International Journal of Applied Engineering Research
ISSN 0973-4562 Volume 10, Number 6 (2015) pp. 15581-15591

http://www.ripublication.com

Distributed Clustering Using Enhanced Hierarchical Methodology For Dense WSN Fields

[1]Dr.S. Sophia, [2]S.R.Boselin Prabhu, [3]P.Dhakshina Moorthi, [4]D.Senthil Raja, [5]N.Arun Kumar
[1]Professor, Sri Krishna College of Engineering and Technology, Coimbatore, India.
[2]Assistant Professor, SVS College of Engineering, Coimbatore, India.
[3]PG Scholar, Nandha Engineering College, Erode, India.
[4]Assistant Professor, Excel Engineering College, Namakkal, India.
[5]Assistant Professor, EASA College of Engineering and Technology, Coimbatore, India.
Corresponding author E-mail: eben4uever@gmail.com

Abstract

Wireless sensor network (WSN) is formed by the grouping of wireless sensor nodes, for cooperative communication, finding applicable in environmental monitoring, battlefield surveillance, military, forest fire, sensor cloud, and in many related fields. One of the peculiar features of wireless sensor network compared to the traditional wireless communication networks is the battery power, due to the fact that the batteries of the sensor nodes have restricted lifetime and are difficult to be replaced. This is why the focus is towards energy utilization, while many of the traditional wireless networks mainly focuses on the Quality of Service (QoS). A typical wireless sensor node consumes most of its energy during communication. However, energy expenditure takes place while performing sensing and data processing operations too. This work suggests the development of an advanced hierarchical clustering technique, the Energy-efficient Hierarchical Distributed Clustering Algorithm (EHDCA). This is a well-distributed clustering mechanism and the cluster head (CH) selection is based on residual energy, communication cost and the distance to the base station (BS). The main characteristic feature of the proposed algorithm is the CH selection in just few steps and its hierarchical nature. Simulation results clearly show an excellent improvement in clustering efficiency and routing efficiency. The backbone energy and the total system energy usage are greatly reduced. Moreover the lifetime of nodes has been found to be greatly prolonged.

Keywords: Wireless sensor network, distributed clustering, cluster head, base station, energy efficiency, routing efficiency, clustering efficiency, network lifetime.

Introduction

The introduction of wireless electronics and sensing technologies has made the fabrication of low-cost wireless sensor nodes. A wireless sensor network normally contains a large number of wireless sensor nodes (or simply nodes). A sensor node comprises of low power processor, tiny memory, radio frequency module, sensing devices and limited powered batteries. Greater amount of energy consumption in a WSN happens during wireless communications between the nodes and BS. The energy usage when transmitting a single bit of data corresponds to thousands of cycles of CPU operations. These wireless sensor nodes gather data from the sensing area which is possibly out-of-access for human beings. Data gathered from the sensing field are usually reported to a remotely located base station or sink node. Some emerging applications of wireless sensor networks are wildlife monitoring, environmental observation, landslide detection and health care monitoring. Since wireless sensor nodes are energy-limited devices, long-distance communications should be kept to bare minimum level in order to expand the network lifetime. Thus, direct communications between nodes and the base station are usually not encouraged. An effective methodology to boost-up the efficiency is to arrange the network into multiple clusters, with every cluster selecting one node as its CH. A cluster head collects data from other sensor nodes within its cluster, either directly or by hopping through other nearby wireless sensor nodes. The data collected from nodes of the same cluster are greatly correlated. The aggregated data will then be forwarded to the base station directly or by forwarding through other CH, thereby only cluster heads are required to transmit the data over larger distances.

The remaining nodes will need to only carryout short-distance communication. To deal with the workload of the cluster heads, CHs will be re-elected from time to time [1]. Clustering has some projected advantages like localizing route setup within a particular cluster radius, efficient topology maintenance, energy efficiency, utilization of communication bandwidth efficiently and makes the best use of network lifetime [2]. Since clustering makes use of the mechanism of data aggregation, unwanted communication between the sensor nodes, CH and BS is avoided [3]. Energy consumption of wireless sensor nodes is greatly minimized and the overall network lifetime can thus be prolonged.

This paper gives a profound description about an Energy-efficient Hierarchical Distributed Clustering Algorithm (EHDCA) for dense wireless sensor networks. The rest of the paper has been organized as follows. Related research works in this domain has been discussed in section II. The limitations of the existing systems have been described in section III. Section IV elaborates the features of the proposed system. The basic concept of the proposed scheme has been discussed in section V. Section VI describes the performance evaluation of the proposed EHDCA algorithm. Section

VII elaborates the assumptions that are to be carried out for implementation, and finally the last section gives the conclusion.

