Energy Aware Uniform Cluster-Head Distribution Technique for Hierarchal Wireless Sensor Networks

Masood Ahmad[†] , Masood Habib [†], Muhammad Zahir Shah[*], Fasee Ullah[†], Shah Hussain[†]

[†]Department of Computer Science, City University of Science & IT Peshawar, Pakistan, [*]IQRA University Islamabad Pakistan.

Summary
Lifetime of a WSN is directly proportional to the energy consumption of its constituent nodes. In cluster-based routing, all the cluster-heads may be selected from one part of the network. Since routing in these networks are one of the major sources of energy drains, therefore Energy Aware Uniform Cluster-Head Distribution (EAUCD) technique which selects one node as a representative node from each part of the network is proposed. Looking at the simulation the proposed approach is better in terms of conservation of power. We also advocate grid deployment for cluster based techniques.

Key words:
Wireless sensor network, routing, cluster-head.

1. Introduction

Wireless Sensor Network (WSN) consists of a group of sensors called nodes, interconnected with each other. These networks are deployed for monitoring the sensor field. Wireless sensor networks can be deployed for many applications such as battle field monitoring, building automation, health care, home security etc. routing in WSN is the main source of energy consumption. In hierarchical routing, high energy nodes are used for computation and data transmission while sensing in targeted area can be carried out by low energy nodes. The concept of hierarchical or cluster-based routing was first used in wired networks [7]. The advantage of this technique is scalability and efficient communication [5]. However in wireless sensor networks the concept of hierarchical routing is used to achieve energy-efficient communication.

Hierarchal routing protocols mainly aim at increasing the life time of the network. In these protocols the cluster heads are selected randomly or based on maximum energy left at the node in the network. In this technique it is also possible that all the cluster heads might be chosen from one part of the network, so in presence of clusters the nodes will use long haul communication. To overcome this problem we propose, Energy Aware Uniform Cluster-Head Distribution (EAUCD) technique. In EAUCD the Representative Nodes are uniformly selected from each part of the network based on maximum energy. The operation of EAUCD is divided into three phases. In initialization phase the sensor filed is divided into parts in a greedy fashion. In setup phase, one node is selected as a representative node from each part of the network. In steady state phase, the resulted data is transmitted to the base station for further action. The rest of the paper is organized as follows: section II presents the related work. Section III, describe the proposed work. In section IV, the simulation results are presented. Finally, we summarize the work of EAUCD and make some remarks on future research in section V.

2. Related Work

Low Energy Adaptive Clustering Hierarchy (LEACH) [6] was the first cluster-based hierarchal routing protocol for wireless sensor networks. In LEACH the clusters are formed in a distributed manner. The cluster-head (CH) nodes in LEACH are selected randomly. This role is rotated among all the sensors to equally distribute the energy load among all the sensors in the network. However in LEACH [5] the cluster-heads are not uniformly distributed. In LEACH all the cluster-heads might be chosen from one part of the network. If this situation occurs LEACH will dissipate more energy than conventional protocols.

An improvement on LEACH protocol called Power-Efficient Gathering in Sensor Information Systems (PEGASIS) [8] was proposed. The main focus of the protocol is to increase the network life time in such a way that, the nodes only communicate with their bordering neighbours and each node takes their part in communicating with the base-station. PEGASIS still needs dynamic topology adjustment, because a sensor node needs to know about energy status of its neighbours in order to know where to route its data. In [9] and [10], two hierarchical routing protocols called TEEN (Threshold-sensitive Energy Efficient sensor Network protocol), and APTEEN (Adaptive Periodic Threshold-sensitive Energy Efficient sensor Network protocol) are proposed respectively. These two protocols work only with time-critical applications. Continuous sensing of the medium is performed in TEEN, and the data is transmitted less frequently. Virtual Grid Architecture routing (VGA): An energy-efficient routing paradigm is proposed in [11] that utilizes data aggregation and in-network processing to maximize the network lifetime. In [2] a new network lifetime definition is presented and the routing problem is

Manuscript received October 5, 2010
Manuscript revised October 20, 2010

formulated with energy-aware network lifetime. An energy-aware routing scheme with the node relay willingness for WSNs is proposed, which considers routing packets not only through the sensor nodes with adequate energy reserves, but also through the light-loaded nodes [7]. A mixture of an enhanced clustering algorithm and directed diffusion, a famous data-centric routing model in sensor networks is proposed in [3]. The aim is to extend the duration of the network by modifying passive clustering regulations for constructing/maintaining the topology so balanced energy consumption is achieved among the nodes in the network.

