Comparative Analysis of LEACH, ILEACH, SEP and HCR using MATLAB

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Abstract—*In this paper the comparative study of LEACH, SEP and HCR, had done because these protocols are cluster based protocols, which divides the sensor network into smaller zones, trying to distribute the load equally among the nodes. By the use of advance nodes the total initial energy of the whole network is increased by 1+a*m times. SEP provides more stability period in the life time of the network than LEACH. Both protocols have a very little difference of stability. The total energy dissipated by the network is decreased in both cases. The question answered here is the effect of increase in node energy on the different network parameters. ILEACH overcomes some of the drawbacks of the LEACH like improvement in the stability period of the network. The cluster head selection mechanism is approximately common in all four protocols except that in SEP weights are assigned to optimal probabilities of the nodes to be the CHs. The fraction of advance nodes is made equal to 1, which implies that all nodes are advance nodes in ILEACH. HCR provides maximum packet transfer rates, and more packets are transmitted to BS per round. ILEACH provides maximum stability than other three protocols. Further improvements can be done to the proposed protocol. HCR performance under different cluster sizes explains the effect of the change in cluster size. Simulink software that comes along with MATLAB was used to simulate the proposed model.*

Keywords : LEACH, SEP and HCR, BS,CHs,ILEACH

I. INTRODUCTION

Wireless sensor network (WSN) [1-3] consist of hundreds and even thousands of tiny devices called sensor nodes distributed autonomously to monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, and motion at different locations. Energy plays an important role in wireless sensor networks because nodes are battery operated. Consequently, many protocols have been proposed in order to minimize the energy consumption of these nodes. Each node in a sensor network is typically equipped with one or more sensors, radio transceiver devices, a small microcontroller, and an energy source. Since in most WSN applications, the energy source is a battery, energy plays an important role in wireless sensor networks, and conserving the energy consumed by each node is an important goal that should be considered when developing a routing protocol for WSNs. In general, routing in WSNs [4] can be classified into flat, hierarchical, and location-based routing, depending on the network structure. Hierarchical routing is a well-known technique with special advantages related to scalability and efficient communication. Low energy adaptive clustering hierarchy (LEACH), power-efficient gathering in sensor information systems (PEGASIS), threshold sensitive energy efficient sensor network protocol (TEEN) [5], and APTEEN use this technique for routing. In hierarchical architecture, higher energy nodes can be used to process and send the information, while low-energy nodes can be used to perform the sensing in the proximity of the target. In this paper, we propose the improved LEACH (ILEACH) protocol that selects cluster heads using different thresholds. The new cluster head selection probability is calculated from the initial energy and the number of neighboring nodes. On a rotating basis, a head-set member

The name wireless sensor network (WSN) consists of three words wireless + sensor + network Wireless means having no wired connection, using wireless media for communication. Sensor is a device having some sensing capability, like sensing the humidity. Network is a collection of different types of nodes like sensor nodes , routers, printers etc. A WSN consists of a large number of sensor nodes in hundreds or thousands. Each sensor node consists of different components which work together to act like as sensor and can sense for some particular application. These units are: a) Sensing unit: which sense the events occurring around it. b) Processing unit: which computes the results based on the sensed information by sensing unit. c) Transmission unit: transmits the computed results to the base station. d) Mobility monitoring unit: monitors the mobility of node to check whether it is mobile or stationary. e) Position finding unit: finds the position of each node, which helps each node to calculate the distance from its neighbors. f) Power Supply unit: provide the energy to all other components of the sensor node . g) ADC: converts the alternate voltage to direct voltage. To improve the quality of service each sensor node can communicate and coordinate with each other. Each sensor node has sensing, computation, and communicational capabilities. Each sensor node has information which it sense and provided by its neighbors. The quality of result which is produced by the sensor node depends upon the above said utilities. The calculated result is then supplied to all its neighbors or to the Base Station. Base Station is a node which queries for data to sensor node and collects the result from the sensor node. A base station can be mobile or fixed.

II. ROUTING PROTOCOLS IN WSN

Three main classifications of routing protocols are:-

Proactive:- Routes from each node to the base station are predefined.