Related Works

In WSNs it becomes infeasible to replace the dead batteries of the nodes. As soon as some of the sensor nodes in a WSN run out of energy, they stop functioning causing progressive deconstruction of the sensor network [4]. Therefore, one of the well-known limitations in the development of WSN is the power consumption. Each and every protocols should be so designed, that minimum energy should be consumed during sensing, processing and wireless communication Three layers are involved in the functioning of a WSN. Physical and data link layers, of the protocol stack deals with the energy awareness, radio communication hardware and energy aware MAC protocols. At the Network layer, of the protocol stack, the main aim is to find ways for energy efficient route setup and reliable data transmission from the nodes to the base station in order to prolong the overall network lifetime as much as possible.

The clustering mechanism proposed here is the hierarchical clustering mechanism. The main idea is that, every sensor node within a WSN is grouped along with some other of its neighboring nodes so as to constitute a cluster. Data collected by the sensor nodes are not directly transmitted to the base station [5]. Instead, a node of the cluster called the Cluster head, aggregates these data and forwards them to the base station. The major hierarchical-based algorithms for sensor networks are LEACH, TEEN and SHPER.

The initial step in the generation of LEACH (Low Energy Adaptive clustering of Hierarchy), is the formation of clusters. More precisely, each sensor nodes decides whether or not to become the cluster head for the particular round. The decision is based on the priority and also on the number to time the node has been a cluster head so for. The cluster nodes collect the data and send them to the CH. The radio module of each cluster nodes can be turned off when there is no sensing takes place. When all the data have been received the cluster head aggregates the data in to a single composite signal. The composite signal is forwarded to the base station [6].

Manjeshwar et al (2001) proposed TEEN (Threshold sensitive Energy Efficient Network) protocol, in which the initial stage is the formation of clusters. In this mechanism each cluster member nodes becomes cluster head for a time interval called cluster period.

The SHPER (Scaling Hierarchical Power efficient Routing) protocol includes base station and sensor nodes which are randomly distributed over a bounded area of interest. Both the base station and sensor nodes are found to be stationary. The end users can access the data from the base station, which is located farther from the sensor field. All the cluster nodes are grouped in to individual clusters [7, 8]. Within each cluster, one of the cluster nodes is elected to be the cluster head. The election of cluster heads in SHPER is based purely on the residual energy. The cluster heads that are nearer to the base station, that can communicate with the base station with reasonable power consumption is considered to the highest level cluster head.

Similarly, the cluster head which is located far away from the base station is considered to be the lowest level cluster head [9].

The operation of SHPER, protocol includes two main phases: the initialization phase and the steady state phase. The base station decides which sensor node should be the cluster head. The nodes other than cluster head become the cluster nodes (member nodes). Each cluster head, along with some cluster nodes are grouped together to form a specific cluster. The base station sends the ID of each cluster heads which are newly elected. Further each node decides, to which cluster it belongs to and it informs its cluster head that, it will be a member of that cluster. The cluster head informs each of its cluster nodes when it can transmit. Accordingly the data is collected by the cluster head and aggregated, further being transmitted to the base station.

The Limitations of The Existing Systems

LEACH protocol has the disadvantage, when periodic transmissions are unnecessary, thus causing much energy usage. The selection of CH is based on priority, and hence there is a possibility for weaker nodes to be drained because they are elected to be cluster heads as frequently as the strong nodes. Also, the existing protocol is based on the assumption that all nodes begin with the same amount of energy capacity in each election round and all the nodes can transmit with enough power to reach the BS if needed. Ultimately, in many cases these assumptions are unrealistic leading to energy hole in the network.

TEEN protocol has been developed for reactive networks so as to respond to sudden changes in the sensed attributes. This makes it appropriate for time critical application areas. Thus, TEEN is not appropriate for applications where periodic reports are needed.

In case of SHPER, the election of cluster heads is purely based on the base station. Hence unnecessary transmissions occur between the base station and cluster heads. Also the base station should keep track on the sensor nodes in order to decide which node has the highest residual energy. Hence unnecessary transmissions occur between the base station and sensor nodes, thus causing maximized energy usage.

