Journal of Engineering and Applied Sciences 13 (24): 10429-10435, 2018
ISSN: 1816-949X

An Enhanced Routing Protocol for Unequal Clustering in Wireless Sensor Networks

[1]K. Thyagarajan and [2]T. Bhaskara Reddy
[1]Department of Computer Science and Engineering, Rayalaseema University, Kurnool, india
[2]Department of Computer Science and Technology, Sri Krishnadevaraya University, Anantapuramu, india

Abstract: From the past decade, the utilization of Wireless Sensor Network (WSN) in the remote areas is grown rapidly. The major issue faced by the WSN is energy consumption of the sensor nodes. To address the issue of energy consumption, this study developed an enhanced version of energy aware unequal clustering protocol. Initially, the nodes in the proposed protocol compute the distance from the sink node. To calculate the distance, the sink node broadcast the signal. Based on the signal strength received by the nodes they calculate the distance to the sink node. The proposed protocol uses distance from the nodes to sink node, residual energy and the count of neighboring nodes to operate the competition radius. It helps in reducing the energy consumption and increasing the lifetime of the network. The performance evaluation of the proposed protocol has been tested with other two existing protocols. The results show that the proposed protocol is efficient in reducing the energy consumption and improving the lifetime of the nodes.

Key words: Relay nodes, sink node, energy consumption, unequal clustering, WSNs, existing protocols

INTRODUCTION

Wireless sensor networks are composed of large number of sensor nodes with capability of shorter range wireless communication (Akkaya and Younis, 2005). Each sensor node is organized with sensing unit, battery unit, storing unit, processing unit and transmitter and receiver. Wireless sensor networks are deployed in secure environments like home, office etc., or some unsafe locations like battle fields, toxic regions etc., However, apart from the usage of the sensor networks, there needs to be address the issues of energy consumption, security and computation for efficient utilization (Akyildiz *et al*., 2002). Among the above issues, energy consumption of the sensor nodes is the major constraint. It is not possible to replenish the batteries of sensor nodes which are distributed in hostile environments. Therefore, the efficient mechanisms are needed to use the battery power as well as to increase the life time of the sensor nodes.

In the recent years, many energy efficient routing protocols are developed and are categorized into three categories, minimum cost routing protocol, max-min routing protocol and, minimum energy routing protocol. The minimum cost routing protocols maximizes the energy of the nodes in the route. The max-min routing protocols such as max-min zP_{min}, CMMBCR and MREP avoids the problem of selecting the route from the less residual energy of the sensor nodes. But these protocols creates network overhead and it is also difficult to calculate the threshold value for the operational nodes. The minimum energy routing protocol reduces the total energy consumption in their path to the destination (Chang and Tassiulas, 1999; Heinzelman *et al*., 2000). Therefore, these protocols are not useful in increasing the life time of the network. Apart from the above three categorized protocols, there are many efforts to increase the life time of the networks.

Most of the discussed protocols are based on the hierarchical protocols or flat protocols. They are not discusses about the implementation details of how the sensor nodes are deployed and distributed in the region. The location information of the senor nodes is easy to determine and it is used to construct the routing protocols for energy saving mechanisms. The major advantage of location based routing protocols is localization and stateless behaviour (Chang and Tassiulas, 1999). The packet forwarding in the location based routing protocol is dependent on the location of the sender node and the vicinity of the receiver node. Therefore, the location based routing is important in reducing the network overhead and to preserve the energy of the nodes.

In clustering protocols, the cluster head selection plays major role that are associated with the cluster formation, data forwarding, data receiving and data

Corresponding Author: K. Thyagarajan; Department of Computer Science and Engineering, Rayalaseema University, Kurnool, india

aggregation (Soro and Heinzelman, 2005; Heinzelma *et al.*, 2000; Younis and Fahmy, 2004). Therefore, the energy consumption of the cluster head is more when compared to the other nodes. In the inter-cluster communication, there is major problem of misbalancing the energy consumption between the nodes for single hop and multi hop communication. For single hop communication, the energy consumption of the nodes is high due to the distance between the nodes and the base station. But in the multi hop communication the cluster head is nearer to the base station consumes more energy because of the extra burden caused by the traffic.