Reactive:- Routes from each node to the base station are defined when there is a demand for the route

Hybrid:- Some routes are predefined and some are defined after the demand is raised.

Other general classifications are: - Based on the structure of the network and Based on the operation of the protocols shown in Fig.1.

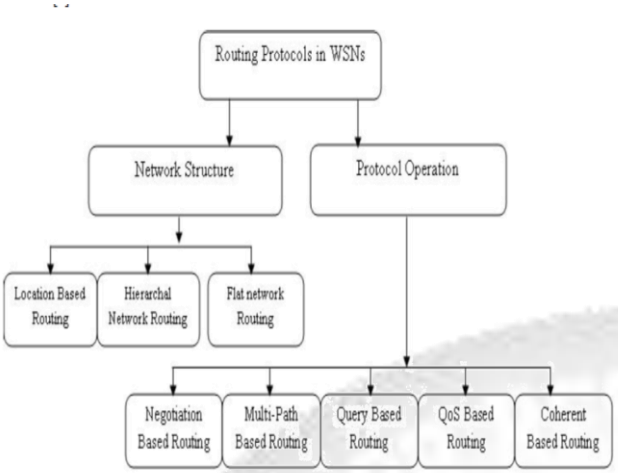


Fig. 1: classification of routing protocols

III. LEACH PROTOCOL

The LEACH protocol for sensor networks, proposed by Heinzelman et al. [13], minimizes energy dissipation in sensor networks. It partitions the nodes into clusters, and in each cluster, a dedicated node with extra privileges called a cluster head (CH) is responsible for creating and manipulating a time division multiple access (TDMA) schedule and sending aggregated data from the nodes to the base station (BS) where these data are needed using code division multiple access (CDMA). The remaining nodes are cluster members. CHs change randomly over time to balance the energy dissipation of nodes. The node chooses a random number between 0 and 1. The node becomes a CH for the current round if the number is less than the following threshold:

T (n)= N/1-N (Round (1/N))

This protocol is divided into rounds, where each round consists of setup phase and steady state phase.

A. Setup Phase

During this phase, each node decides whether or not to become a CH for the current round. This decision is based on choosing a random number between 0 and 1, and if the number is less than a threshold T ( ) n , the node becomes a CH for the current round. The CH node sets up a TDMA schedule and transmits this schedule to all the nodes in its cluster, completing the setup phase, which is then followed by a steady-state operation. That is shown in figure 2.

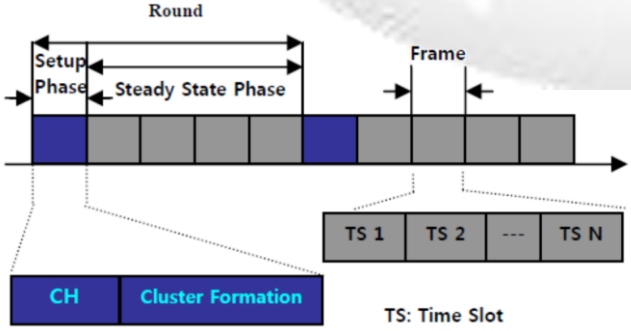


Fig. 2: Time line of the operation of the LEACH protocol

B. Steady State Phase

The steady-state [14] operation is broken into frames, where nodes send their data to the CH at most once per frame during their allocated slot shown in Fig. 3. It assumes that nodes always have data to send, and they send it during their allocated transmission time to the CH. This transmission uses a minimal amount of energy. The radio of each non-CH node can be turned off until the node's allocated transmission time, thus minimizing energy dissipation in these nodes. The CH node must keep its receiver on to receive all the data from the nodes in the cluster. When all the data has been received, the CH node performs signal processing functions to compress the data into a single signal. For example, if the data are audio or seismic signals, the CH node can beam form the individual signals to generate a composite signal. Since the BS is far away, this is a high energy transmission.