All the nodes in the sensor network are assembled into clusters dynamically in [12]. In each cluster only one node is elected as a cluster-head. The cluster heads positioned near to the network base station are assigned the role of direct transmission with the base station with less energy consumption. These cluster heads are supposed to be the Upper Level cluster heads. In a similar way, cluster heads located distant away from the network base station, are considered to be the Lower Level cluster heads. Due to random selection of cluster-heads all the cluster-heads might be chosen from one part of the level.

3. Proposed Model

The operations of EAUCD technique are divided into three phases which are, initialization phase, setup phase and the steady state phase; each one is thoroughly discussed in the remaining section of this part.

3.1 Initialization Phase

The initialization phase is divided into four steps. As shown in figure 1 the nodes in the fist step of initialization phase switch on their receivers. After step 2, all the nodes in the network know that when to transmit the location information to the base station. So all the nodes transmit their location information which includes the node_ID and node_LOC fields according to TDMA schedule received from the base station. This transmission to base station is carried out in step 3 of initialization phase. It is assumed that each node knows its location. After the base station knows the location of each node, it selects k points from the simulation space using algorithm 1 in step 4 of initialization phase.

3.2 Setup Phase

When the base station knows the location of all the nodes in the network, a set of k points are selected from the simulation space using algorithm 1. The next step is to assign location information to all the nodes in the network. A node is marked as a neighbour of that selected point (in step 4) which is very near to it among a set of k points. In step 5 the base station elect one node as a Representative Node (RN) from each point and that node is selected on the base of maximum energy among its neighbours. In case of tie, a node is chosen randomly. The number of nodes which are selected as the Representative Nodes is assumed to be predefined as in [6].

```
Algorithm 1
Point_selection (P, S, N)
// where P is the percentage/probability of clusters, S is the side of the area, N is the total
// number of nodes in the network.
        Area ← S²
        No_of_cluters ← P*N
        C_Area ← Area/No_of_clusters
        R ← 1
        C ← 1
While ((R*C) < No_of_clusters)
        {
        If ( (R*C) = = No_of_clusters)
        Break
                If (R < = C)
                        R++
                Else
                        C++
                End If
End while
M[R][C]
C_ s1 ← S/ R
C_ s2 ← C_Area / C_s1
If (R > C)
        {
        For(X ← 1 to R-1)
        For (Y ← 1 to C)
        M[C_s1/2 + (X-1)* C_ s1][ C_   s2/2 * (Y-1)*C_ s2)]
        }
Temp ← No_of_clusters – (R-1)*C
For (i ← 1 to temp)
        M[C_ s1/2 + (R-1)*(C_ s1)][ C_ s2/2 + (i-1)*(C_ s2)]
End Point_selection
```

In step 2 of setup phase each elected representative node broadcast it status to other nodes in its vicinity. After step 2 of the setup phase the actual cluster is formed. So in step 3 of this phase each non representative node decides to participate to that representative node cluster which requires minimum communication energy. After every node has determined to which cluster it wants to go, it must informs its matching RN that it is going to be an element of its cluster. In step 4 of setup phase all the nodes send back a JOIN_REQ message to its corresponding RN. All representative nodes switch on their receivers in this step to receive the Join message from its members. Similarly in step 5 of setup phase, the elected representative nodes create a TDMA schedule for all its members. This schedule is then transmitted to all its members in order to know when to transmit. After receiving the TDMA schedule, all the nodes knows about their transmission time, so it turns off its receivers except their allocated transmission time as shown in step 7 of setup phase.

3.3 Steady state phase

In steady state phase the actual transmission from the representative nodes to the base station occurs. In step 1 of the steady state phase the RNs of all the clusters are responsible for collecting the data from all its participated members. When all the data has been received by the RNs, it performs signal processing function such as data aggregation [6] on the data in step 2 of steady state phase. In step 3 of steady state phase the RNs transmits the composite data to the base station. And in the last step of steady state phase the base station keeps their receiver on and collects the data from the Representative nodes.

