Journal of Engineering and Applied Sciences 12 (Special Issue 9): 8757-8763, 2017
ISSN: 1816-949X

Improved Energy Efficient Cluster Based Routing Protocol (I-EECBRP) for Wireless Sensor Network

[1]Hawa Madani Traore, [1, 2]Kamilia Kamardin, [1]Suriani Mohd Sam, [1]Kamarul Zaman Panatik,
[1]Salwani Mohd Daud, [3]Nurul Aini Bani and [1]Hafiza Abas
[1]Advanced Informatics School, Universiti Teknologi Malaysia, Kuala Lumpur, Malaysia
[2]Wireless Communication Centre,
[3]Razak School of Engineering and Advanced Technology, Universiti Teknologi Malaysia,
Jalan Sultan Yahya Petra, 54100 Kuala Lumpur, Malaysia

Abstract: Hierarchical routing is one of the efficient techniques for routing the sensed data from the source node to the base station. Energy efficient cluster based routing protocol deals with cluster formation based on different events, cluster head selection, aggregation of the sensed data within a cluster and sending that to the base station in an energy efficient way. It resolved the drawbacks in most of the existing protocol that does not check the occurrence of events at the time of cluster formation phases. Thus energy efficient cluster-based routing protocol performs efficiently than Energy-Efficient Heterogeneous Clustered scheme for wireless sensor network (EEHC) and smart cluster Head Selection Scheme for Clustering algorithms in wireless sensor network (SCHS) but it does not deal with the association mechanism when the node lies in the transmission range of two cluster heads. On such condition, it is inefficient if the node joins any one of the two cluster heads randomly. In this research, EECBRP is improved using location based node association mechanism in which node sends its association request to the cluster head which has the shortest distance to it. The research was conducted using the Network Simulator NS-2. Three metrics, the throughput, number of dead nodes and average residual energy was used to compare the performance of the two protocols. Analysis of the network trace file shows that the proposed protocol I-EECBRP achieve increased throughput and average residual energy and reduced dead nodes count compare to EECBRP.

Key words: Cluster-based routing protocol, wireless sensor network, energy efficient, dead nodes, EECBRP, metrics, reduced

INTRODUCTION

Wireless Sensor Networks (WSN) comprise of devices that are powered by a small battery and with restricted energy resources. After installed, these devices or sensor nodes cannot usually be accessed by the user and is not feasible to replace the energy source. As a consequence, energy efficiency is the main issues that require enhancement in order to improve the network lifespan. Different protocols have been suggested to improve the effectiveness of network lifetime with a restricted supply of energy (Guo and Zhang, 2014; Tyagi and Kumar, 2013; Nikolidakis *et al*., 2013; Attea and Khalil, 2012).

As many nodes with low-power must be networked together, standard techniques such as direct transmission from any node to a Base Station (BS) have to be avoided. In this technique, the BS is just like the destination node to the other nodes within the network where the sensed data can be accessed by the user. When the data is directly sent to the BS, the loss of energy can be large depending on where the sensor nodes are located in regards to the BS. Therefore, in this kind of scenario the nodes far from the BS will lose their power sources much faster than the ones nearer to the BS.

On the other hand, using a standard multi-hop routing scheme, like MTE protocols will evenly produce the same effect. In MTE, the closest nodes to the BS will easily lose their energy resources as they participate in the routing of many data messages from other nodes to the BS.

SCHS protocol has been proposed by Pal *et al.* (2012) and states that the energy consumed is due to intra-cluster communication that depends on the cluster head location in the cluster. Thus in this scheme, the network area was divided into two portions which are

Corresponding Author: Hawa Madani Traore, Advanced Informatics School, Universiti Teknologi Malaysia, Kuala Lumpur, Malaysia

inner area and border area but only the nodes in the internal area can become cluster heads and the distance of the intra-cluster communication is diminished this approach, thereby increasing the lifetime of the network. However, the border area nodes having more energy values never gets a chance to become a cluster head which can cause the energy distribution in the cluster without any even.

Energy Efficient Cluster Based Routing Protocol (EECBRP) is another cluster-based method proposed by Roy and Das (2014). The clusters formation start off when event occur and the process of cluster head selection is based on few parameters like the number of neighboring nodes and residual energy. This is followed by data sensing and aggregation by the selected cluster head and transmitting the data to the base station following an energy efficient path. On this condition, energy wasting due to the absence of events could be prevented, hence, makes it more superior than the other scheme such as EEHC and SCHS that ignore the occurrence of events. That being said, the fact that EECBRP does not deal with the location base node association mechanism when the node lies in the transmission range of two cluster heads could significantly affect the efficiency if the node joins any one of the two cluster heads randomly. Therefore, there is a need for a better cluster head selection mechanism that not only reduces energy consumption but also improves the network performance.