IV. IMPROVED LEACH PROTOCOL

In this section, we propose the improved LEACH (ILEACH) protocol, which is based on the initial energy and number of neighbors of the nodes. This protocol is more applicable than any type that assumes a protocol in which each node knows the total energy of the network and then adapts its election probability of becoming a cluster head according to its remaining energy. In the ILEACH protocol, we assign a weighting probability to each node. This weighting probability must be equal to the initial energy of each node divided by the initial energy of the normal node. The weighting probabilities for normal and advanced nodes can be given as

Pnrm= P/1+(a*m)
Pnrm= (P/1+(a*m))*(1+a)

V. SIMULINK IMPLEMENTATION

The proposed work is implemented with the help of MATLAB simulator. ILEACH algorithm is an algorithm which enhance the performance of traditional Leach protocol by making the fraction 'm' of advance nodes equals to 1 (m=1). Algorithm is similar to that of traditional Leach having **m=1.** Proposed protocol enhances the stability of wireless sensor network, because all nodes are advance nodes in the algorithm.

List of Parameters Used

- Field Dimensions- x-axis and y-axis.
- n (number of nodes in the field), initialized by 100.
- p optimal election probability of a node to become cluster head
- E_0 initial energy of node in Joules.
- ETX- energy of transmitter, ERX- energy of receiver, Efs and Emp are transmitting amplifier types.
- EDA energy consumed in data aggregation.
- 'm' percentage of advance nodes in the network set equal to 1.
- 'a' additional energy factor for advance nodes, set equal to 1.
- rmax maximum number of rounds initialized by 4000.

- 'do' initial distance of node from base station, do= sqrt (Efs/Emp).
- DEAD to denote number of dead nodes.

Algorithm- A step by step description of implementation of proposed work

1. Randomly create wireless sensor network
2. Chose normal nodes
3. Chose advance nodes
4. Now randomly select the cluster head nodes, having optimal probability less than threshold value T (n) = p/ 1-p(r mod (1/p)), where 'r' is current round.
5. Count the number of dead nodes, initially all nodes are alive
6. Calculate the energy dissipated in transmission:-
   E_DISP(r+1) = E_DISP(r+1) + ((ETX+EDA)*r +E_{fs}*r*d^2) when distance > d_0 (d_o=$\sqrt{E_{fs}/E_{mp}}$)
   E_DISP(r+1) = E_DISP(r+1) + ((ETX+EDA)*r +E_{mp}*r*d^4) when distance<= d_0(initial distance)
7. Now calculate the energy associated by each cluster head:
   If (min_dis>do)
   E_DISP(r+1)=E_DISP(r+1)+(ETX*(4000)+Emp*4000 *(min_dis)^4);
   But if(min_dis<=do) then
   E_DISP(r+1)=E_DISP(r+1)+(ETX*(4000)+ Efs*4000*(min_dis)^2);

   Repeate steps 1 to 7 for all rounds

A. *Low Energy Adaptive Clustering Hierarchy (LEACH)*

[8] LEACH is a cluster based hierarchical protocol. The protocol divides the sensor network into clusters each cluster may consists of same or different number of nodes. Each cluster has a cluster head which is responsible for direct communication with the BS. Cluster heads are chosen on random basis. In LEACH it is assumed that nodes become cluster heads according to their priorities. Nodes in a network are of two types i) normal nodes and ii) advance nodes. If there are n number of nodes in a network and both types of nodes have equal chance to become cluster head , it is assumed that a fraction 'm' of 'n' is advanced nodes. Advanced nodes have alpha(α=a) times more energy than that of the normal nodes. Each node in the network have a probability associated with them which decides their priority to become cluster head this probability is denoted by 'p'. If this probability is less than threshold value T(s_i), then the node s_i become cluster head for current round. T (s_i) = p/1-p(r mod(1/p)) when s_i € G

Where 'r' is the current round number, 's_i' is the current node and G is the set of nodes which have not yet been become the cluster heads. After each round nodes in G increase their priority value to become the cluster head. Total Energy dissipated per round of the cluster in LEACH is given by:

$$\boldsymbol{E\_DISP(r+1) = E\_DISP(r+1) + ((ETX+EDA) * r + Efs * r * d2)\ when\ distance > d0\ (do = \sqrt{Efs/Emp})}$$

$$E\_DISP(r+1) = E\_DISP(r+1) + ((ETX+EDA) * r + Emp * r * d4)\ when\ distance <= d0\ (initial\ distance)$$