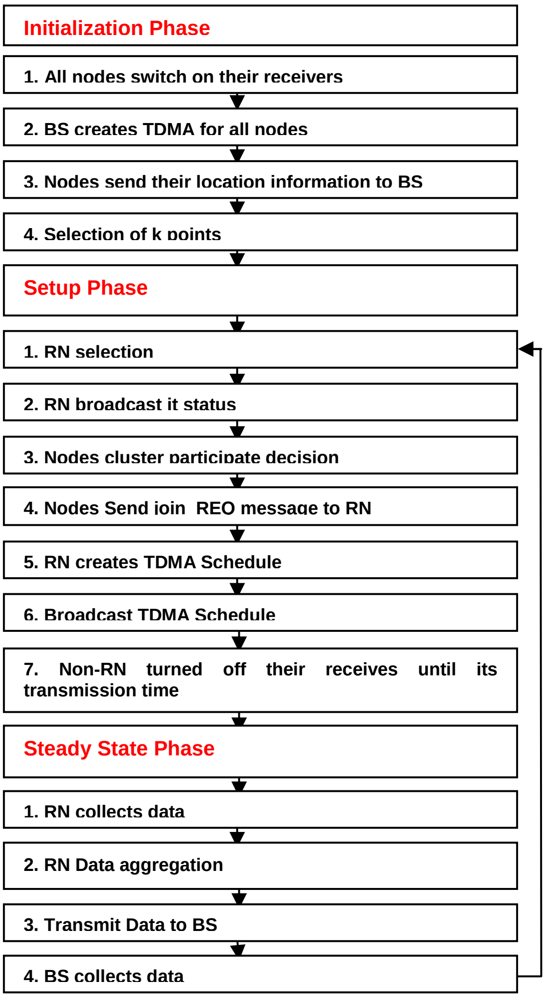


Fig. 1 Overview of the algorithm chart of EAUCD Technique.

After the steady state phase is completed, the setup phase of next round begins again immediately. The same procedure is followed in next round. The duration of the steady state phase is same as in [5]. The illustration of the EAUCD technique assumes that a set of uniform sensor nodes which are distributed randomly within a surrounded area of interest are deployed and a base station is fixed at a remote position away from the targeted area. In this scenario all the deployed nodes along with the base station are stationary i.e. immoveable. In EAUCD technique it is also supposed that the base station will communicate with enough power to other sensor nodes in the network. The two-dimension sensing ground is filled with sensor nodes deployed randomly. Similarly the simulation area is supposed to be a square area.

In EAUCD the nodes arrange themselves into local clusters with one node acting as a representative node. The representative nodes must gather the data from all the nodes in its cluster and all the nodes must transmit their data to the representative node, which carries out signal processing function (i.e. Data Aggregation) on the data received in the current round, and sends it to the base station. So a non-Representative Node can consume less energy as compared to representative nodes. In this protocol all the nodes have limited power and if the representative nodes are chosen in advance and are fixed through out the system life span then the nodes selected to be representative nodes would pass away quickly. The nodes in the network are no longer operational when the power of a representative node reaches to its low level i.e. the nodes in cluster can not communicate when the battery of the representative node pass away. In order to avoid draining the battery of a single sensor, this role of being representative node is rotated along the entire network. In this fashion the energy load is spread among all the nodes in the network.

3.4 Determining Representative Nodes

There will be no overly-utilized nodes that will run out of energy before the others if we want to equally share out the energy usage among all the sensors in the network. Being a Representative Node, will receives all the data from the nodes in its cluster so it is more energy demanding than a non-Representative node. All the nodes take its turn to be a representative node in order to equally distribute the energy use among all the nodes in the network. Thus the cluster formation algorithm should be designed in such a way that all the nodes become representative nodes for the same number of times.

Then these points are marked as Area one to Area n (i.e. A1 to An). Where A1 is the area No. 1 and An is the area no "n". The number of clusters will be equal to An. If we know the percentage of clusters as in [5], then the points may be selected from a square area using the algorithm 1. In this way the simulation area is divided into An sub areas and then representative nodes are selected from each area based on maximum energy and its location. Then the representative nodes broadcast their status to all other nodes in the network. The nodes which require minimum communication energy will participate to that representative node cluster. And then the steady state phase starts, in which the transmission to base station occurs.

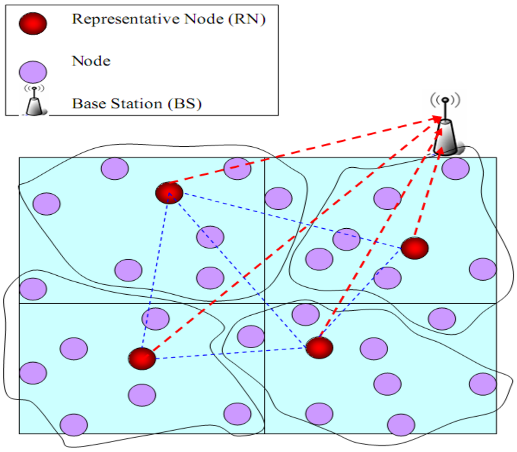


Fig. 2. Graphical representation of the architecture of the WSN scheme adopted.

