ISSN: 2278 – 1323
International Journal of Advanced Research in Computer Engineering & Technology (IJARCET)
Volume 5, Issue 5, May 2016

Improved High Energy First Clustering Algorithm for Wireless Sensor Networks

A.Asha, J.Julia

Abstract— **Wireless sensor networks (WSNs) consists of large number of spatially distributed autonomous sensor nodes. The sensor nodes have limited energy resources, processing and storage capabilities. Clustering is an energy efficient and scalable way to organize the WSN. Clustering algorithm is often adopted in wireless sensor networks but many clustering algorithm do not provide the required energy efficiency. The main objective of this research is to increase the throughput and to improve the energy efficiency of wireless sensor networks. In this paper we propose a modified High Energy First (mHEF) clustering algorithm, which is an optimal cluster head selection algorithm where a node with higher residual energy have higher probability to become a cluster head than those with lower residual energy, so that the network energy can be dissipated uniformly . The network simulator 2 (NS2) is used to compare Low Energy Adaptive Clustering Hierarchy (LEACH) and the clustering network model mHEF. Simulation results show that proposed mHEF can provide better results compared to LEACH.**

Keywords—**Clustering, energy efficiency, HEF, residual energy, WSN**

I. Introduction

Wireless Sensor Networks (WSNs) are large scale networks of small embedded devices, each with sensing, data processing and communicating components, making it feasible for a large number of applications in industrial, military, and agricultural applications. These nodes monitor their immediate surroundings and cooperatively pass their data through the network to a central destination. In these applications, sensors are usually remotely deployed in large numbers and operated autonomously. Therefore, in these unattended environments, the sensors cannot be recharged and hence energy constraint is the most critical problem that must be considered and has been widely discussed in recent years. Wireless sensor network is facing the problem of energy constraints in terms of limited battery lifetime. In WSNs the only source of life for the nodes is the battery. Communicating with other nodes or sensing activities consumes a lot of energy in processing the data and transmitting the collected data to the sink. The purpose of this paper is to find protocol that is energy efficient and which improves the network lifetime.

To prolong the network lifetime and to improve the energy efficiency of the wireless sensor networks, several operations can be carried out in the different layers. In physical layer, the choice of proper topology and the channel selection influences the energy of the sensor. In data link layer, efficient data aggregation methods can be used. However, the conservation of energy in the network layer yields the best results. Clustering performed in the network layer, has become a prominent approach to reduce energy consumption. Network Clustering is the process of organizing the network into connected groups of nodes called clusters, with one node elected to be the leader called as the cluster head (CH). Each cluster member (CM) senses the surrounding and sends the data periodically to their cluster head. Each cluster head in the network aggregates the redundant data from its cluster members and sends it to the base station or sink. Clustering is proposed to WSNs because of its network scalability, energy-saving attributes and network topology stability.

Clustering schemes have some prominent advantages which are listed here. Clustering reduces redundancy by data aggregation. In a cluster, CMs' sensed data have a large similarity due to a small distance between the CMs. Therefore the CH can aggregate the data and remove the redundancy before sending to the sink and this reduces the size of the relayed packets. The change of nodes only affects part of topology of the clustering network, making the topology more stable. Only cluster heads need to maintain the route information. Cluster members can transmit with lower power. CHs take part in the control and management of the network, while CMs only communicate with respective CHs. Clustering provides the spatial reuse of resources to increase system capacity. For example, if the clusters are not neighbors, they can use the same frequency for wireless communication.

II. Related Works

In this section, we analyze some popular and effective clustering algorithms for WSNs.

EEUC (Energy Efficient Unequal Clustering) [1] scheme is distance based scheme and it also required that every node has global identification such as its locations and distances to the base station. Hotspot is the main problem in WSNs because of multi hopping that occurs when CHs closer to the sink tend to die faster compared to another node in the WSNS, because they relay much more traffic than remote nodes. This algorithms partition all nodes into clusters of unequal size, and clusters closer to the sink have smaller sizes than those farther away from the sink. Thus cluster heads (CHs) closer to the sink can conserve some energy for the inter-cluster data forwarding. . However, the extra global data aggregation adds overheads to all sensors and deteriorates the network performance, especially for a multi-hop network.