Features of The Proposed System (EHDCA)

This work suggests a new idea over the existing techniques. In case of existing techniques, the election of cluster heads and cluster nodes are entirely done by the base station. Hence they require additional power consumption. The work mainly suggests the cluster head to be completely responsible for all the process including the election of cluster heads and cluster nodes. The cluster head normally calculates the power consumed by the nodes which normally depends on the available power at the nodes and distance between the nodes and the cluster head. Two thresholds are used namely hard threshold and soft threshold. Hard threshold is the possible minimum value of the attribute to trigger a wireless sensor node to switch on its transmitter and transmit to the cluster head. Soft threshold is a small change in the value of the sensed attribute that triggers the node to switch on its transmitter and transmit data. The hard threshold tries to reduce the number of transmission by allowing their nodes to transmit only when the sensed attribute is beyond a particular critical value. Similarly, soft threshold reduces the number of transmissions that might have otherwise occurred when there is little or no change in the value of sensed attribute. At every cluster change the values of both the thresholds can be changed and thus enabling the user to control the tradeoff between energy efficiency and data accuracy. The cluster nodes transmit the sensed data to the cluster head. The main characteristic feature of this method is that, residual energy is transmitted along with the sensed data by the cluster nodes to the cluster head. The cluster head only transmits the aggregated data to the base station. Figure 1 shows the hierarchical clustering architecture of the proposed EHDCA algorithm.

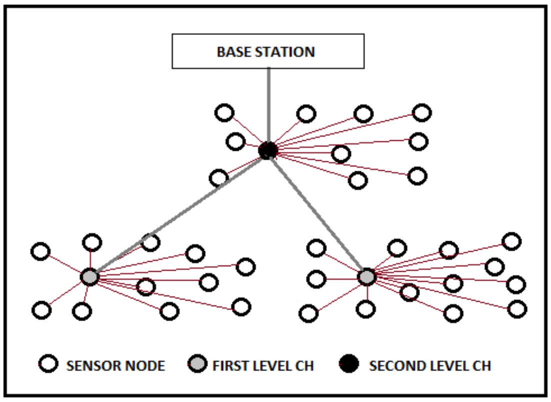

Figure 1: Hierarchical clustering Architecture of EHDCA algorithm

Moreover every process such as initialization, formation of clusters, election of cluster heads and monitoring the residual energy are entirely done by the cluster head. Store and forward technique is followed at the cluster head, so that the sensed attribute along with the residual energy is collected from the cluster nodes, stored at the cluster head, further the aggregated data alone is forwarded to the base station. Since the base station has no direct link with the cluster nodes, unnecessary transmissions are avoided, thereby saving enormous power.

Basic Concept of The Proposed System

As described in the preceding sections, cluster heads need to be evenly distributed over the whole network for saving energy. In the proposed EHDCA scheme, redundant creation of cluster heads in a small area has been avoided. Figure 2 shows the timeline concept of the proposed scheme.

A. The Set-up Phase

The main activities in the set-up phase are election of cluster nodes, selection of CHs, scheduling at every cluster, and discovery of the CH for CH-to-CH data transmittal.

During set-up phase, each node first decides whether or not it can become a candidate node in each region for the current round. An advertisement message has been used to elect the cluster heads. For this, the candidate nodes use MAC protocol. Every candidate node usually broadcasts an advertisement message within its transmission range. This range is dependent on the maximum distance between the levels. In EHDCA, the advertisement range is given double of the maximum distance to cover other levels. This decision is based on the signal strength of the advertisement message.

After each node has decided to which cluster it belongs, the sensor node transmits its data to the appropriate CH. After CH receives all the messages from the sensor nodes that would like to be included in the cluster and based on the number of nodes contained in the particular cluster, the CH creates a TDMA schedule and thereby assigns each node a definite time slot when it can transmit. For this, each cluster head utilizes two-way handshake technique, with REQ and ACK message. Each cluster head broadcasts REQ message within the advertisement range. Upward cluster head receiving this REQ message transmits ACK message back to the cluster head that transmitted REQ message. When the node that transmitted REQ message receives ACK message, it chooses this cluster head which transmitted ACK message as the next hop. If cluster head cannot find upward cluster head, it chooses the sink as the next hop.

B. The Steady-State Phase

The steady-state phase of the proposed scheme is similar to other cluster-based routing protocol. Main activities of this phase are sensing and transmission of sensed data. Each sensor nodes senses and transmits the sensed data to its cluster head according to own TDMA time schedule. When all the needed data have been received, the CH performs data aggregation process in order to further reduce the amount of data transmissions.