Where 'r' is current round, ETX is the energy used by transmitter, EDA is the energy of aggregator, E_{fs} and E_{mp} depends upon the model of receiver used and E_DISP is initially zero. Initially the energy of nodes is stabilized but after 1000 rounds first node dies, and after that the energy declines instantly and up to 2000 round all nodes of the cluster has died. Number of packets to CH are minimum initially but these are constant up to 1500th round and then decrease abruptly similarly number of packets transmitted to the BS by CHs starts with an average of 20 packets which is fluctuating between 20 and 30 up to 1500 rounds and then starts falling down to zero.

B. *SEP (Stability Election Protocol)*

[10] SEP is also cluster based protocol which provides more reliability and efficiency than LEACH. In SEP the load is distributed very well among the nodes. Advance nodes are assumed to be more probable to become cluster heads. The optimal probability of advance and normal nodes are assigned with a weighted value, which is used to calculate the threshold values of each node. The fraction 'm' of 'n' which denote the advanced nodes have additional energy 'a' is responsible for the stability region of the SEP. SEP provides more stability than LEACH.

p_{nrm} = (p/(1+a*m)) and p_{adv} = (p*(1+a)/(1+a*m)) are the weights assigned the optimal probabilities of normal and advance nodes respectively. T (s_{nrm}) is the threshold for normal nodes which have become a cluster head and T(s_{adv}) is the threshold of advance node which is cluster head for current round.

$T(s_{nrm}) = p_{nrm} / 1- p_{nrm}(r\ mod(1/ p_{nrm}))$ and $T(s_{adv}) = p_{adv}/1- p_{adv}(r\ mod(1/ p_{adv}))$

The initial energy of normal nodes is Eo and that of advance nodes is Eo*(1+a). Total initial energy of the system is increased by1+a*m times. The SEP protocol begins with optimal energy which is lesser than that of LEACH and starts decline after 1800 rounds, the decreased energy remains constant for around 2000rounds. Nodes start dying after 1500 round as in LEACH, but all nodes did not die one after another, it takes more time than LEACH to die all nodes. Maximum numbers of packets have been transferred to cluster heads initially, which is not possible with LEACH. Also the packets transmitted to base station per round are maximum, fluctuating between 20 and 30 but for a longer period of time than LEACH.

VI. Simulation Results

On the basis of simulation we have collected, we have many results; these results are in the form of graphs. All four protocols are compared on the basis of these graphs which are the result of their simulation. Packets transmitted to cluster head per round and packets transmitted to base station by cluster heads are shown with the help of graphs. Efficiency of LEACH, SEP, ILEACH, HCR is compared with the help of graphs which are produced using MATLAB simulator.

A. *Energy Dissipated Per Round*

Energy dissipated per round in transmission of packets from source to destination is lesser in LEACH protocol, because

of which the first node dies after 1500th round, and all nodes starts dying. ,energy dissipation of these four protocols can be observed with the help of graph shown below.

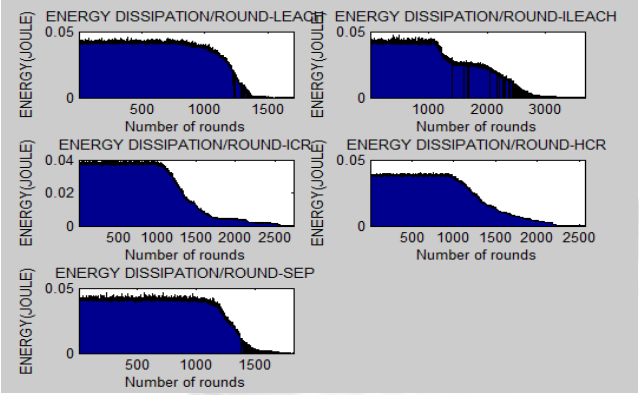


Fig. 3: Energy dissipated per round for leach, SEP, protocols

From figure 3 we can see that if leach use 0.028 joules of energy, SEP uses 4 to 8 joules, it is 0.025 for ILEACH and 0.04 joules for HCR, hence ILEACH uses minimum energy which is stable up to 2300rd round, hence have maximum stability. In the SEP protocol energy dissipated is greater than that of all other protocols, but like LEACH all nodes die instantaneously. ILEACH energy dissipated is almost equals to that of LEACH but first node dies after 2500th round. HCR consumes lesser energy than SEP.

