amount of initial energy.
   d.   The nodes will die only due to energy depletion.

The energy model employed is the simplified first order radio model. The energy required for transmission (E_T) and reception (E_r) depends on the length of the message and distance between sender and receiver. Equation 1 and 2 describes the energy consumption.

$$E_T = \begin{cases} l\,E_e + l\,\varepsilon_{fs}\,(d*d) & d \le d_t \\ l\,E_e + l\,\varepsilon_{mp}\,(d*d*d*d) & d > d_t \end{cases} \text{----- (1)}$$

$$E_r = lE_e \qquad \text{------------ (2)}$$

$$d_t = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}} \qquad \text{------------ (3)}$$

Where
l - Number of bits in a packet
E_e – Electrical energy required per bit to run the

transmitter or receiver circuit.
d – Distance between the sender and receiver
d_t -threshold distance
ε_{fs} and ε_{mp} are used for free space and multipath fading model respectively

If distance is less than the threshold distance free space model is being used and if it is greater than the threshold distance, multipath fading model is used.

The proposed model employs a clustering technique based on battery threshold and fuzzy logic. Battery threshold concept deals with the fact that, if the battery level goes below 75% of the initial energy the depletion or draining of the battery occurs at a faster rate rather than when the battery power is greater than 75%. So here it is seen that when compared to the other works, the possibility of a node becoming CH uses this concept of battery threshold voltage [.

Another important concept that has been employed is Fuzzy Logic which employs Mamdani Fuzzy System. Usually, the CH is randomly selected or based on the residual energy CH is selected and the clustering process is taken up. But here the fuzzy logic concept is given with three input variables, the residual energy, distance to base station and the data packets to the base station. The output is the chance for a node to become a cluster head or not. The above two concepts along with the basic concept of LEACH proves to improve the network life time of the wireless sensor network [8, 17, 18, 25].

Initially the sensor nodes are deployed in the area of interest. Each and every node generates a random number between 0 and 1. The cluster heads are chosen randomly using the concept of LEACH. The cluster head broadcasts the information of it being the cluster head. The neighbouring nodes, based on the shortest distance join with its cluster head. So now the clusters are formed. Once the clusters are formed, the data is transmitted from the members of the cluster to the cluster head. Once the data is received from the members, the data is aggregated and the aggregated data is sent to the base station by the cluster heads. Once when this process is completed, the residual energy of the CHs is compared with the battery threshold voltage. If the residual energy is greater than the battery threshold voltage the process of data transmission continues, else the CH whose energy goes below the battery threshold voltage cannot continue to be the cluster head.

During this phase, the cluster members of the cluster, whose CH resigns from its position, sends their data namely the residual energy, distance to BS and data packets to BS, to the sink. Now the sink executes the Fuzzy Logic Algorithm and the node with the highest priority of becoming CH is found. This data is sent to the cluster. Now the new CH is selected for the clusters which had to go for a new Cluster Head. Now the steady state phase of data transmission continues and the whole
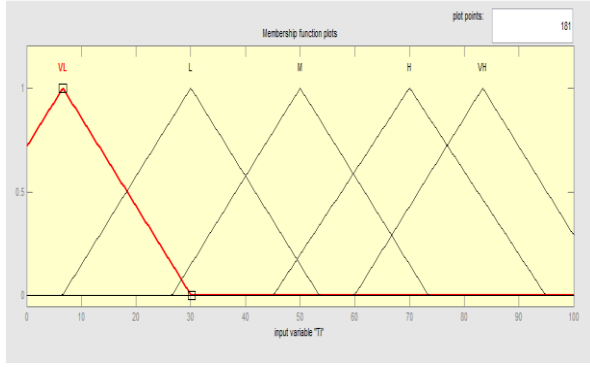
process is repeated.

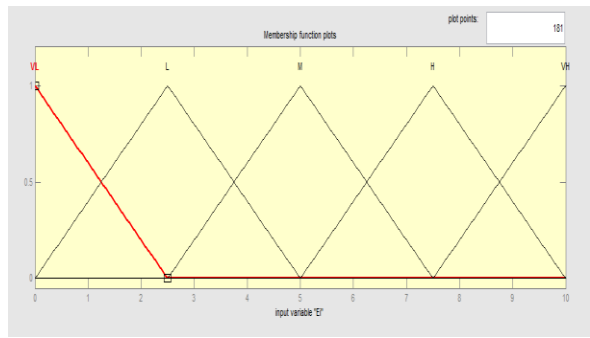**Figure 1: Membership Function for Number of packets to base station**