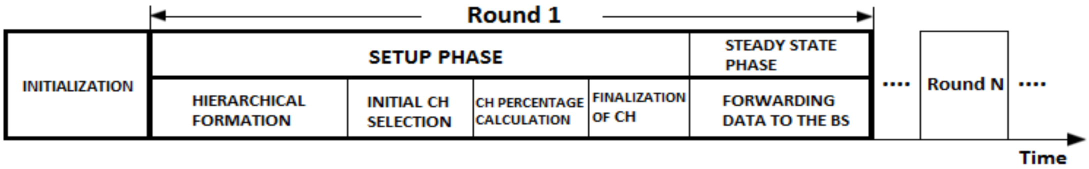

Figure 2: Timeline of the proposed EHDCA Scheme

Performance Evaluation

The proposed EHDCA clustering scheme has been evaluated through simulations. For the simulations, a network model similar to the one used in the conventional routing protocols, with the following properties has been assumed. All sensor nodes are considered to be immobile. Each sensor node initially has uniform energy level of 1 Joule/node. A fixed sink node is located 80 m away from the edge of network. The sensor nodes are equipped with power control capabilities. For experiments, the network parameters and the communication energy parameters has been set as shown in table 1.

Table 1: Simulation parameters

Simulation parameters	Values
Number of nodes	30
Field size	500 m x 500 m
Distance to sink	80 m
Initial energy of nodes	1 Joule/node
Data packet size	500 bytes
Aggregation energy	10 nJ/bit/signal
Threshold distance	75 m

Figure 3 shows the total energy dissipation for each round for both LEACH and EHDCA. Initially, at 500 rounds the total energy dissipation is 0.3 Joules and 0.18 Joules for LEACH and EHDCA respectively. Similarly for 4500 rounds, the energy dissipation is 0.26 Joules and 0.17 Joules for LEACH and EHDCA respectively. Throughout the process, the energy dissipation is found to be reduced in EHDCA when compared to LEACH. This is because, the proposed scheme reduces unnecessary redundant creation of cluster heads and utilizes CH-to-CH routing path and hence unnecessary energy dissipation is avoided.

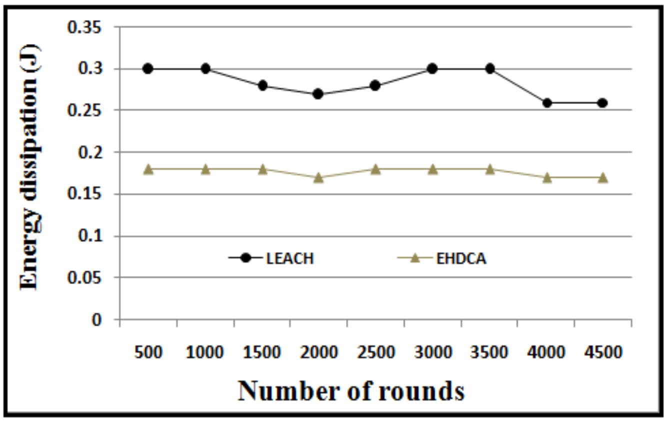

Figure 3: Total energy dissipation of LEACH and EHDCA

Figure 4 shows the number of nodes alive in each round for both LEACH and EHDCA. All the 30 sensor nodes are alive till 1500 rounds for both the algorithms. But in 2000 rounds, the number of nodes alive is 30 and 26 for EHDCA and LEACH. Similarly in 3500 rounds, the number of sensor nodes alive is 18 and 0 for EHDCA and LEACH respectively. It could be clearly seen that all the nodes die in LEACH for 3500 rounds, but in EHDCA every nodes die only in 4500 rounds. This clearly shows that the proposed EHDCA scheme has a longer life time than LEACH, because of the hierarchical concepts employed in the proposed methodology.