The energy dissipated per round is minimized with the help of ILEACH, because additional energy factor 'a' is added to initial energy of each node in the network, which balance the energy consumed in transmission by the distance nodes.

B. Packets to Cluster Head per Round

Each non cluster head node sends its result to the cluster head to which it is associated, result is send in the form of tiny packets. The comparison of packets transmitted to cluster head per round is done with the help of graph given below

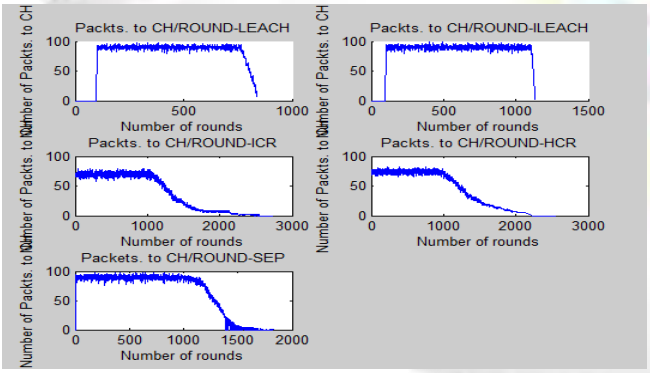
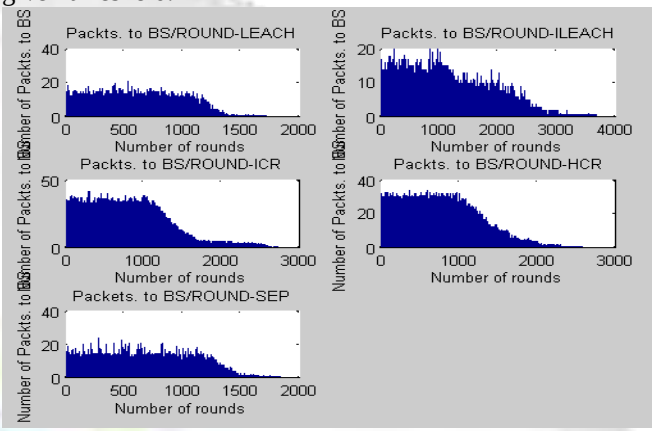


Fig. 4: Packets transmitted to cluster head per round of each protocol

From the above graph we can see that maximum number of packets are transmitted by SEP per round and then by HCR. LEACH and ILEACH transmits equal number of packets per round to cluster head but the number of rounds for which the ILEACH transmits is greatest(up to 3000 rounds) which is about 2000 for other three protocols. Only cluster head nodes are responsible for the transmission of packets to the base station, cluster head nodes collects information from all non cluster head nodes associated to it , performs data aggregation and then transmit packets to BS. If the associative nodes sending data to cluster heads at faster rates, these are not forwarded to BS at the same rate, because of the delay caused by fusion and aggregation.

C. Packets Send to Base Station per Round

After all non cluster head nodes have send their data to the cluster head nodes; each cluster head node aggregates the data to remove the redundancy and forwards this data to the BS. A protocol should transmit maximum number of packets to BS before energy of all nodes goes below the given threshold.



Fig, 5: Packets transmitted to BS per round

HCR transfers maximum packets to BS per round (about 30 to 35 packets up to 1800th round), LEACH send minimum number of packets per round. ILEACH transfer up to 25 packets per round but for a longer period of time (for 2000 round). SEP transmits about 25 packets per round. As large the number of packets transmitted to BS, the greater will be the efficiency of the network. BS is located at the centre in the proposed protocol, which directly interact with cluster heads. Packets transmitted to BS are not equal for every round which is shown by the graph with the help of fluctuating lines.

D. Number of Dead Nodes per Round

When the nodes begin to transmit they start to consume their energy and their energy goes down after every transmission, and when the energy of node goes below the threshold value node is declared as a dead node. The time from beginning of transmission to first node dies is the stability period of the network and time when all nodes have died describes the overall life time of the network.