In HEED (Hybrid, Energy-Efficient Distributed) [2] clustering, periodical selection of cluster heads based on hybrid of residual energy and a secondary index called node proximity. Secondary index is used to break ties. HEED uses a combination strategy of energy and communication cost to generate CHs. Since the energy is non-uniform distributed among all nodes, it is approximately avoided that two nodes within each other's transmission range have the same probability to become CHs in HEED. But achieving global goals cannot always be guaranteed and energy consumption during the data transmission for far away cluster heads is significant.

PEACH (Power-Efficient And Adaptive Clustering Hierarchy protocol) [3] , was proposed to overcome the problems such as consumption of large amount of energy, incurred by cluster formation overhead and fixed level clustering, particularly when sensor nodes are densely deployed in wireless sensor networks. In PEACH, cluster formation is performed by using overhearing characteristics of wireless communication to support adaptive multi-level clustering and avoid additional overheads. In WSNs, overhearing a node can recognize the source and the destination of packets transmitted by the neighbor nodes. PEACH is applicable in both location-unaware and location-aware wireless sensor networks.

EECS [4] an energy efficient clustering scheme in wireless sensor networks proposed a model to produce clusters of unequal size in single hop networks in which cluster formation is based on transmission distance. EECS uses a weighted function ensure that clusters farther away from the base station have smaller sizes such that more energy could be saved for long-distance data transmission to the base station. However, it requires more global knowledge about the distances between the cluster-heads and the base station. And this extra requirement of aggregating data globally adds overheads to all sensors.

ACE [5] uses an emergent algorithm to cluster the sensor network in a fixed number of iterations, which uses the node degree as the main parameter. During each iteration, a node is allowed to assess its potential as a CH before becoming real one and stepping down if it is not the best CH at the moment. When a node finishes executing a number of iterations, it makes a decision based on the available information. The sensor node elects itself as a CH if it detects that many nodes in its neighborhood do not belong to any cluster. However, it is hard to decide the number of iterations for ACE while satisfying the communication cost requirements and energy consumptions. Moreover, migratory mechanism adds additional overheads in ACE.

TEEN [6] Threshold sensitive Energy Efficient sensor Network protocol is a hierarchical clustering protocol. TEEN is useful for applications where the users can control a trade-off between energy efficiency, data accuracy, and response time dynamically. TEEN uses a data-centric method with hierarchical approach. Important features of TEEN include its suitability for time critical sensing applications. At every cluster change time, fresh parameters are broadcast and so, the user can change them as required. However, TEEN is not suitable for sensing applications where periodic reports are needed since the user may not get any data at all if the thresholds are not reached.

III. Energy Efficient Clustering

A. LEACH- An Existing Clustering Algorithm

LEACH (Low Energy Adaptive Clustering Hierarchy) [10][15][16] is one of the most popular clustering algorithms for WSNs. It is an application specific, distributed and autonomous clustering algorithm and can significantly improve the network lifetime. Here the cluster head is selected in a randomized rotation pattern. In LEACH, it is assumed that every node is reachable in one hop distance and the load distribution is uniform among all nodes. There a two phases of operation in LEACH. They are: Setup phase and steady state phase.

In setup phase, the cluster head selection and the cluster formation are carried out. Initially a node elects itself to be a CH with a probability and broadcasts its decision. The probability $P_i(t)$ with which a node chooses itself to be cluster head at a round r is given by the equation,

$$P_i(t) = \begin{cases} \frac{k}{N-k*(r \bmod \frac{N}{k})}, & C_i(t)=1 \\ 0, & C_i(t)=0 \end{cases} \quad (1)$$

where, k is the expected number of CH nodes for a round and N is the total number of nodes in the network. $C_i(t)$ is called the indicator function which indicates whether a node has been a CH in the most recent rounds or not. As in the above equation, $C_i(t)$ = 0 the node has been a CH and $C_i(t)$ = 0 if not. Thus the CH selection depends upon this indicator factor and hence each node in the network gets a chance to become a CH no matter how much energy is left in it. Therefore this leads to the death of some nodes as the whole energy get drained out which leads to decrease in network lifetime.