The aim of the current project is to improve EECBRP protocol through the location-based node association mechanism to cluster head which can improve the network lifetime. NS2 simulator is used to develop the system. Residual energy, throughput and the number of dead nodes are the metrics used for performance evaluation. This research has been performed with two main objectives namely: to formulate an improved energy cluster based routing protocol and to evaluate the improved energy efficient cluster-based routing protocol.

Literature review: Energy efficient heterogeneous clustered (EEHC) scheme for wireless sensor networks was proposed by Kumar *et al*. (2009). In EEHC, they assume that most of the sensor nodes population is equipped with additional energy resources and the nodes of the sensor are distributed randomly and are not mobile, the sensor field dimensions and the base station coordinates are known. The model uses the clustering hierarchy clustering as LEACH protocol. In LEACH in each round, the clusters are restored. In each round, new CH are chosen and that will lead to a well distributed and balanced load in between the network nodes. Moreover, every node transmits to the closest CH in order to divide the cost of the communication to the base station which is greater than the operation cost. The CH only has to state to the base station and much energy may spend in this case but for every node, this occurs periodically. In LEACH, CH is selected based on the optimal percentage P_{opt} of nodes in every round supposing identic distribution of space nodes. For the CH selection, the node that is going to be chosen as a CH optimal probability has a spatial density function when nodes are identically distributed in the sensor field. This clustering is optimal in a way that the consumption of the energy is well distributed in all sensors, the overall consumption of the overall energy used is less such optimal clustering relies on the model of energy used. In this proposed model, they used the same model of energy and analysis proposed by Heinzelman *et al*. (2002) which is the radio energy dissipation model.

A scheme for an efficient selection of cluster head was proposed by Pal *et al*. (2012) for clustering algorithms in WSN named Smart Cluster Head Selection (SCHS). In this scheme, the area is divided into two different parts, the border and the inner area but only the inner area nodes are permitted for the role of being a CH. SCHS use distributed clustering approach. The network were modeled with six network assumptions all the nodes of sensor are homogeneous, all nodes have data to send, nodes are location aware (i.e., integrated with GPS) when the node's energy is exhausted they are inspected to die, a single base station is located outside the field and all nodes are stationary once deployed in the field. The energy model used is based on the one proposed by Al-Karaki and Kamal (2004). The main driving factor for clustering protocols is intra-cluster communication which energy consumption relies on the CH position within the cluster. If the CH is positioned wrongly it makes the cluster more energy consuming. In these studies, fifty nodes were randomly deployed in a 50×50 m^2 area with a single cluster in the network. For each node, the total distance of the cluster is calculated based on it CH. The result shows that the total distance of the cluster with CH nodes position close to the cluster center is less compared to the one positioned far from the cluster center. So, the selections of the CH is a significant issue and have an impact on the efficiency of the energy in clustering approach especially when the selection is not done properly. As a consequence, this selection must be done correctly to reduce the intra-cluster communication.

H-HEED protocol for WSN for a longer network lifetime was proposed by Kour and Sharma (2010). In HEED, the metric for the selection of cluster in order to achieve a balancing loads energy residual and the topology features for the network such as the degree of the node or the distances to neighbors are used as parameters. All nodes are homogeneous means the nodes have the same initial energy. But in H-HEED they opt for heterogeneous sensor nodes which mean that on the network most of the nodes population have more energy than the rest of nodes within the same network. The formation of network model is based on four assumptions, the network nodes are stationary, after deployment nodes are ignored, nodes have similar communication and processing capabilities with similar significance, node's location are unknown (i.e., Not equipped with GPS). CH selection is based on residual energy on each node which is estimated based on the energy used per bit for communication, sensing or processing. Three different level of heterogeneity is used 2 and 3-level and multi-level H-HEED protocol. In the level 2, there are two types of nodes the normal and advanced nodes. Energy model by Heinzelman *et al*. (2002) was used for analysis.

Energy-Efficient Cluster-Based Routing Protocol (EECBRP) has been proposed by Roy and Das (2014). According to the researcher, this protocol performs more efficiently than SCHS and EEHC. EECBRP protocol deals with the formation of cluster based different events, the selection of CH, data aggregation in a cluster and forwarding that to the BS in an energy efficient way. Two parameters are used in the process of the selection of CH which the number of neighboring nodes and the residual energy. In the proposed scheme the nodes are supposed to be static. The BS is configured in a way that it has high energy, enough memory and it located in a controllable place outside the region of the network. It also supposed that can aggregate data, evaluating their residual energy and determining their geographical location. The protocol is split into four modules: CH formation phases, CH selection phase, sensing and transmission to the BS. In WSN the nodes are located densely. In a small region, many nodes can sense the same event and might wish to forward that data across multiple paths. This can cause energy wastage and network congestion. By grouping the nodes in a location that is near which is named as a cluster and make a head node named CH within those nodes in that location can solve this problem. The accumulation of the data and redundant data cancellation sensed by the associated nodes is performed by the CH and it also conveys the data that is aggregated to the base station.