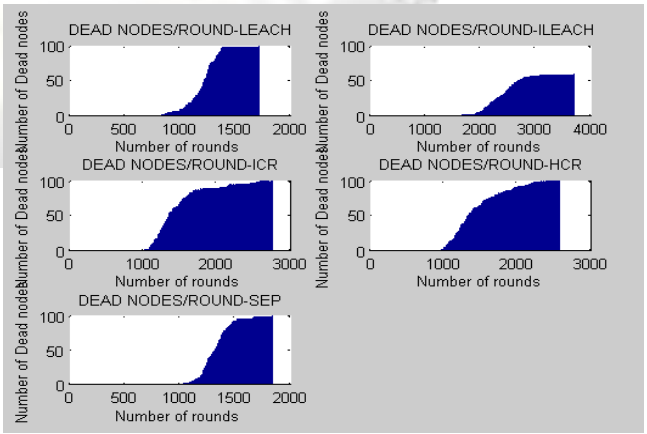


Fig. 6: Number of nodes died per round

Above figure shows that ILEACH is most stable protocol among all four protocols because first node dies after 2000 rounds, and for other three protocols first node dies after 1000 rounds. But the nodes die one after another at faster rates for LEACH and ILEACH which is slower for HCR. The line is smooth for ILEACH and Leach this implies that the nodes dying in every round are approximately equal or have a constant difference. But for the line is not smooth, hence the difference between the numbers of nodes dying per round is not equal.

E. Number of Cluster Heads Elected per Round

The process of cluster head election is randomized for each protocol. When the new round begins new cluster heads are elected. Advance nodes are more likely to be the cluster heads. The variation of election of cluster head for each protocol per round is shown with the help of graph . The cluster heads elected are greater in number for HCR protocol, approximately equal for other three protocols.

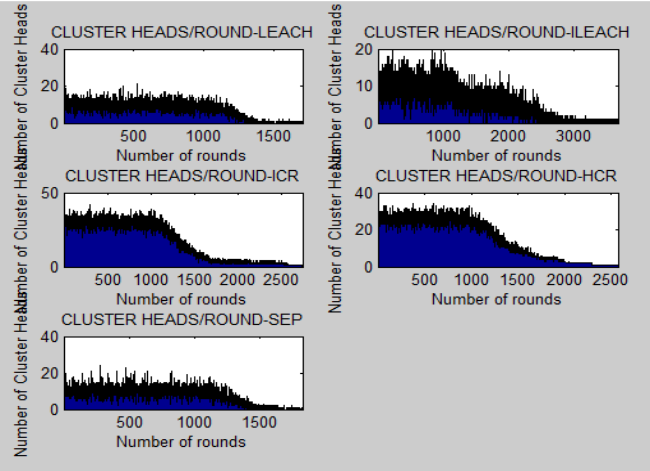


Fig. 7: Number of cluster heads per Round

But the stability of ILEACH is greatest in this case too. Number cluster heads vary for each round that's why the graph line is not smooth rather it is fluctuating. As the number of cluster heads increase the number of cluster formed by the protocol also increased. Greater the number of cluster head lesser will be the chance of transmission of redundant data.

Figure.7 shows the simulation result for each protocol, with the help of which comparison of protocols can be made easy with the help of graphs.

VII. CONCLUSION

The conclusion made on the basis of study of LEACH and SEP is that both protocols are cluster based protocols, which divides the sensor network into smaller zones, trying to distribute the load equally among the nodes. By the use of advance nodes the total initial energy of the whole network is increased by 1+a*m times. SEP provides more stability period in the life time of the network than LEACH. Both protocols have a very little difference of stability. The total energy dissipated buy the network is decreased in both cases but still there is instantaneous decrease in the energy and after about 1200 rounds nodes start dying one after another at faster rates.

ILEACH overcomes some of the drawbacks of the LEACH like improvement in the stability period of the network. The cluster head selection mechanism is approximately common in all four protocols except that in SEP weights are assigned to optimal probabilities of the nodes to be the CHs. The fraction of advance nodes is made equal to 1, which implies that all nodes are advance nodes in ILEACH. HCR provides maximum packet transfer rates, and more packets are transmitted to BS per round. ILEACH provides maximum stability than other three protocols. Further improvements can be done to the proposed protocol.

