Density Based Protocol For Head Selection In Wireless Sensor Networks

Priti Narwal, S.S. Tyagi

***Abstract*—In wireless sensor networks nodes have several limitations such as limited battery life, low computational capability, short radio transmission range and small memory space. However, the most severe constraint of the nodes is their limited energy resource because they cease to function when their battery has been depleted. To reduce energy usage in wireless sensor networks, many cluster-based algorithms have been proposed. Among those proposed, LEACH (Low Energy Adaptive Clustering Hierarchy) is a well-known cluster-based sensor network architecture . In this paper, subtractive clustering technique, which is an enhancement in the basic LEACH protocol to deal with its severe shortcomings with respect to handling of node‘s non-uniform and time variant energy distribution.**

Keywords: Clustering, Density based clustering, LEACH protocol, Subtractive clustering, Wireless Sensor Networks

I . INTRODUCTION

A wireless sensor network is composed of a large number of sensor nodes and base station. The base station typically serves as a gateway to some other networks. It provides powerful data processing, storage center, and an access point to the sensor nodes in its network. Sensor nodes sense their environment, collect sensed data and transmit it to the base station. However, they are limited in power, computational capacity and memory. Moreover, they have only short-range radio transmission. In a given network, the sensor nodes must be intelligent enough to make the network capable of self-organizing and selfhealing. The nodes must be robust to changes in size and shape of the network and able to constantly maintain their connectivity to the network. Note that these nodes are the resource-constrained devices and last until their battery has been depleted. When all sensors die, the network is gone. Due to these peculiar characteristics of the sensor nodes such as low battery life, low computing capabilities and low transmission power, the traditional routing protocols employed in wired networks and ad hoc networks are not suitable for the sensor networks.

Many research works have been proposed to deal with nodes' limitation problems; they are related to routing within the sensor networks. Cluster-based routing algorithms are used to reduce the energy consumption of nodes and prolong the network lifetime [4, 5, 6, 7]. In most cluster-based algorithms, a predefined number of clusters or cluster heads is required. Cluster-based routing algorithms are used to reduce the energy consumption of nodes and prolong the network lifetime [4, 5, 6, 7]. In most cluster-based algorithms, a predefined number of clusters or cluster heads is required. In this paper, we propose an intelligent cluster formation method which is an energy-aware cluster head selection method and it can partition a given network into an appropriate number of clusters without the need to predefine the number, an energy-aware cluster head selection method.

II. LEACH PROTOCOL

Many cluster-based communication protocols have been developed [4, 5, 6]. The main idea of these protocols is based on dynamically selecting a cluster head among eligible active nodes. In [7], energy-efficient communication architecture named LEACH has been proposed to not only evenly distribute the energy load among sensor nodes in the network but also extend the network lifetime. LEACH is adaptive clustering-based sensor network architecture, which is based on a completely distributed algorithm. Clusters are formed by local coordination among sensor nodes in the network. Cluster heads are randomly and rotationally selected; nodes within each cluster submit their sensed information to a respective cluster head where local computation within each cluster reduces the amount of data that must be transmitted to the base station. This achieves a large reduction in the total energy dissipation.

In [1] the operation of LEACH is divided into rounds and each round separated into two phases, the set-up phase and the steady-state phase, as shown in Figure 1. In the set-up phase, each node decides whether or not to become a cluster head for

Manuscript received May 28, 2011.

Priti Narwal is a M.Tech student in computer science and engineering in Manav Rachna International University, Faidabad ,India .
e-mail : narwal..priti@gmail.com

Dr. S.S.Tyagi is a professor in department of computer science and engineering in Manav Rachna International University ,Faridabad , India
e-mail : shyam.fet@mriu.edu.in

the current round.

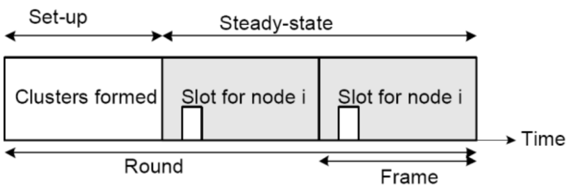

Figure.1 LEACH operations

$$T(n) = \begin{cases} \dfrac{p}{1 - p * (r \bmod \frac{1}{p})} & \text{if } n \in G \\ 0 & \text{otherwise} \end{cases}$$

This decision is based on the threshold T(n). (e.g., p = 0.05), r is the current round, and G is the set of nodes that have not been cluster heads in the last 1/p rounds. Cluster head broadcasts an advertisement message to the rest of the nodes. Depend on the signal strength of the advertisement messages, each node selects the cluster head it will belong to. The cluster head creates a TDMA scheme and assigns each node a time slot. In the steady-state phase, the cluster heads collect data from sensor nodes, aggregate the data and send it to the base station.