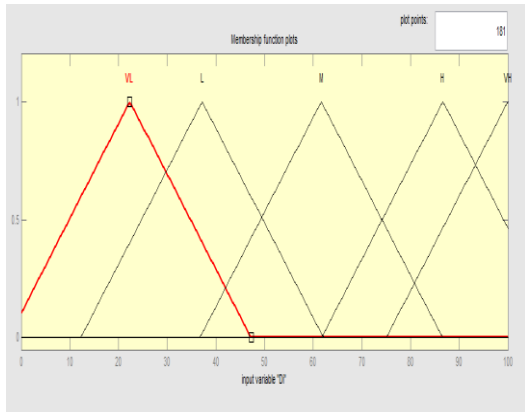**Figure 2: Membership Function for residual energy**

Figure 3: Membership Function for Distance from the node to base station

It can be seen that at one point of time all he nodes of a particular cluster might not be dead but might have energy level less than the battery threshold voltage. Under such circumstances, Fuzzy Logic Algorithm alone is employed and the energy checking is done with respect to the minimal energy.

CBTFL protocol ensures to improve the energy efficiency and thereby improves the network lifetime.

4. Results and Discussion

The performance of CBTFL is compared with the standard clustering protocol named LEACH. The performance of the protocols is compared with the help of the simulation results obtained using MATLAB software. The various performance metrics used for comparison includes number of alive nodes, average energy of each node, number of data packets to base station. The simulation is carried out for 200 nodes and the number of rounds is 200. The data packet size is 4000 bits. The parameters used for the simulation is listed in table 1.

Table 1: Simulation Parameters

| Network Parameters	Value
Number of nodes	200
Initial energy	0.1 J
Energy dissipated per bit to run the transmit circuitry, E_{tr}	50 nJ
Energy dissipated per bit to run the receiver circuitry, E_{rr}	50 nJ
Energy dissipated per bit to run the Transmit amplifier in free space model, E_{fs}	10 pJ
Energy dissipated per bit to run the Transmit amplifier in multipath fading model, E_{mp}	0.0013 pJ
Energy spent for data aggregation, E_{DA}	5 nJ
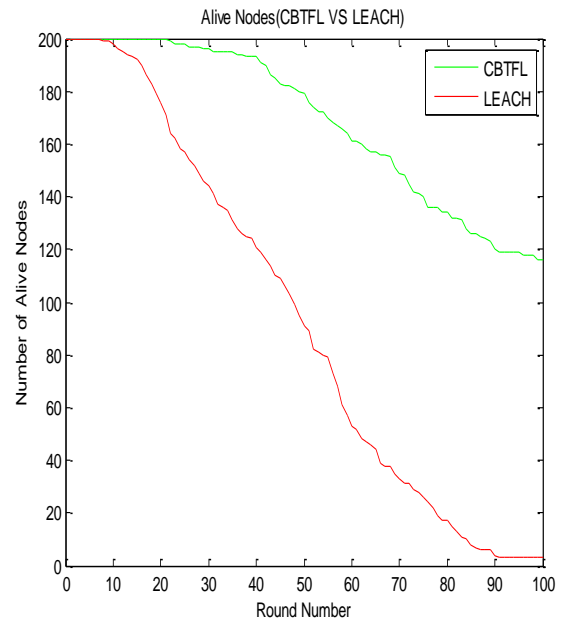
Figure 4: Rounds vs No. of alive nodes

The above Figure 4 shows that the number of alive nodes in CBTFL is promising when compared to LEACH. This improves the stability and the network lifetime of the wireless sensor network. The improvement of CBTFL is 10 times when compared to LEACH with respect to the alive nodes count. Figure 5 illustrates the average energy of the nodes with respect to the number of rounds.
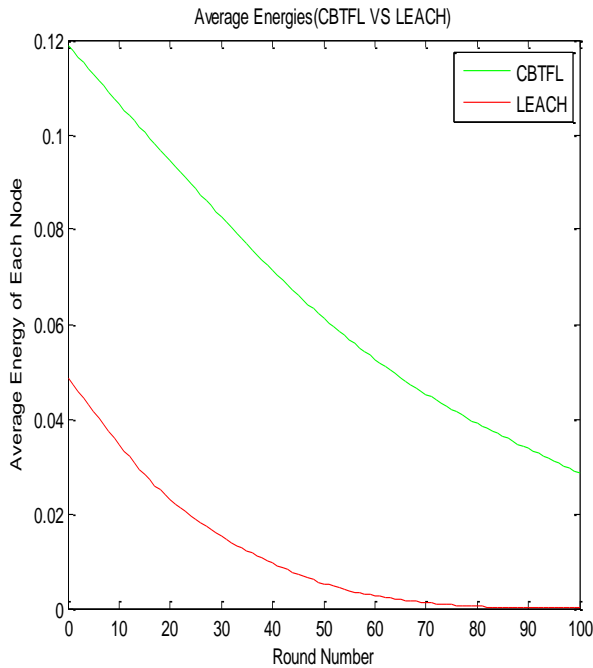