Each non-CH node chooses to join a cluster that can be reached using the least communication energy. That is, cluster formation in LEACH is based on the strength of received signal. CH nodes serve as routers to the base-stations and all the data fusion and aggregation are performed locally. LEACH uses a fixed probability to generate a CH periodically and all nodes have the same probability to be a CH during the network lifetime, which alleviates the load unbalancing among cluster nodes. However, it is assumed that CH node has longer communication range and can send the data to the base-station directly. This cannot hold in real environments that the CH nodes are also regular sensors and not all the nodes can reach to the base-station directly due to signal propagation problems, e.g., due to the presence of obstacles. Consequently, it cannot perform well in a large scale networks deployed in large areas.
Moreover, it also assumes that energy consumption is equal for each node to be a cluster head. It is not applicable in a highly heterogeneous network which consists of various kinds of nodes and has non-uniform energy distributions. This completes the setup phase and then the steady state phase.

In steady state phase, the CH sends the TDMA schedule to each CM. CMs send data to CH once per frame during allocated timeslot. The CH performs the data aggregation and transmits the aggregated data to the base station. LEACH assumes uniform energy for all nodes. Due to the random CH election, CHs are formed closer to each other and also in low node density areas. Due to these disadvantages, large number of algorithms has been proposed to improve LEACH.

B. Proposed Energy Efficient Clustering Algorithm

The core idea of the proposed algorithm is to choose the cluster head based on the highest residual energy[17][18] remaining in the nodes. This reduces the risk of early death of nodes with lower residual energy, which will be elected as cluster head if random probability CH selection is used. Highest Energy First (HEF) clustering algorithm which is an existing model, selects the set of *'M'* highest ranking energy residue sensors for cluster heads at round τ where M denotes the required cluster numbers at round τ.

There are three phases of operation in HEF algorithm which are: Cluster Head Selection phase, Cluster Formation phase and Data Communication phase.

In Cluster Head Selection phase, the base station sends the notification to the sensor network about the cluster heads selected for that particular round, based on the residual energy remaining in each node. Next is the Cluster Formation phase, where the selected CHs send advertisement messages to every node it can reach on the network. Based on the received signal strength of the advertisement, the nodes send join request to the CHs. The CH accepts the request and joins them as a cluster member. Thus several clusters are formed. The last phase is the Data Communication phase, in which the CH sends TDMA schedule to each of its member nodes. This TDMA schedule indicates when a node has to transmit its data to the CH in order to avoid collisions during transmission. The nodes can keep their radio turned off till their turn to transmit data arrives. This considerably reduces the wastage of energy if radio maintained in ON state always. Each node transmits the sensed data along with the remaining or residual energy information to the CH.

The CH aggregates the data and energy information transmitted by each node and sends it to the base station or the sink node. Here the HEF scheduler checks for the nodes with high residual energy and selects them as the cluster heads for the next round. Then again the CH selection phase continues.

The energy consumption for the cluster head is always more than that for a regular node. Let C_m and C_h be the energy consumed by the CM node and CH node. Consider a sensor node n which has a residual energy $E_n(r)$ at the beginning of round r, and $E_n(r+1)$ at the next round $r+1$, then

$$E_i(r+1) = \begin{cases} E_n(r) - C_m, & \text{if it is a CM} \\ E_n(r) - C_h, & \text{if it is a CH} \end{cases} \tag{2}$$

If two nodes say, n and q have the same energy at the beginning of round r, then after $(r+\tau)$ rounds both nodes will have almost equal energy based on whether both are cluster head or cluster members.

$$\left|E_n(r+\tau) - E_q(r+\tau)\right| = \left|E_n(r) - E_q(r)\right| \\ = 0 \le (C_h - C_m) \tag{3}$$

With the HEF clustering algorithm, the proposed model includes the use of multi hop transmission and distance based routing mechanism. In multi-hop wireless networks, communication between two end nodes is carried out through a number of intermediate nodes whose function is to relay information from one point to another. Using multi hop transmission, the energy consumed is considerably reduced. Looking at the exponential path loss model it is immediately obvious, that with more hops n we can save lots of energy:

$$P_{loss} = \left(\frac{d}{n}\right)^{\alpha} \tag{4}$$

where α denotes the path loss index and P_{loss} the overall power loss at a distance d. Cluster heads, which cannot reach the base station directly because of the considerable distance from the base station are given possibility to access it via other cluster heads which are near to the base station, making a much larger network feasible. But if the entire network is structured based on multi hop transmission, it may be a time consuming process. The distance based approach is helpful in such a way that it invokes multi hop transmission only when required i.e., only when the CH is far away from the base station.