Many of the proposed algorithms do not check when events occur during the formation of the cluster, this will cause cluster formation in the absence of event thus wasting energy. In this situation, it may happen that nodes sensing single event be part of other clusters many CH can get involved in distributing the same data to the BS. EECBRP is proposed to avoid these inconveniences in which the formation of the cluster is started when an event occur in the region of the network.

MATERIALS AND METHODS

In this study, the methodology is explained in each sub-section. The main work that was done to improve the efficiency which is the location based node association to cluster head.

Cluster formation: In cluster formation, a node that first senses the event acts as the initiator node to broadcast the request message to its neighbors within two-hop distance. The node receiving the request joins with the initiator node and forms a cluster. In case, two nodes sense the event at the same time, the node with higher remaining energy will act as the initiator.

Cluster head selection: To become the Cluster Head (CH) a cluster nodes compete in each round. If the node residual energy is more than the value of the threshold then it becomes a candidate node for the selection process of the CH. The value of the threshold can be determined as the least required energy in receiving data from all nodes, aggregating them and sending that to a neighbor node. The bid of the competition will be calculated by every candidate node for becoming a CH for itself which is given by:

$$CV_i = ER_i \times Nad_j$$

Where:

CV_i = The cluster value
ER_i = The residual energy
Nad_j = The Number of adjacent nodes of a node

After the calculation of the bid of the competition, each node of a cluster broadcasts its own cluster value to all its neighbor nodes. Each node receives the cluster value of all its neighbors and compares them with its own cluster value and finally the node with the highest cluster value is chosen as the cluster head. The node containing the maximum cluster value will send the success message to all its neighbors. After broadcasting the declaration message, all the nodes of a cluster are updated about the cluster head of the current round and thus the phase of cluster head selection completes.

Data aggregation and routing process: The nodes that are within the sensing radius of the cluster head start the sensing phase. After sensing, each member node forwards the sensed data to the associated head node, called the cluster head. After receipt of the sensed data from the member nodes, the head node removes the redundant information, aggregates the data. Next starts the phase of sending the aggregated data to the BS. The

Table 1: Performance metrics

Metrics	Description
Average residual energy	The amount of energy remaining in the node after certain network operation is the residual energy
Throughput	It is the rate of successfully delivered data to the destination. Given by throughput (bit/sec) = Total data/Data transmission duration
No. of dead nodes	The total number of nodes for which energy is completely depleted is known as dead nodes

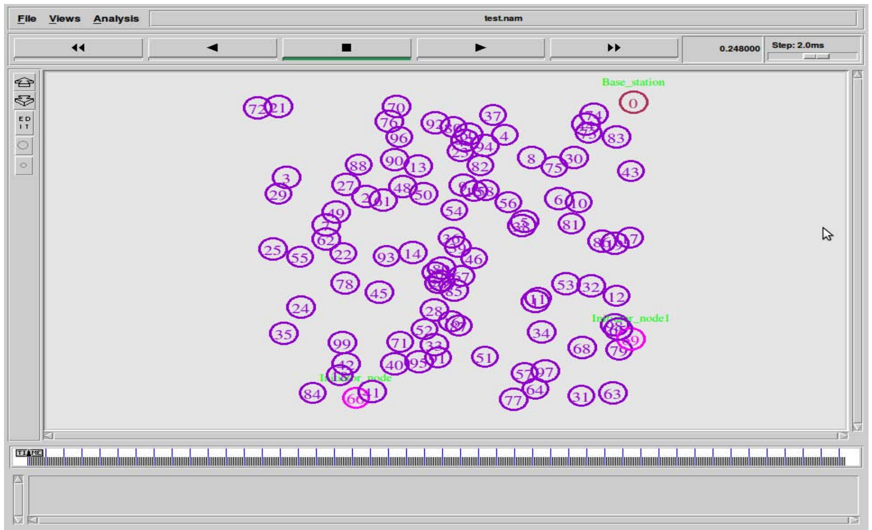

Fig. 1: The network environment

aggregated data should reach the BS in an energy efficient way in the minimum time. The cluster head will calculate a weight value for all of its neighbors that have a distance from the base station lower than itself to send the aggregated data. A weight value of a neighbor j, calculated by node i is given as follows (Fig. 1).

$$W_{ij} = k1 \times \left(\frac{ER_i \times N_j}{DB_j^{\,2} \times CR_j \times load_j} \right)$$

Where:

ER_j = The Residual Energy of neighbor node j
N_j = The Number of adjacent nodes of neighbor node j
DB_j = The Distance Between node j and the base station
CR_j = The rate of Energy Consumption of node j
$Load_j$ = The number of packets already sent to node j by node i in the current round

The neighbor node with the highest weight value of the link receives the aggregated data from the cluster head. Then that node will send the aggregated data to its neighbor with highest weight value and so on. The nodes that are neighboring to the base station can directly forward the data to the base station.