This study made an attempt to improve the network lifetime by developing the model for energy aware unequal clustering protocol. The basic idea behind this protocol is to select the cluster head based on the node residual energy, distance factor and number of neighbouring nodes.

Literature review: In the earlier research, the cluster algorithms are primarily designed based on the residual energy of the nodes and rotation of cluster heads after each round. Low Energy Clustering Hierarchy (LEACH) is one of the protocol comes into this category (Heinzelman *et al.*, 2002). The LEACH protocol considers single hop communication between the nodes to the base station and it is not suitable for the large scale networks. Many routing protocols are developed based on the LEACH protocol such as M-LEACH (Mhatre and Rosenberg, 2004) and LEACH-DT (Kang and Nguyen, 2012). The distributed energy efficient clustering algorithm uses the residual energy of the node and average energy of the network to elect the cluster head. But it is not sufficient to many to one data gathering process in wireless sensor networks.

The algorithms for overcoming the energy consumption are divided into three categories. First is transmission range adjustment mechanisms discussed in reference (Amgoth and Jana, 2015) has developed to increase the lifetime of the network. By Abdulla *et al.* (2014), the energy consumption problem is investigated by adjusting the radii of the sensor nodes. But, this mechanism has high impact on the area of the network. By Kong *et al.* (2014), the mobility of the base station is considered as the solution for the energy consumption of the nodes.

The researchers made a contribution towards developing the strategy of reducing the energy consumption in cluster based wireless sensor networks (Yao *et al.*, 2015; Nadeem *et al.*, 2013; Jabbar *et al.*, 2016; Yao *et al.*, 2013). Many mechanisms are developed for both equal clustering and unequal clustering approaches. They consider the unequal cluster only to address the unequal energy consumption of the nodes in the network (Dong *et al.*, 2014; Ahvar *et al.*, 2014; Omar *et al.*, 2016).

MATERIALS AND METHODS

Preliminaries: The research presents the enhanced energy aware unequal clustering algorithm. Here, the network is configured with N number of sensor nodes which is deployed in M×M region. The sensor nodes and the sink node are in static mode and also the initial energy of the nodes is in the form of heterogeneous. The location of the sink node is far away from the sensor nodes. The sensor nodes adjust their power distribution based on the transmission distance. The sensor node forms their communication with another node based on the received signal strength. The communication links between the sensor nodes assumed to be symmetric (Li *et al.*, 2005; Min *et al.*, 2010). The Cluster Heads (CH) can transmit the Control Messages (CM) and Data Messages (DM) with the sink node. The data sensed by the sensor nodes are assumed to be highly correlated.

Energy consumption model: To transmit the data from one sensor node to another node, it consumes some energy and the energy consumption model of the wireless sensor networks is given in Fig. 1.

$$E_{Tran}(x, d) = \begin{cases} xE_e + x\varepsilon_f d^2, & \text{where } d < d_0 \\ xE_e + x\varepsilon_a d^4, & \text{where } d > d_0 \end{cases} \quad (1)$$

The transmission energy for x bit packet for a distance of d between two nodes is given by Eq. 1:

$$d_0 = \sqrt{\frac{\varepsilon_f}{\varepsilon_a}} \quad (2)$$

The receiving energy for x bit packet is given by Eq. 3:

$$E_{Rec}(x) = xE_e \quad (3)$$

Where:

x = The number of bits
E_{tran} = The transmission energy
E_{rec} = The receiving energy
d = The distance between the nodes
E_e, E_f, E_a = The coefficients of the energy consumption model