The main advantage of High Energy First clustering algorithm over Low Energy Adaptive Clustering Hierarchy clustering is the CH selection process. The randomized and probability based CH selection in LEACH causes the performance of the system to vary in accordance with the autonomous decision values generated. The CH selection involves the action among the regular nodes and the base station has nothing to do with CH selection. But in HEF, the base station plays an important role in CH selection by collecting the data and also the residual energy information of all the nodes which are aggregated by each cluster heads. After this the base station itself sends the information on which node to be selected as the CH based on the highest residual energy values.

LEACH does not work well in dynamic networks, because for the probability based election of CH, equal probability is given to each node only if it remains in the same position. If the nodes are dynamic, then whenever a node which has already been a CH in a cluster, joins another cluster, the probability is taken as if it has never been a cluster head before. But HEF holds well in dynamic networks, because wherever a node goes in a network, it is chosen as CH only based on the residual energy by the base station.

In LEACH, the CHs far away from the base station will use higher power and die more quickly than the nearby ones, due to the single hop transmission. But in HEF, we have introduced the multi hop transmission to avoid this problem.

Thus in several cases our proposed HEF is found to be more efficient than LEACH and HEF is regarded as an optimal cluster head selection algorithm. Next section deals with the comparison of these algorithms.

IV. Performance Evaluation

Clustering algorithms are generally implemented to improve the performance of the WSNs, by increasing their energy efficiency so that the lifetime of the nodes can be extended. There are several energy efficient hierarchical routing protocols. LEACH algorithm is a milestone in clustering methodology, which initiated the development of energy saving process by

ISSN: 2278 – 1323
International Journal of Advanced Research in Computer Engineering & Technology (IJARCET)
Volume 5, Issue 5, May 2016

proper CH selection methods. But, as discussed earlier it has few disadvantages which can be overcome by using HEF algorithm for cluster head selection along with multi hop transmission and distance based routing. Comparing the performance of both the algorithms using NS-2 (Network Simulator) the following results were obtained.

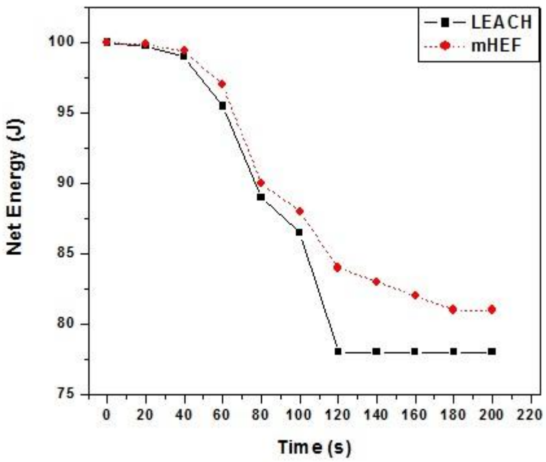

Fig.1 Net Energy Comparison

Fig 1 shows the Net Energy Comparison for LEACH and modified HEF. Initially the net energy is set as 100 J. As the transmission begins, the energy begins to drop slowly. As it is seen, the energy curve of LEACH falls a way below the HEF energy curve. This is because the randomized cluster head selection in LEACH causes unwanted reduction in energy. The reason for the mHEF curve to rise above the LEACH curve is due to the optimal cluster head selection in HEF which is based on the residual energy and the use of multi hop transmission among the cluster heads whenever the transmitting cluster head is far away from the base station. This plot is considered for a round in which the simulation period is set to 200 s. As the simulation begins, the nodes send their collected data to the CH and CH aggregates and relays this information to the base station. This process consumes some amount of energy while CH selection consumes the other part.

The throughput values of LEACH and mHEF are plotted in a graph as indicated in Fig.2.

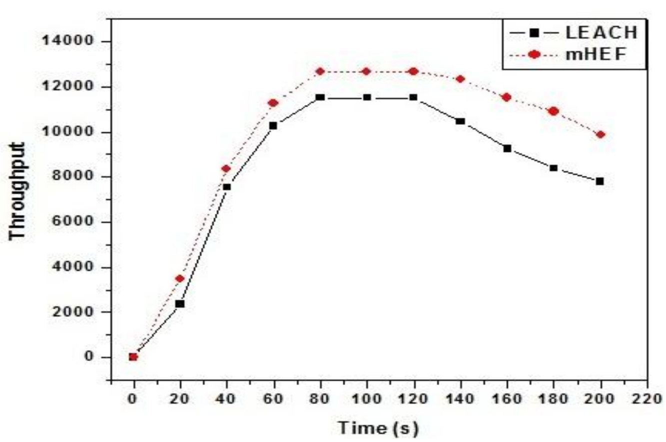

Fig.2 Throughput Comparison

Throughput indicates the successful message delivery over a communication channel. Here throughput indicates the number of data packets delivered to destination at a particular instant. Fig 2 shows that the maximum numbers of packets are received when HEF is preferred over LEACH. The curves are found to attain a stable nature at the peak value of throughput and then again the throughput drops from peak throughput value. This graph indicates that HEF can provide a better throughput than LEACH.