In LEACH, the cluster heads are elected randomly, so the optimal number [3] and distribution of cluster heads [3] cannot be ensured. The nodes with low residual energy have the same priority to be a cluster head as the node with high residual energy, resulting in some node with low residual energy may die first.

III. SUBTRACTIVE CLUSTERING

Subtractive clustering is an efficient clustering method that determines the adequate number of clusters as well provides the appropriate position for any cluster to initiate. This clustering method assumes that each sensor node is a potential cluster center. It calculates a measure of the likelihood that each data point would be defined as the cluster center, based on the density of the surrounding data points. The algorithm functions as the following:

- It identifies the sensor node with the highest probability to be the first cluster center.
- It eliminates all sensor node in the vicinity of the first cluster center (determined by radii), in order to determine the next probable cluster and its center location.
- It iterates this process until all of the data points (sensors) are covered, i.e. each of the data point lies within the range of some cluster.

The subtractive clustering method is considered as an extension of a popularly known density based clustering method, called mountain clustering method.

The variables required for subtractive clustering are enlisted in tabular form along with their interpretation in the Table 1. In order to use subtractive clustering, four parameters values are pre-initialized in Table 2.

Consider a collection of q sensor nodes $\{x_1, x_2, \ldots, x_q\}$ specified by m-dimensional x_j.

Without loss of generality, assume the feature space is normalized so that all data are bounded by a unit hypercube. Calculate potential for each sensor node by using equation below:

$p_i = \sum_{j=1}^{q} e^{-\alpha \|x_i - x_j\|^2}$ with $\alpha = \frac{4}{r_a^2}$ where $\|.\|$ denotes Euclidean distance. It is noteworthy that only the fuzzy neighborhood within the radius r_a to the measure of potential. After the potential of every sensor node has been computed, the sensor node with the highest potential is selected as the first cluster center.

Table 1:Notations for Subtractive Clustering

Symbol	***Meaning***	***Interpretation***
x_i	Sensor Node	represents i^{th} sensor node in the sensor network
p_i	Sensor Potential	associates a potential with the i^{th} sensor node
x_k^*	Cluster Center	represents the k^{th} cluster center
p_k^*	Cluster Potential	defines the potential associated with the k^{th} cluster center
r_a	Cluster Radius	creates a neighborhood of influence for a cluster
r_b	Penalty Radius	defines a neighborhood of a subsequent cluster with reduced potential
η	Quash Factor	the predefined factor that multiplies the radii values of the distant nodes so as to suppress (squash) their potential from being considered as a part of that cluster
$\bar{\varepsilon}$	Reject Ratio	a user defined threshold for potential above which a node is accepted as a cluster center
$\underline{\varepsilon}$	Accept Ratio	a user defined threshold for potential below which a node is rejected from being a cluster center

.

Symbol	*Chui*	*Demirli*
r_a (Cluster Radius)	[0.25 , 0.50]	[0.15 , 1]
η (Quash Factor)	1.25	[0.05 , 2]
$\bar{\varepsilon}$ (Reject Ratio)	0.15	[0 , 0.9]
$\underline{\varepsilon}$ (Accept Ratio)	0.5	[0 , 1]

Table 2: Parameters for Subtractive Clustering

We assume x_1^* is the location of the first cluster center and p1* is its potential value, the potential of each sensor node x_j can be revised by the formula:

$$p_i \Leftarrow p_i - p_1^* e^{-\beta\|x_i - x_1^*\|^2}, \ \beta = 4/r_a^2, \ r_b = \eta r_a \tag{2}$$

When the potential of all sensor nodes have been reduced by equation (2), the sensor node with the highest remaining potential is selected as the second cluster center. Then further reduce the potential of each sensor node. Generally, after k^{th} cluster center has been obtained, the potential of each sensor node is revised by formula:

$$p_i \Leftarrow p_i - p_k^* e^{-\beta\|x_i - x_k^*\|^2} \tag{3}$$

Where x_1^* is the location of the k^{th} cluster center and p_1^* is its potential value. The process of acquiring new cluster center & revising potential is done by using following algorithm:

Algorithm 1: Discovery of Subsequent Cluster Centers:

BEGIN:

1. if $p_k^* > \bar{\varepsilon} p_1^*$
2. accept x_k^* as a cluster center and continue
3. else if
4. reject x_k^* and end the clustering process
5. else
6. let $d_{\min}$ = shortest of the distances between x_k^* and all previously found cluster centers
7. if $\frac{d_{\min}}{r_a} + \frac{p_k^*}{p_1^*} \geq 1$
8. accept x_k^* as a cluster center and

x_k^* x_k^*

IV. CLUSTER-HEAD SELECTION

A cluster head is a distinguished node in a cluster that performs data aggregation and monitors that inter- as well as intra-cluster transmission of data in the network.We have constructed a multi-layer selection criteria for choosing the head nodes for clusters (algorithm 2). The members of the dominating set (DS) are considered for cluster head election. The first level is the Energy Filtration. In this level, we take two energy extremes [ξmin, ξmax] and check the energy level ($ENRL_{node}$) of the all the nodes in DS. The nodes that satisfy the condition form the set L1.

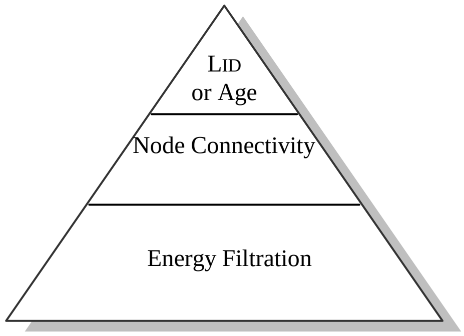

Figure 2: Cluster Head Selection Levels

Once the nodes are filtered energy-wise, we progress to the next level, which is based on *Node Connectivity*. Connectivity of a node in the sensor network can be defined as the degree of that node, i.e. the count of number of nodes to which it connected via single hop links. All the nodes that have the same maximum number of neighboring nodes (maximum degree) are put in the set L2. If the cardinality of the set is 1, then we skip the third level and elect the node in the set L2 as the cluster head. However, in case the set contains more than one element, we choose to move onto the third level.
The third level is based on considering the node ids. Initially when the nodes are deployed they are provided a unique identity (ID), which is basically a numeral. Lowest identity or LID is simple algorithm that selects a node with its ID lowest among the remaining nodes in the given set or cluster. Therefore, the node with LID in the set L2 becomes the cluster head. However, LID alone in the third level is considered only for the first round of cluster head selection. Age is another criterion that is regarded as the load balancing parameter for selecting head nodes from the second round onwards in wireless sensor networks. Proper load distribution within clusters is eminent for ultimately increasing the lifespan of the sensor network. Rotation of the cluster head is one such

Algorithm 2: Cluster Head Selection

BEGIN:

if ($\xi_{min} < ENRL_{node} < \xi_{max}$)

$L_1 \leftarrow$ Filter dominator nodes

end if

$L_2 \leftarrow$ select nodes with maximum degree from L_1

if ($|L_2| > 1$)

c_head ← select node with lowest id (LID)

seed.hop = 0

c_head.state = '*cluster head*'

c_head.age = c_head.age + 1

way of achieving power control in a cluster that requires dynamic selection of cluster heads. Previously, static cluster head selection procedures were used in which the head was elected once, and continued to be the cluster head till the cluster exists.

This not only placed additional pressure on the single node, but also led to energy imbalances in the network. Dynamic selection of cluster head ultimately helps in distributing the load over a subset of nodes in a cluster. This subset of probable nodes can be regarded as nominees for the cluster head.

V. CONCLUSION

In our research, we have introduced the concept of aging (of the cluster heads) to accomplish the purpose. Aging is a phenomenon that induces linear increase in an attribute of an object, in order to record the time period of its functional existence. In our case, the recording attribute is the age of the sensor nodes. Once a node becomes cluster head, it performs aggregation and monitoring activities till its energy level drops below a certain thresholdλ. The value of λ determines the frequency by which the head node will be rotated. This factor is implementation dependent based on requirement. As the energy falls, the head node increases age by 1 and floods a re-election message to all the remaining members of the independence set. On receiving the message, the probable nodes initiate the multi-level cluster head selection algorithm to select the next cluster head. The advancement of the age is interpreted as:

- Number of times the node has become cluster head.
- An estimation of its remaining energy level.
- Its probability to be re-elected as the cluster head.

Once, a node from IDS becomes a cluster head, it starts loosing its priority to get re-elected as a head node in the cluster, i.e. an aged IDS node has less probability to contest for cluster head election process.

This kind of rotation scheme ensures that the clusters keep altering the turns among several probable nodes (or nominees) for determining cluster head. This eradicates the major problem of the static cluster heads becoming a bottleneck in the performance of the sensor network.