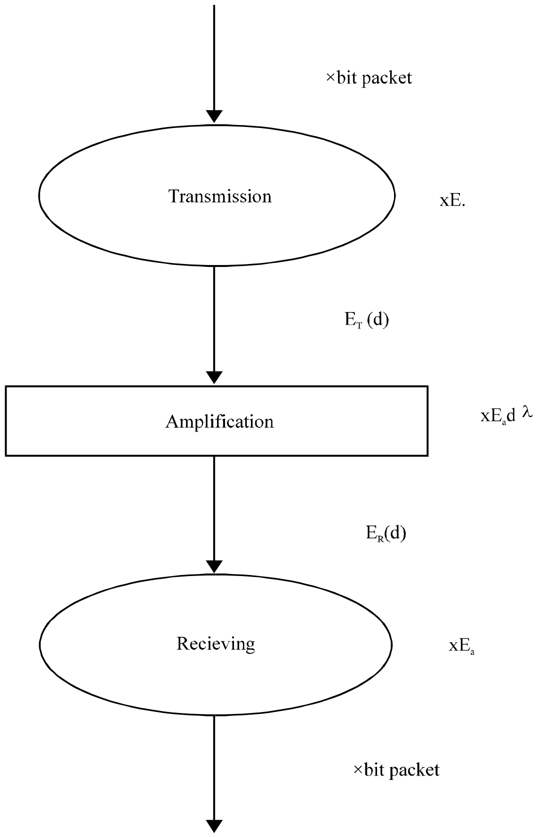

Fig.1: Energy consumption model of two nodes

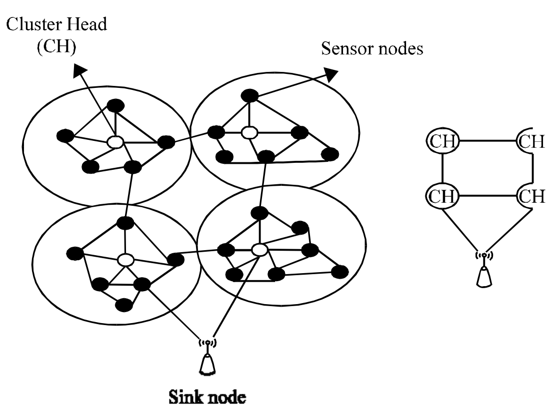

Fig. 2: Architecture of wireless sensor networks

Data aggregation model for WSNs: In the proposed research, the infinity compressed model is selected for data aggregation process (Akkaya and Younis, 2005; Akyildiz etal., 2002; Chang and Tassiulas, 1999). In WSNs, the sensor nodes forward the sensed data to the cluster head where it aggregates and transfers them in to single packet of fixed size to the sink node. The architecture of wireless sensor network is shown in Fig. 2.

Enhanced energy aware unequal clustering protocol: In this research, the proposed approach uses the clustering mechanism that is similar to the Energy Aware Distributed Unequal Clustering (EADUC) protocol (Xu *et al*., 2011). Initially, the nodes in the proposed protocol compute the distance from the sink node. To calculate the distance, the sink node broadcast the signal. Based on the signal strength received by the nodes they calculate the distance from the sink node. The proposed protocol is organized with two phases. One is cluster setup phase and another one is steady state phase which is responsible for data transfer. The cluster setup phase is again divided in to three sub modules with in the time intervals of α_1, α_2 and α_3. The first sub module is responsible for collection of neighboring node information. After the initialization of first sub module, each node in the network broadcasts the message N_{msg} having the information of node id and residual energy. All the nodes are located in the transmission range, receives the message from its neighboring nodes. Then, the average residual energy of the cluster E_{ARE} is calculated by each node which is shown in Eq. 4:

$$E_{ARE} = (\sum_{i=1}^{m} N_i \times E_{res}) / \beta \quad (4)$$

Where:

N_i = The one of the node in the network
$N_i \times E_{res}$ = The residual energy of the node
N_i, β = The number of neighbouring nodes

After completion of time interval α_1, the sec sub module will start with the completion for cluster head whose time interval is α_2. After completion of information collection, each node uses Eq. 5 to calculate the waiting time for broadcasting the head message H_{Msg}.

$$w = \begin{cases} \frac{E_{ARE}}{E_{res}} \alpha_2 v_{res}, & E_{res} \geq E_{ARE} \\ \alpha_2 v_{res} & E_{res} < E_{ARE} \end{cases} \quad (5)$$

Where:

w = The waiting time of the node
E_{res} = The residual energy of the node
v_{res} = The real values lies in between 0.9-1.