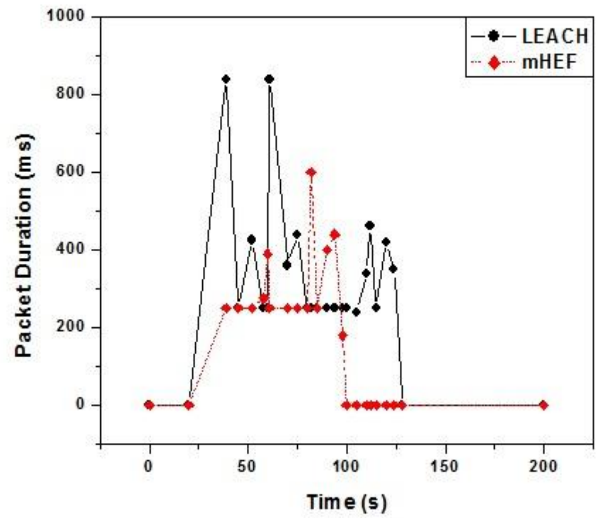

Fig.3. Delay comparison

Delay (also known as packetization delay) is the amount of time required to push all of the packet's bits from source to the destination. Delay can be compared by analyzing the packet duration or the time taken for the packet to reach destination from source. Packet duration is measured in milliseconds. The packet duration is plotted for the simulation period of about 200 seconds. It can be clearly seen that, in LEACH the packet duration is as high as 860 ms while the packets take a maximum of about 600 ms in mHEF. The curve of LEACH is found to be a way below the mHEF curve all along the total simulation.

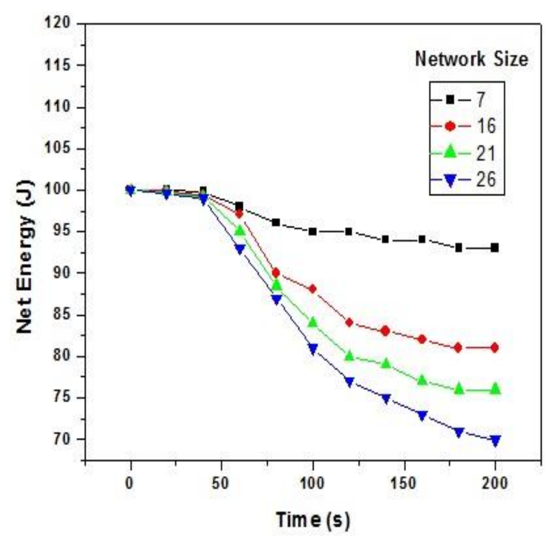

Fig 4 Net Energy for different Network Sizes

The net energy against total simulation time of about 200 s is plotted for different network sizes i.e. for networks with different number of nodes. It is found from the above graph that as the number of nodes in the network increases the net energy of the network falls as the additional nodes consume energy for their operation. The graph in Fig 4 indicates the net energy curves of the network when the total number of nodes in the network is 7, 16, 21 and 26 respectively. When the total number of nodes is 7, the net energy is maintained at 95 J and for a total of 26 nodes the energy falls to about 70 J.

V. Conclusion

In this paper, we have devised a technique to select the CHs in every round which depends on the residual energy in each nodes and the notification received from the base station. Also the data transmission among cluster heads enabled with multi hop transmission, when the CH is far away from the base station, provides a better performance. In performance simulation, we have compared our algorithm modified HEF with prevalent algorithm LEACH based on net energy and throughput values. As we select the most eligible node as the cluster head in terms of its current residual energy and distance, so that multi hop transmission can be implemented, the nodes' die rate is less than the other compared algorithm.