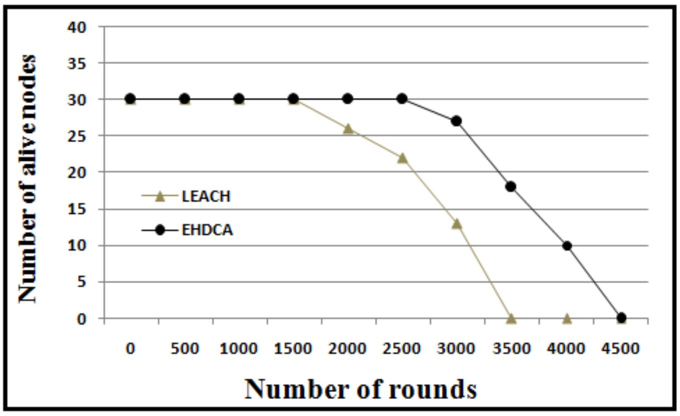

Figure 4: Number of nodes alive in LEACH and EHDCA

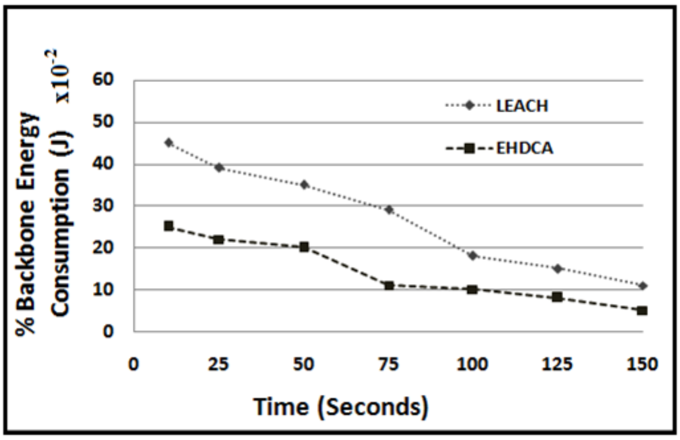

Figure 5: Backbone Energy Consumption versus time for LEACH and EHDCA

Figure 5 shows the backbone energy consumption versus time for both LEACH and EHDCA. Initially at 25 seconds, the backbone energy consumption is 0.39 Joules and 0.22 Joules for LEACH and EHDCA respectively. Similarly in 150 seconds, the backbone energy consumption is 0.11 Joules and 0.05 Joules respectively for LEACH and EHDCA. Throughout the process, the backbone energy consumption is found to be very less in EHDCA, when compared to LEACH. This is mainly because LEACH uses random CH selection mechanism and direct forwarding of the aggregated data to the base station. But EHDCA employs hierarchical method for cluster formation and the aggregated data is not directly forwarded to the base station. Thus, it could be clearly seen that the proposed methodology is highly efficient in terms of backbone energy consumption when compared to LEACH.

Figure 6 shows the routing efficiency comparison of both ECDCA and LEACH. Initially in 500 rounds, the percentage routing efficiency is 52 and 84 for both

LEACH and EHDCA respectively. Similarly in 4500 rounds, the percentage routing efficiency is 61 and 82 respectively for both LEACH and EHDCA. It could be evidently seen that, the routing efficiency of EHDCA is better than LEACH throughout the clustering-routing process. This is because of the avoidance of direct forwarding of aggregated data from CH to the BS, in the proposed EHDCA mechanism.

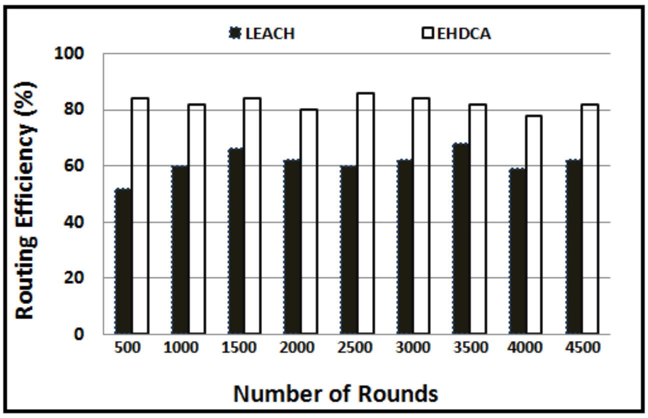

Figure 6: Routing efficiency comparisons in LEACH and EHDCA

Figure 7 shows the energy efficiency comparison of both EHDCA and LEACH. Initially in 500 rounds, the percentage energy efficiency is 45 and 76 for both LEACH and EHDCA respectively. Similarly in 4500 rounds, the percentage energy efficiency is 20 and 48 respectively for LEACH and EHDCA. Throughout the process, the energy efficiency is better in EHDCA when compared to LEACH. Thus, it could be clearly mentioned that the proposed EHDCA mechanism is a well-distributed and energy-efficient clustering-routing mechanism.