These real values decrease the chances of sending the head message H_{msg} by the two nodes at the same time (Li and Mohapatra, 2005). If any node in the network does not receive the H_{msg} then it broadcasts the H_{msg} with in the competition radius and it will declares its position as cluster head. The proposed protocol uses different rules in the competition radius and it is calculated by using Eq. 6:

$$R = \left[1\text{-}k\left(\frac{d_{max}\text{-}d(N_i,S)}{d_{max}\text{-}d_{min}}\right)\text{-}l\left(1\text{-}\frac{E_{res}}{E_{max}}\right)\text{+}m\left(1\text{-}\frac{N_i(\beta)}{\beta_{max}}\right)\right]R_{max} \quad (6)$$

where, k, l, m represents the weights range from 0-1, d_{min} and d_{max} represent the minimum and maximum distance from the nodes from the sink node, E_{max} represents the maximum initial energy of the nodes in the network. d (Ni, S) represents the distance of the node 'i' from the sink node S. R_{max} denotes the maximum value of the transmission radius. Therefore, the proposed protocol considers the distance of the nodes from the sink node, node's residual energy, neighbouring nodes information and the cluster size.

After the second sub module, the cluster head selection is completed. The cluster formation is initiated at the time interval α_3. In this module, the nodes send the join message $J_{msg}$to the nearest cluster head. Then as a reply, the cluster head broadcast the TDMA scheduling message $M_{schedule}$ to the cluster members for the transmission of data. The nodes in the cluster only active during their schedule and in other times the nodes are in the sleep mode. This process will helps in minimizing the energy consumption of the nodes.

After the cluster formation is completed, the steady state phase is initialized. This phase is responsible for data transmission. The nodes follow intra process communication to send their sensed data to their respective cluster heads in the prescribed time slots. The cluster head receives the sensed data and stores the average aggregated data. The cluster head makes all the aggregated data in to one single packet. This process is continuous in all the clusters.

The cluster head forwards the aggregated data packet to the sink node directly or by using the relay mode. If the distance from the cluster head to the sink is maximum than the threshold ($d_{treshold}$), then it follows the inter cluster communication, otherwise it transfers directly to the sink node. If the relay mode is selected by the cluster head, then the energy consumption of the relay process is given in Eq. 7:

$$E_{Relay} = d^2(N_i,N_j)+d^2(N_i,S) \quad (7)$$

In the proposed protocol, the distance between the nodes and the energy consumption is not only sufficient to find the route but also it requires finding the relay nodes energy consumption E_{Relay}. Finally, one of the feasible nodes is selected as a relay node based on the Eq. 8. In the proposed routing protocol, each cluster head broadcasts the message with its residual energy, node id, count of the cluster members and distance to the sink node. The CH is elected as relay node if its residual energy is having the largest value compared to all the nodes in the cluster:

$$N_{Relay} = \frac{N_i \times E_{i,res} \times N_i \times Count \times xE_{Rec}\text{-}(N_i \times Count\text{+}1) \times x \times EDA\text{-}xE_{Tran}}{E_{max}} \quad (8)$$

where, $Ni \times Ei_{,res}$ represents the residual energy of the ith node, Count represents the ith node member count, xERec represents the energy cost for receiving the data packet of size x. EDA represents the energy consumed for data aggregation and xE_{Trans} represents the energy consumption to transfer the data from one CH to another CH. The cluster head Ni transmits the data directly to the sink node, if there is no CH is available to route the packet or is Ni has predefined threshold distance to the sink node. Therefore, the CH selects the relay node that having the highest residual energy. The selection of relay nodes will keep the network energy balanced and also increases the lifetime.

Analysis of the proposed routing protocol: The proposed protocol consists of the following properties such as in WSNs, the selection of cluster head is based on the ratio of the average residual energy and the energy consumed by remaining nodes is shown in Eq. 5. This approach will reduce the energy consumption of the network and also improves the life time.

The selected cluster heads covers overall network, From the Eq. 5, it is confirmed that any node can be a cluster head with in the time interval α_2 and also, if any node doesn't receive the H_{msg}, it broadcast the generated H_{Msg} to the sink node.

The proposed protocol uses distance to the sink node, residual energy and the count of neighbouring nodes to operate the competition radius. It helps in reducing the energy consumption and increasing the lifetime of the network. The relay nodes help in reducing the energy as well as to prolong the lifetime of the network.

RESULTS AND DISCUSSION

The simulation environment is deployed with 100 nodes that are uniformly distributed over the region of 400×400 m^2. The nodes in the region are non-uniformly distributed. The parameters for the simulation environment are given in Table 1.