REFERENCES

[1] S. Lindsey, C. Raghavendra, "PEGASIS: Power-Efficient Gathering in Sensor Information Systems", published in: IEEE Aerospace Conference Proceedings, 2002, Vol. 3, pp. 1125-1130.

[2] M. Chu, H. Haussecker, and F. Zhao, "Scalable Information-Driven Sensor Querying and Routing for ad hoc Heterogeneous Sensor Networks," published in The International Journal of High Performance Computing Applications, Aug. 2002, Vol. 16, pp: 106-109.

[3] Smaragdakis. Georgios. Ibrahim Matta. And Azer Bestavros. "SEP: A stable election protocol for clustered heterogeneous wireless sensor networks", Boston University Computer Science Department, pp: 223-230, 2004.

[4] Al-Karaki, J.N, "Routing Techniques in WSN: A Survey", Wireless Communications, IEEE, vol: 11, pp: 6-28, Dec. 2004.

[5] Yuhua Liu Yongfeng Zhao Jingju Gao "A New Clustering Mechanism Based On LEACH Protocol", International Joint Conference on Artificial Intelligence (IEEE), Hainan, pp.715-718, April 2009.

[6] Bhaskar Krishnamchari, Deborah Estrin,"Impact of Data Aggregation in WSN", IEEE Journal Selected Areas in Communications, pp. 1333-36, Aug.2009.

[7] Ma Chaw Mon Thein, ThandarThein "An Energy Efficient Cluster-Head Selection for Wireless Sensor Networks", International Conference on Intelligent Systems, Modeling and Simulation (IEEE), vol:-8, pp.287-291, Jan. 2010.

[8] Shio Kumar Singh, M P Singh, D K Singh, "A Survey of Energy-Efficient Hierarchical Cluster-Based Routing in Wireless Sensor Networks", International Journal. of Advanced Networking and Applications, vol: 02, pp: 570-580, 2010.

[9] Linlin Wang, JieLiu, Wei Wang "An Improvement and Simulation of LEACH Protocol for Wireless Sensor Network", First International Conference on Pervasive Computing, Signal Processing and Applications (IEEE), pp: 444-447, Sept. 2010.

[10] Vivek Katiyar, Narottam Chand, Gopal Chand Gautam, Anil Kumar "Improvement in LEACH Protocol for Large-scale Wireless Sensor Networks", (IEEE), vol:32, pp:-1070-1075, Mar. 2011.

[11] Yun Li, Nan Yu, Weiyi Zhang, Weiliang Zhao, "Enhancing the Performance of Leach Protocol for WSN", IEEE INFOCOM, pp:-223-228, 2011.

[12] Rathna and Sivasubramanian, "Improving Energy Efficiency in Wireless Sensor Networks through Scheduling and Routing", Research Scholar, Sathyabama University, TamilNadu, India, International Journal of Advanced Smart Sensor Network Systems, vol: 2, pp: 21-27, January 2012.

[13] Reetika Munjal, Bhavneesh Malik "Approach for Improvement in LEACH Protocol for Wireless Sensor Network", Second International Conference on Advanced Computing & Communication Technologies (IEEE), pp.517-521, Jan. 2012

[14] Yamunadevi, S.P,"Efficient Comparison of Multipath Routing Protocols in WSN", Computing Electronics and Electrical Technologies (ICCEET), vol: 2, pp: -807-811, mar. 2012.

[15] Jia Xu,Ning Jin, Xizhong Lou,Ting Peng,Qian Zhou,Yanmin Chen, "Improvement of Leach Protocol for WSN",Fuzzy System and Knowledge Discovery(FSKD), , vol:-11, pp:-2174-2177 May. 2012.

[16] M M Islaml, M A Matin2, T K Mondol l "Extended Stable Election Protocol (SEP) for Threelevel Hierarchical Clustered Heterogeneous WSN", (IEEE), vol: 5, pp. l -4, June 2012