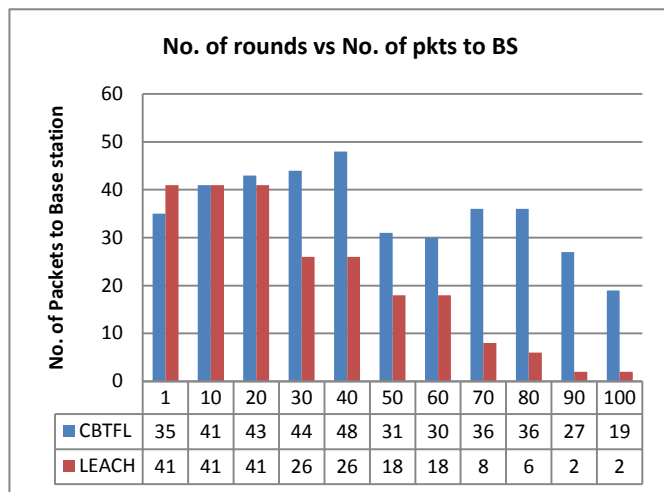**Figure 5: Rounds vs Average energy of each node**

Figure 6: Rounds vs no. of packets to Base station

The number of data packets transmitted to the base station is almost same for nearly 20 rounds as shown in Figure 6. There is a drastic difference after 20 rounds because of the employment of battery threshold concept

and fuzzy logic. This ensures that the throughput of CBTFL is promising when compared to LEACH.

5. Conclusion

The proposed method, Clustering based on Battery Threshold and Fuzzy Logic (CBTFL) employs a novel technique to select the cluster head. Initially the node can be elected as CH only if its energy is greater than the battery threshold voltage. The nodes which have energy greater than the threshold sends its residual energy distance to BS and number of data packets to BS as inputs to the fuzzy system. The output of the Fuzzy Logic gives the priority list of nodes that can become CHs. Simulation results ensures that the lifetime of the sensor network is maximized and the throughput is also enhanced in the proposed method. This method will prove to be effective when it is employed for the Wireless Automatic Meter Reading system. This will improve the electric utility services by reducing the human intervention. In the monitoring system the latency might lead to taking up wrong decisions and hence latency has to be considered, which can be addressed as a future work.

References

1. I.F. Akyildiz , W. Su, , Y. Sankarasubramaniam, E. Cayirci, (2002) Wireless sensor networks: a survey, Computer Networks Vol. 38, No. 4, pp. 393–422.
2. W. B. Heinzelman, A. P. Chandrakasan, and H. Balakrishnan,(2002). An application-specific protocol architecture for wireless micro sensor networks, IEEE Trans. Wireless Commun., vol. 1, no. 4, pp. 660–670.
3. Moussaoui, A. Ksentini, M. Naimi, M. Gueroui, (2006). A novel clustering algorithm for efficient energy saving in wireless sensor networks, in: Computer Networks, 2006 International, Symposium on, IEEE, pp. 66– 72.
4. Haining Shu, Qilian Liang, and Jean Gao, Wireless Sensor Network Lifetime Analysis Using Interval Type-2 Fuzzy Logic Systems, IEEE Transactions On Fuzzy Systems, VOL. 16, NO. 2, APRIL 2008
5. Chih-Lyang Hwang, Associate Member, IEEE, and Nai-Wen Chang, (2008) "Fuzzy Decentralized Sliding-Mode Control of a Car-Like Mobile Robot in Distributed Sensor-Network Spaces", IEEE Transactions On Fuzzy Systems, VOL. 16, NO. 1.
6. J. Yang, M. Xu, W. Zhao, B. Xu, (2010.).A multipath routing protocol based on clustering and ant colony optimization for wireless sensor networks, Sensors 10 (5) 4521–4540.
7. R.Maheswar, Jayaparvathy, Performance Analysis of Cluster based Sensor Networks Using N-Policy

M/G/1 Queueing Model. European Journal of Scientific Research, 58(2), 177-188, (2011).

8. R.Kanagachidambaresan, Sarma Dhulipala, V.R., Vanusha, D., Udhaya, M.S, (2011). Matlab Based Modeling of Body Sensor Network Using ZigBee Protocol. CIIT 2011, 773-776.

9. Hoda Taheriet.al., (2012). An energy-aware distributed clustering protocol in wireless sensor networks using fuzzy logic, Ad hoc Networks 10), pp. 1469-1481.

10. R.Maheswar, Jayaparvathy, Performance Analysis of Fault Tolerant Node in Wireless Sensor Network. Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering book series, 108, 121-126, (2012).

11. S. H. Kang and T. Nguyen, (2012). Distance based thresholds for cluster head selection in wireless sensor networks, IEEE Commun. Lett., vol. 16,no. 9, pp. 1396–1399.