Table 1: The parameters for the simulation environment

Parameter	Values
Region of the network (m^2)	400×400
No. of nodes	100
Size of the data packet (bytes)	500
Initial energy of nodes (J)	0.5-1.5
E_e (nJ/bit)	50
E_a (pJ/bit/m^4)	0.0013
E_f (pJ/bit/m^2)	10
E_{DA} (nJ/bit/signal)	5
R_{max} (m)	110
K, l, m	0.3333

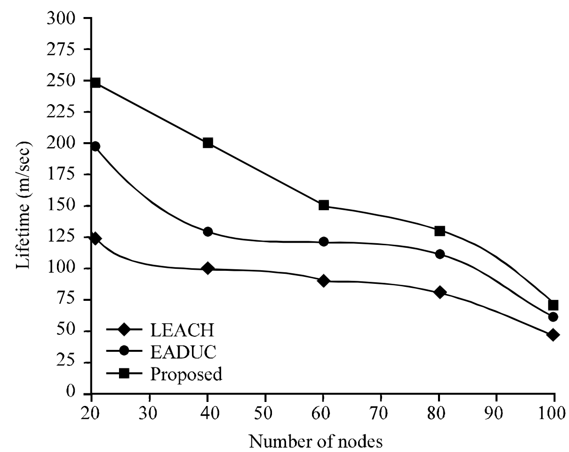

Fig. 3: Network lifetime of the nodes

To know the performance of the proposed protocol, we developed the other existing models such as Energy Aware Distributed Unequal Clustering (EADUC) protocol (Xu *et al*., 2011) and Low Energy Clustering Hierarchy (LEACH) protocol (Heinzelman *et al*., 2002). The simulations are carried by using the QualNet 6.1 simulator. In the simulation experiment, the energy model and data aggregation models are used as per explanation given in

Network lifetime evaluation: The performance of the EADUC, LEACH and the proposed protocol in terms of network lifetime are shown in Fig. 3. The LEACH protocol considers single hop communication between the nodes to the base station and it is not suitable for the large scale networks. The EADUC protocol uses the residual energy of the nodes to select the cluster head that will increase the network life time. But the proposed protocol selection of cluster head is based on the ratio of the average residual energy and the energy consumed by remaining nodes. This will automatically decreases the energy consumption of the network.

Evaluation of network remaining energy: Figure 4 shows the total energy preserved by the network with respect to the protocol such as LEACH, EADUC and the proposed