REFERENCES

[1] Giuseppe Anastasi, Marco Conti, Mario Di Francesco, Andrea Passarella, Energy Conservation in Wireless Sensor Networks: a Survey, Ad Hoc Networks, 2009.

[2] W. R. Heinzelman, A. P. Chandrakasan, and H. Balakrishnan, "An Application-Specific protocol Architecture for wireless microsensor networks," IEEE Transactions on Wireless Communications, October, 2002.

[3] W. R. Heinzelman, J. Kulik, and H. Balakrishnan, "Adaptive protocols for information dissemination in wireless sensor networks," in Proceedings of the ACM MobiCom'99.

[4] C.R. Lin and M. Gerla, "Adaptive Clustering for Mobile Wireless Network," IEEE J. Select. Area Commun., vol 15, pp. 1265-1275, Sept 1997.

[5] J. H. Ryu, S. Song, and D. H. Cho, "Energy-Conserving Clustering Scheme for Multicasting in Two-tier Mobile Ad-Hoc Networks," Elec-tron. Lett., vol. 37, pp. 1253- 1255, Sept 2001.

[6] T. C. Hou and T. J. Tsai, "Distributed Clustering for Multimedia Support in Mobile Multihop Ad Hoc Network," IEICE Trans. Commun., vol. E84B, pp. 760- 770, Apr 2001.

[7] Wendi Rabiner Heinzelman, Anantha Chanfrakasan, and Hari Balakrishnam, "Energy-Efficient Communication Protocol for Wireless Microsensor Networks," 2000 IEEE The Hawaii International Conference on System Sciences Proceeding, January 2000.

[8] A. Manjeshwar and D. P. Agarwal, "APTEEN: A Hybrid Protocol for Efficient Routing and Comprehensive Information Retrieval in Wireless Sensor Networks," Proc.Int'l. Parallel and Distrib. Proc. Symp., 2002, pp. 195– 202.

[9] P. Tillapart, T. Thumthawatworn, P. Pakdeepinit, T. Yeophantong, S. Charoenvikrom and J. Daengdey, "Method for Cluster Heads Selection in Wireless Sensor Network," Proc. of the 2004 IEEE Aerospace Conference, Big Sky, Montana, USA, 2004.

[10] C. Intanagonwiwat, R. Govindan, and D. Estrin, "Directed Diffusion: A Scalable and Robust Communication Paradigm for Sensor Networks," in Proceedings of the ACM/IEEE International Conference on Mobile Computing and Networking (MOBICOM), 2000.

[11] D. Ganesan et al., ''Highly-Resilient, Energy-Efficient Multipath Routing in Wireless Sensor Networks,'' Mobile Computing and Communications Review, Vol. 1, No. 2, 2002.

[12] R. Kannan, et al., ''Sensor-Centric Quality of Routing in Sensor Networks,'' Proceedings of the 22nd Annual Joint Conference of the IEEE Computer and Communications Societies (InfoCom'03), Vol. 1, Apr. 2003.

[13] B. Krishnamachari, D. Estrin, S. Wicker, ''Modelling Data-Centric Routing in Wireless Sensor Networks,'' Proceedings of the 21st Annual Joint Conference of the IEEE Computer and Communications Societies (InfoCom'02), New York, June 2002.

[14] N. Bulusu et al., ''Adaptive Beacon Placement,'' Proceedings of the 21st International Conference on Distributed

Computing Systems (ICDCS'21), Phoenix, AZ, Apr. 2001, pp. 489ff.

[15] P. Bergamo, G. Mazzini, ''Localization in Sensor Networks with Fading and Mobility,'' Proceedings of the 13th IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC'02), Vol. 2, Sept. 2002.

[16] Q. Li et al., ''Distributed Algorithms for Guiding Navigation Across a Sensor Network,'' Proceedings of the 9th ACM International Conference on Mobile Computing and Networking (MobiCom'03), San Diego, CA, Sept. 2003.

Priti Narwal received B.Tech degree in Computer Science & Engineering from Maharshi Dayanand University in 2008 and is pursuing M.Tech. in CSE from Manav Rachna International University,Faridabad . Presently, she is working as Lecturer in Computer Science & Engineering department in Delhi College of Technology & Management, Palwal. Her areas of interest is Wireless Sensor Networks..

Dr. S. S. Tyagi received B.Tech in Computer Science and Engineering from Nagpur University and M.E from BITS, Pilani and Ph.D in Computer Science from Kurukshetra University, Kururkshetra. Presently, he is working as Professor in department of Computer Science & Engineering in Manav Rachna International University, Faridabad. His areas of interests are Wireless Security, Mobile Ad hoc Networks and Wireless Mesh Networks.