References

[1] C. Li, M. Ye, G. Chen, J. Wu, "An energy-efficient unequal clustering mechanism for wireless sensor networks," in: Proceedings of 2005 IEEE International Conference on Mobile Adhoc and Sensor Systems Conference (MASS05), Washington,D.C., pp. 604-611, November 2005

[2] O. Younis, S. Fahmy, "HEED: A hybrid, energy-efficient, distributed clustering approach for Ad Hoc sensor networks," IEEE Transactions on Mobile Computing,vol. 3,pp. 366-379, October 2004.

[3] S. Yi, J. Heo, Y. Cho, and J. Hong, "PEACH: power-efficient and adaptive clustering hierarchy protocol for wireless sensor networks,"Computer Communications,vol. 30, pp. 2842-2852,October 2007.

[4] M. Ye, C. Li , G. Chen,J. Wu, "EECS: an energy efficient clustering scheme in wireless sensor networks", in: Proceedings of 24th IEEE International Performance, Computing and Communications Conference (IPCCC 2005), Phoenix, Arizona, pp.535- 540, April 2005.

[5] H. Chan and A. Perrig, "ACE: an emergent algorithm for highly uniform cluster formation,"Lecture Notes in Computer Science,vol. 2920,pp. 154-171, January 2004

[6] A. Manjeshwar, D. Agrawal, "TEEN: a routing protocol for enhanced efficiency in wireless sensor networks," in:Proceedings of 15th International Parallel and Distributed Processing Symposium(IPDPS'01), San Francisco , CA, pp.2009-2015, April 2001..

[7] W. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "An application-specific protocol architecture for wireless microsensor networks", IEEE Transactions on wireless communications, vol. 1, pp. 660-669, October 2002.

[8] Bo-Chao Cheng, Hsi-Hsun Yeh and Ping-Hai Hsu, "Schedulability Analysis for Hard Network Lifetime Wireless Sensor Networks With High Energy First Clustering", Pub: IEEE Transactions On Reliability, Vol. 60, No. 3, September 2011

[9] M.Shankar, Dr.M.Sridar, Dr.M.Rajani, "Performance Evaluation of LEACH Protocol in Wireless Network", Pub: International Journal of Scientific & Engineering Research, Volume 3, Issue 1, January-2012

[10] A. Abbasi, M. Younis, "A survey on clustering algorithms for wireless sensor networks, " Computer Communications, vol. 30, pp. 2826-2841, October 2007.

[11] I. Akyildiz, W. Su, Y. Sankarasubramaniam and E. Cayirci, "Wireless sensor networks: a survey," Computer Networks,vol. 38,pp. 393-422, April 2002.

[12] Wernhuar Tarng, Hao-Wei Lin and Kuo-Liang Ou, "A Cluster Allocation And Routing Algorithm Based On Node Density For Extending The Lifetime Of Wireless Sensor Networks", Pub: International Journal of Computer Science & Information Technology (IJCSIT) Vol 4, No 1, Feb 2012

[13] D. Wang, "An energy-efficient clusterhead assignment scheme for hierarchical wireless sensor networks,"International Journal of Wireless Information Networks,vol. 15, pp. 61-71, Feburary 2008.

[14] Sha Chao, Wang Ru-Chuan, Huang Hai-Ping, Sun Li-Juan, "Energy efficient clustering algorithm for data aggregation in wireless sensor networks", Pub: Science Direct, December 2010, 17(Suppl. 2): 104–109

[15] Aimin Wang, Dailiang Yang, Dayang Sun, "A clustering algorithm based on energy information and cluster heads expectation for wireless sensor networks", Pub: Computers and Electrical Engineering, Elsevier, 2011

[16] Congfeng Jiang, Daomin Yuan, Yinghui Zhao, "Towards Clustering Algorithms in Wireless Sensor Networks-A Survey", Pub: IEEE Communications in WCNC,2009 proceedings

[17] Feng Zhao, Leonidas Guibas, "Wireless Sensor Networks: An Information Processing Approach", Pub: Elsevier, 2004 edition

[18] Jiguo Yu, Yingying Qia, Guanghui Wangb, Xin Gua, "A cluster-based routing protocol for wireless sensor networks with non-uniform node distribution", Pub: Int. J. Electron. Commun. (AEÜ) 66 (2012) 54– 61

A.Asha is working as an Associate Professor in the Department of Electronics and Communication Engineering , Rajalakshmi Engineering College ,Chennai, India

J.Julia was a PG scholar in the Department of Electronics and Communication Engineering , Rajalakshmi Engineering College ,Chennai, India