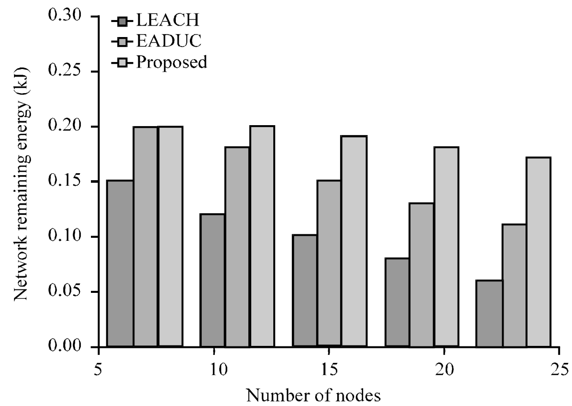

Fig. 4: Network remaining energy

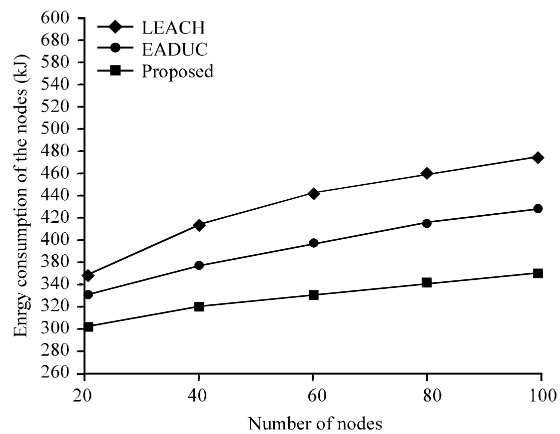

Fig. 5: Energy consumption of the nodes

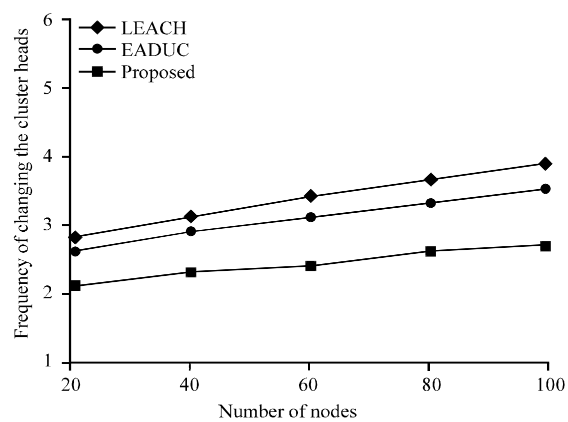

Fig. 6: Frequency of changing the cluster heads

protocol. It is observed the initial energy of all the nodes in different protocols is same but the total remaining energy of the LEACH and EADUC is less when compared to the proposed protocol. This is due to the relay nodes assigned to the proposed protocol.

Evaluation of energy consumption: The average energy consumption of the three protocols is given in Fig. 5. For each single round, the average energy consumption is calculated until the lifetime of the nodes ends. The average energy consumption also considers the energy consumed at the time of cluster formation and data transmission. The average energy consumption is quite less in the proposed protocol when compared to the LEACH and EADUC.

Frequency of changing the CHs: Figure 6 shows the changing frequency of cluster heads for every round in the proposed protocol. The energy consumption of the network is depending on the cluster head selection. If the cluster heads are changing in the rotation policy, the energy consumption overhead will be increased. Therefore, it is observed on the Fig. 6 that the proposed protocol had less frequency of changing the cluster heads compared to the LEACH and EADUC.

CONCLUSION

In this study, we presented the enhanced version of the energy aware unequal clustering algorithm in order to increase the lifetime of the nodes and to decrease the energy consumption of the network. The unequal radius is selected for unequal cluster formation with different sizes. The clusters that are nearer to the sink node have the uniform clustering properties and the remaining clusters have on uniform properties. The completion radius is operated based on the distance to the sink node, average residual energy and count of neighbours. Therefore, the energy consumption of the clusters is equally balanced.

REFERENCES

Abdulla, A.E., H. Nishiyama, N. Ansari and N. Kato, 2014. Energy-Aware Routing for Wireless Sensor Networks. In: The Art of Wireless Sensor Networks, Ammari, H. (Ed.). Springer, Berlin, Germany, ISBN:978-3-642-40008-7, pp: 201.

Ahvar, E., S. Ahvar, G.M. Lee and N. Crespi, 2014. An energy-aware routing protocol for query-based applications in wireless sensor networks. Sci. World J., 2014: 1-9.

Akkaya, K. and M. Younis, 2005. A survey on routing protocols for wireless sensor networks. Ad Hoc Networks, 3: 325-349.

Akyildiz, I.F., W. Su, Y. Sankarasubramaniam and E. Cayirci, 2002. Wireless sensor networks: A survey. Comput. Networks, 38: 393-422.

Amgoth, T. and P.K. Jana, 2015. Energy-aware routing algorithm for wireless sensor networks. Comput. Electr. Eng., 41: 357-367.

Chang, J.H. and L. Tassiulas, 1999. Routing for maximum system lifetime in wireless ad-hoc networks. Proceedings of the 37th Annual Allerton Conference on Communication Control and Computing Vol. 37, September 22-24, 1999, University of Illinois at Urbana-Champaign, Illinois, USA., pp: 1191-1200.

Dong, M., K. Ota, L.T. Yang, S. Chang and H. Zhu *et al*., 2014. Mobile agent-based energy-aware and user-centric data collection in wireless sensor networks. Comput. Netw., 74: 58-70.

Heinzelman, W.B., A.P. Chandrakasan and H. Balakrishnan, 2002. An application-specific protocol architecture for wireless microsensor networks. IEEE Trans. Wireless Commun., 1: 660-670.