Simulation results show that EAUCD technique is much better than LEACH [6], PEGASIS [8] and BCDCP [13] in energy consumption and may be applied to protocols that form LEACH as basis such as [1, 2, 3, and 4].

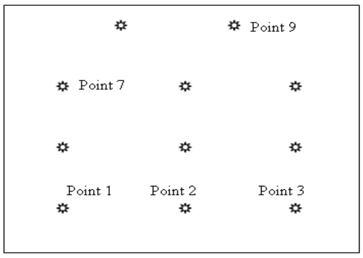


Fig. 3. Points Selected

4. Simulation

The set-up used in the simulation consists of 100 stationary sensors deployed randomly and a base station. More accurately, the nodes are supposed to be randomly deployed within the sensor field which is a square area of side L = 100 m. The base station is positioned at a distance D away from the closest point of the targeted area. D gets one value between 100m - 1000m at each one of the simulation tests. The nodes send out sensed data throughout their own time frames. It is also assumed that each node in the network sends information about the remaining energy to the base station and the radio channel is symmetrical. In conclusion, it is also assumed that there is free space communication environment with out any obstacles. Therefore, retransmission of a message is not required. Similar to [6] the parameters adopted during simulation tests along with their respective values are summarized in Table 1.

Table 1: Simulation Parameters

Parameter	***Value***
Network dimension	100m×100m
Number of sensors	100
Distance between BS and sensor field	100-1000m
Node original energy	0.5 j
Transmitter circuitry dissipation (Eelec)	50 nJ/bit
Amplifier dissipation (εamp)	100 pJ/bit/m2
Data packet size	4000 bits

In simulation test the performance of EAUCD technique versus LEACH, PEGASIS and BCDCP protocols were examined. More explicitly, the number of nodes remaining alive over time was simulated for both EAUCD and other protocols.

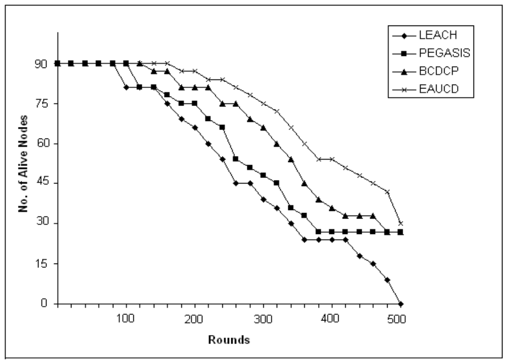
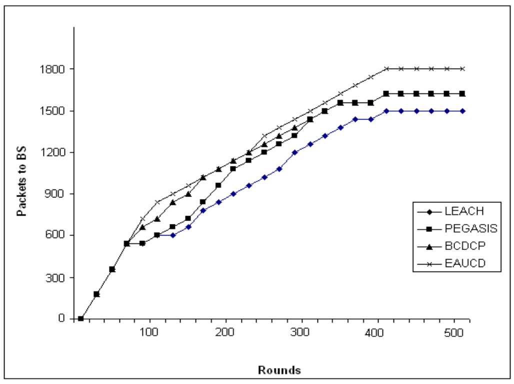


Fig. 4. Comparative depictions of [6, 8, 13] VS EAUCD, the nodes remaining alive after each round over the 90 nodes randomly deployed network in a 100mx100m area.

Figure 4 shows the number of Alive nodes after each round. In EAUCD the simulation is run for 500 rounds. The graph in the figure clearly shows that after each round the number of alive nodes in EAUCD is greater than



LEACH [6], PEGASIS [8] and BCDCP [13].

Fig. 5. Total number of packets transmitted to base station after each round.

Figure 5 shows the number of packets transmitted to base station. The packets transfer rate in EAUCD is greater than the packet rate in LEACH and other protocols because the number of dead nodes in LEACH, PEGASIS and BCDCP are greater than the number of nodes in EAUCD after each round or in other words the number of alive nodes in EAUCD is greater than the number of alive nodes in LEACH, PEGASIS, BCDCP. In LEACH the number of cluster-heads is in each round depends on random number generator so there is a chance that no cluster-head may be selected in a round.

We simulated EAUCD (with 10% of the nodes being cluster-heads) using MATLAB with the E_{elec}=50 nJ/bit random network. Figure 5 shows the total number of packets/messages transmitted to base station. The line of EAUCD in the graph shows that the number of messages transmitted to base station using EAUCD is greater than LEACH, PEGASIS, BCDCP. This is because the number of alive nodes in EAUCD is greater.