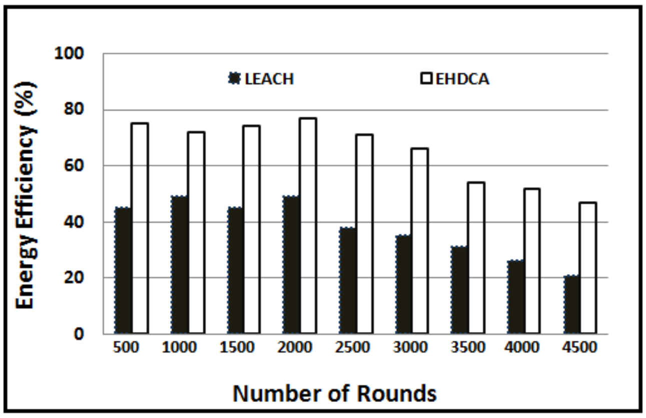

Figure 7: Energy efficiency comparisons in LEACH and EHDCA

Assumptions

The radio channel is assumed to be symmetrical. Thus, the energy required to transmit a message from a source to a destination node is the same as the energy required to transmit the same message from the destination node back to the source node for a given SNR (Signal to Noise Ratio). Moreover, it is assumed that the communication medium is contention (error free). Ultimately, retransmission is not needed. The initial energy of each node is assumed to be the same.

Conclusion

This paper is concerned with the proposal of an energy-efficient hierarchical distributed clustering algorithm (EHDCA) for static wireless sensor networks. The main feature of this technique, compared to the existing techniques is that the election of cluster head, cluster nodes and monitoring of residual energy, etc are purely done by the cluster head. Since base station does not involve in these processes, unnecessary energy wastage for long distances communication is avoided, thereby reducing power consumption to much extent. The concept of threshold employed in the proposed methodology reduces unwanted transmissions from CH to the BS. Also the CH election is done in just few steps when compared to the existing distributed clustering algorithms. Simulation results clearly show that the proposed EHDCA scheme depicts an excellent improvement in clustering efficiency and routing efficiency. The backbone energy consumption and energy dissipation have been reduced to a greater extent. It is noted that the first node death and the last node death are delayed and the overall network lifetime is prolonged in case of the proposed EHDCA mechanism.

Acknowledgements

The authors owe their thanks to their respective institutions for supporting them with necessary laboratory facilities for conducting this research work. All the authors have equally contributed for developing this research article with appreciable technical quality.

References

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

[2] Manjeshwar, A., and Agarwal., 2001, "TEEN: A Routing Protocol for Enhanced Efficiency in Wireless Sensor Networks,", 1st International Workshop on Parallel and Distributed Computing Issues in Wireless Networks and Mobile Computing., San Francisco., USA.

[3] Younis, O., and Fahmy, S., 2004, "HEED: A hybrid Energy-Efficient Distributed Clustering Approach for Ad Hoc Sensor Networks," IEEE Transactions on Mobile Computing.
[4] Chan, H., and Perrig, A., 2004, "ACE: An Emergent Algorithm for Highly Uniform Cluster Formation," Proceedings of 1st European Workshop on Sensor Networks (EWSN)., Germany.
[5] Guangfeng Li., and Taieb Znati., 2007, "A Ring-Structured Energy-Efficient Clustering Architecture for Robust Communication in Wireless Sensor Networks," International Journal of Sensor Networks., Volume 2.
[6] Nagpal, R., and Coore, D., 1998, "An Algorithm for Group Formation in an Amorphous Computer," Proceedings of the 10th International Conference on Parallel and Distributed Systems (PDCS'98)., Las Vegas.
[7] Youssef, A., Younis, M., Youssef, M., and Agrawala, A., 2006, "Distributed Formation of Overlapping Multi-Hop Clusters in Wireless Sensor Networks," Proceedings of the 49th Annual IEEE Global Communication Conference (GLOBECOM '06)., San Francisco., CA.
[8] Nikolaos Pantazis., Dimitrios, J., and Vergados., 2006, "Increasing Intelligent Wireless Sensor Networks Survivability by Applying Energy-Efficient Schemes," Proceedings of the 3rd IFIP Conference on Artificial Intelligence Innovations & Applications (AIAI 2006)., Athens., Greece.
[9] Manjeshwar, A., and Agrawal., 2002, "APTEEN: A Hybrid Protocol for Efficient Routing and Comprehensive Information Retrieval in Wireless Sensor Networks," Proceedings of the 2nd International Workshop on Parallel and Distributed Computing Issues in Wireless Networks and Mobile computing., FL., USA.
[10] Akkaya, K., and Younis, M., "A Survey of Routing Protocols in Wireless Sensor Networks," Elsevier Ad Hoc Network Journal, 3(1), pp.325-349.