12. Vaibhav Godbole, (2012). Performance Analysis of Clustering Protocol Using Fuzzy Logic for Wireless Sensor Network, IAES International Journal of Artificial Intelligence, Vol. 1, No. 3, pp. 103-111.

13. Haifeng Jiang, Yanjing Sun, Renke Sun, and Hongli Xu, Fuzzy-Logic-Based Energy Optimized Routing for Wireless Sensor Networks, International Journal of Distributed Sensor Networks, 2013.

14. Jin Wang, Zhongqi Zhang, Feng Xia , Weiwei Yuan and Sungyoung Lee. (2013) An Energy Efficient Stable Election-Based Routing Algorithm for Wireless Sensor Networks, SENSORS, ISSN 1424-8220.

15. Padmalaya Nayak, D. Anurag, (2013). A Fuzzy Logic based Clustering Algorithm for WSN to extend the Network Lifetime, IEEE Sensors Journal, Vol. 16, No. 1, pp. 137 – 144, 2016.

16. Thakkar and K. Kotecha, (2014). "Cluster head election for energy and delay constraint applications of wireless sensor network", IEEE Sensors J.,vol. 14, no. 8, pp. 2658–2664.

17. R.Kanagachidambaresan, Sarma Dhulipala, (2014). V.R.: Cardiac Care Assistance using Self Configured Sensor Network – a Remote Patient Monitoring System. J. Inst. Eng. India Ser. B 95(2), 101-106.

18. R.Kanagachidambaresan, Chitra, A.(2014). Fail Safe Fault Tolerant Mechanism for Wireless Body Sensor Network. Wireless Personnel Communications, 78(2).

19. M. Tarhani, Y. S. Kavian, and S. Siavoshi, (2014). SEECH: Scalable energy efficient clustering hierarchy protocol in wireless sensor networks, IEEE Sensors J., vol. 14, no. 11, pp. 3944–3954.

20. MeLike Yigit, Cagri Gungor, Etimad Fadel, Laila Nassef, Nadine Akkari, Ian F. Akyildiz, (2016). Channel-aware routing and priority-aware multi-channel scheduling for WSN-based smart grid applications, Journal of Network and Computer Applications, Vol 71, pp. 50-58.

21. Ado Adamou Abba Ari, Blaise Omer Yenke, Nabila Labraoui, Irepran Damakoa, Abdelhak Gueroui, (2016). "A power efficient cluster-based routing algorithm for wireless sensor networks: Honeybees swarm intelligence based approach", Journal of Network and Computer Applications, Vol 69, pp. 77-97.

22. D. Jia, H. Zhu, S. Zou, and P. Hu, (2016). Dynamic cluster head selection method for wireless sensor network, IEEE Sensors J., vol. 16, no. 8, pp. 2746–2754.

23. V. Cagri Gungory, Frank C. Lambert, (2006) A Survey on Communication Networks for Electric System Automation, Computer Networks, Elsevier, Volume 50, Issue 7, Pages 877-897.

24. Z. Xu, L. Chen, C. Chen, and X. Guan, (2016). Joint clustering and routing design for reliable and efficient data collection in large-scale wireless sensor networks, IEEE Internet Things J., vol. 3, no. 4, pp. 520–532.

25. Ashraf Darwish, G.R. Kanagachidambaresan, R. Maheswar, Kamalajith I Laktharia and V. Mahima, (2017). "Buffer Capacity Based Node Life Time Estimation In Wireless Sensor Network", The Eighth IEEE International Conference On Computing, Communication And Networking Technologies (ICCCNT), IIT Delhi, 3rd-5th July.

26. Mohammad Shokouhifar, Ali Jalali, (2017) Optimized sugeno fuzzy clustering algorithm for wireless sensor networks, Engineering Applications of Artificial Intelligence, Elsevier

27. De-gan Zhang, Si Liu, Ting Zhang and Zhao Liang, (2017).Novel unequal clustering routing protocol considering energy balancing based on network partition & distance for mobile education, Journal of Network and Computer Applications, Vol. 88,

28. P.Jayarajan, R. Maheswar and G.R. Kanagachidambaresan (2017) , Modified Energy Minimization Scheme Using Queue Threshold Based on Priority Queueing Model, Cluster Computing

29. Peyman Neamatollahi, Mahmoud Naghibzadeh, and Saeid Abrishami, (2017) Fuzzy-Based Clustering-Task Scheduling for Lifetime Enhancement in Wireless Sensor Networks, IEEE SENSORS JOURNAL, VOL. 17, NO. 20,.

30. Raja Al-Kiyumi, Chuan Heng Foh, Serdar Vural, Periklis Chatzimisios, Rahim Tafazolli, (2018). Fuzzy Logic-based Routing Algorithm for

Lifetime Enhancement in Heterogeneous Wireless Sensor Networks, IEEE Transactions On Green Communications And Networking, Vol 99.