5. Conclusion

Uniform distribution of cluster heads is the focus of this work. This is achieved by dividing the simulation space into sub parts and representative nodes are selected from each part based on maximum energy left at the node in the part. When the representative nodes have all the data from the nodes in its cluster it aggregates the data and then the aggregated message is transmitted to base station. In this way each area have a representative nodes unlike LEACH in which the cluster heads may be selected from only one part of the network. Simulation results show that using this approach increases the life time of the network.

References

[1] Zhicheng Dai, Zhi Li,Bingwin Wang, and Tiang Tang, "An EnwrgyAwar Cluster Based Routing Protocol for Wireless Sensor and Actor Network", Information Technology Journal 8 (7): 1044-1048 2009.

[2] Houda Zeghile, Nadjib Badache, Moufida Maimour, "Energy Efficient Cluster-based Routing in Wireless Sensor Networks", 14th IEEE Symposium on Computers and Communications, ISCC'09, Sousse : Tunisia (2009).

[3] Dionisis Kandris, Panagiotis Tsioumas,Anthony Tzes, George Nikolakopoulos and Dimitrios D. Vergados, "Power Conservation through Energy Efficient Routing in Wireless Sensor Networks", Sensors journal 2009.

[4] S. Chandramathi, U.Anand, T.Ganesh, S.Sriraman and D.Velmurugan, "Energy Aware Optimal Routing for Wireless Sensor Networks", Journal of Computer Science 3 (11): 836-840, 2007.

[5] W. Heinzelman, A. Chandrakasan and H.Balakrishnan, "Energy Efficient Communication Protocol for Wireless Micro sensor Networks", Proceedings of the 33rd Hawaii International Conference on System Sciences (HICSS '00), January 2000.

[6] Anantha Chandrakasan, Wendi Rabiner Heinzelman, and Hari Balakrishnan, "An Application Specific Protocol Architecture for Wireless Microsensor Networks", IEEE Transaction on wireless communication,2002.

[7] Al-Karaki, J.N.; Kamal, A.E "Routing techniques in wireless sensor networks: a survey", IEEE Wirel. Commun. 2004, 11, 6–28.

[8] Lindsey, S.; Raghavendra, C.S "PEGASIS: Power-efficient gathering in sensor information systems", In Proceedings of IEEE Aerospace Conference, Big Sky, MT, USA, 2002; pp. 1125–1130.

[9] Manjeshwar, A.; Agrawal, D.P "TEEN: a routing protocol for enhanced efficiency in wireless sensor networks", In 15th International Parallel and Distributed Symposium, San Francisco, CA, USA, April 2001; pp. 2009–2015.

[10] Manjeshwar, A.; Agarwal, D.P. "APTEEN: A hybrid protocol for efficient routing and comprehensive information retrieval in wireless sensor networks", In Proceedings of the 16th International Parallel and Distributed Processing Symposium, Ft. Lauderdale, FL, USA, April 2002, pp. 195–202.

[11] Jamal N. Al-Karaki, Raza Ul-Mustafa, Ahmed E. Kamal, "Data Aggregation in Wireless Sensor Networks - Exact and Approximate Algorithms'", Proceedings of IEEE Workshop on High Performance Switching and Routing (HPSR) 2004, April 18-21, 2004, Phoenix, Arizona, USA.

[12] Yoshitsugu Obashi, Huifang Chen, Hiroshi Mineno and Tadanori Mizuno "An Energy-Aware Routing Scheme With Node Relay Willingness In Wireless Sensor Networks", International Journal of Innovative Computing, Information and Control, ISSN 1349-4198Volume 3, Number 3, June 2007.

Masood Ahmad has received M.S degree in Computer Science from National University of Computer & emerging Sciences Islamabad. He is currently enrolled in PhD at IQRA University Islamabad and working as a Lecturer at Department of Computer Science, City University of Science & IT Peshawar, Pakistan

Masood Habib is an active researcher in the field of Network Management & Security, currently working as a Lecturer at Department of Computer Science, City University of Science & IT Peshawar, Pakistan. He has done M.S in Information Technology and his PhD is in progress from Shaheed Zulfikar Ali Bhutto Institute of Science and Technology Islamabad, Pakistan.

Muhammad Zahir Shah has received M.S degree in Computer Science from National University of Computer & emerging Sciences Islamabad. He is currently enrolled in PhD at IQRA University Islamabad.

Fasee Ullah is an active researcher in the field of Network and System security, currently working as a Lecturer in the Department of Computer Science, City University of Science & IT Peshawar. He has done MS (Information Technology) from SZABIST Islamabad Pakistan.

Shah Hussain is currently enrolled in MS (Computer Science) in Department of Computer Science, City University of Science & IT Peshawar, Pakistan.