Heinzelman, W.R., A. Chandrakasan and H. Balakrishnan, 2000. Energy-efficient communication protocol for wireless microsensor networks. Proceedings of the 33rd Annual Hawaii International Conference on System Sciences, January 7, 2000, IEEE, New York, USA., ISBN:0-7695-0493-0, pp: 1-10.

Jabbar, S., A.A. Minhas, T. Rashid and S. Rho, 2016. Heuristic approach for stagnation free energy aware routing in wireless sensor networks. Adhoc Sens. Wirel. Netw., 31: 21-25.

Kang, S.H. and T. Nguyen, 2012. Distance based thresholds for cluster head selection in wireless sensor networks. IEEE Commun. Lett., 16: 1396-1399.

Kong, L., C.M. Chen, H.C. Shih, C.W. Lin, B.Z. He and J.S. Pan, 2014. An energy-aware routing protocol using cat swarm optimization for wireless sensor networks. In: Advanced Technologies, Embedded and Multimedia for Human-Centric Computing. Huang, Yueh-Min., C. Han-Chieh , D. Der-Jiunn, J.J.H.P. James.(Ed.). Springer, Netherlands, pp: 311-318.

Li, C., M. Ye, G. Chen and J. Wu, 2005. An energy-efficient unequal clustering mechanism for wireless sensor networks. Proceedings of the IEEE International Conference on Mobile Ad Hoc and Sensor Systems Conference, November 7, 2005, IEEE, Nanjing, China, ISBN: 0-7803-9465-8, pp: 604-604.

Li, J. and P. Mohapatra, 2005. An analytical model for the energy hole problem in many-to-one sensor networks. Proceedings of the 62nd Semiannual Vehicular Technology Conference, September 25-28, 2005, IEEE Press, Dallas, USA., pp: 2721-2725.

Mhatre, V. and C. Rosenberg, 2004. Homogeneous vs heterogeneous clustered sensor networks: A comparative study. Proceedings of the 2004 IEEE International Conference on Communications Vol. 6, June 20-24, 2004, IEEE, Paris, France, pp: 3646-3651.

Min, X., S. Wei-Ren, J. Chang-Jiang and Z. Ying, 2010. Energy efficient clustering algorithm for maximizing lifetime of wireless sensor networks. AEU-Int. J. Electron. Commun., 64: 289-298.

Nadeem, Q., M.B. Rasheed, N. Javaid, Z.A. Khan and Y. Maqsood *et al*., 2013. M-GEAR: Gateway-based energy-aware multi-hop routing protocol for WSNs. Proceedings of the 8th International Conference on Broadband and Wireless Computing, Communication and Applications (BWCCA), October 28-30, 2013, IEEE, Compiegne, France, ISBN:978-0-7695-5093-0, pp: 164-169.

Omar, M., S. Yahiaoui and A. Bouabdallah, 2016. Reliable and energy aware query-driven routing protocol for wireless sensor networks. Ann. Telecommun., 71: 73-85.

Soro, S. and W.B. Heinzelman, 2005. Prolonging the lifetime of wireless sensor networks via unequal clustering. Proceedings of the 19th IEEE International Conference on Parallel and Distributed Processing Symposium, April 4-8, 2005, IEEE, Denver, Colorado, USA., ISBN:0-7695-2312-9, pp: 1-8.

Yao, Y., Q. Cao and A.V. Vasilakos, 2013. EDAL: An energy-efficient, delay-aware and lifetime-balancing data collection protocol for wireless sensor networks. Proceedings of the 2013 IEEE 10th International Conference on Mobile Ad-hoc and Sensor Systems (MASS), October 14-16, 2013, IEEE, Hangzhou, China, ISBN:978-1-4799-3408-9, pp: 182-190.

Yao, Y., Q. Cao and A.V. Vasilakos, 2015. EDAL: An energy-efficient, delay-aware and lifetime-balancing data collection protocol for heterogeneous wireless sensor networks. IEEE. ACM. Trans. Networking, 23: 810-823.

Younis, O. and S. Fahmy, 2004. HEED: A hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks. IEEE Trans. Mobile Comput., 3: 366-379.

Yu, J., Y. Qi, G. Wang, Q. Guo and X. Gu, 2011. An energy-aware distributed unequal clustering protocol for wireless sensor networks. Int. J. Distrib. Sensor Networks, 10.1155/2011/202145.