Location based node association to cluster head: The improvement of the existing protocol is being implemented in which location based cluster joining is contributed through which network lifetime is improved further. In this mechanism, after the nodes hear the advertisements of the Cluster Head (CH), they determine their nearest CH based on the strengths of the received signal of multiple CHs. Nodes broadcast their requests for the association to the CH that has the smallest distance to them. During the broadcasts, the nodes also forward the levels of their residual energy and their positions to respective CHs. So, the received signal from the CH that placed near to the node will be in high strength which reduces the consumption of the energy and also ameliorates reliability of the data.

Performance evaluation: The performance of the proposed I-EECBRP is evaluated for the simulation settings and compared with existing protocol. The metrics as shown in Table 1, such as average residual energy, throughput and number of dead nodes are measured and analysed from the trace file using awk script.

Simulation model: In this experiment, we assume that the sensor networks with 100 nodes are placed on a square field of 100×100 m^2. Setdest tool is used to generate the nodes initial position and their moving speed and moving directions. The connections between nodes are created using cbrgen.tcl. In the simulation connections are created for two types of traffic agents which are UDP and CBR. The simulation parameters for the experiment is listed in Table 2 and the network environment is illustrated in Fig. 1.

Table 2: Simulation parameters

Simulator	Network simulator 2
No. of nodes	100
Interface type	Phy/Wireless Phy
MAC type	IEEE 802.15.4
Queue type	Drop tail/Priority queue
Routing protocol	I-EECBRP
Transport agent	UDP
Application agent	CBR
Initial energy	50 J/node
Simulation time	100 sec
Packet size	10 bytes
Area size	100×100 m^2

RESULTS AND DISCUSSION

The result of each performance metrics is analyzed and compared regardless the literature review. Besides, we also compared few more metrics for further performance check about the two protocols.

Number of dead nodes vs. number of rounds: According to Roy and Das (2014), round refers as an overall to form a cluster which is followed by the cluster head selection, data aggregation and forwarding the aggregated data to the base station.

For every node, the initial power is considered as 50 J. The size of each packet of data is taken as 10 bytes. The total diminution in energy and the total number of dead nodes is calculated after some rounds. The result obtained is compared with that of EECBRP which shows that after the realization of some rounds there is many dead nodes in EECBRP compare to I-EECBRP (Fig. 2).

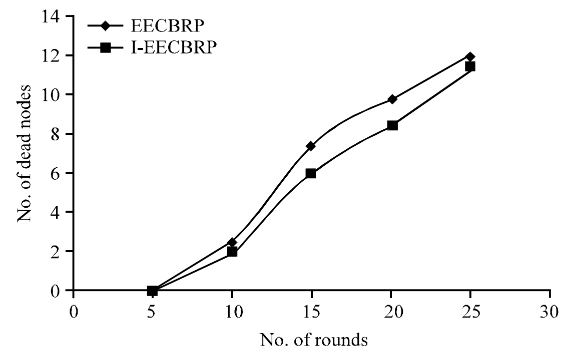

Fig. 2: Number of dead nodes vs. number of rounds

Average residual energy vs. number of rounds: The average residual energy of the network is calculated after each round. As plotted in Fig. 3, we can see that from round 20th, EECBRPS lost more energy than I-EECBRP. Hence, I-EECBRP can transmit the aggregated data to the bases station in energy efficient and thus the network lifetime is expanded.

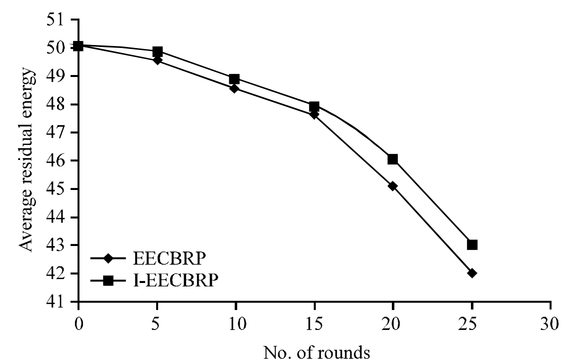

Fig. 3: Average residual energy vs. number of rounds

Throughput vs. load: The load versus the amount of packets of data successfully sent to the sink, called as throughput is plotted in the graph in Fig. 4. On the graph, we can see that when the number of loads increase, the throughout increase as well and I-EECBRP achieves increased throughput when compared to EECBRP. From the performance metrics result discussed earlier, the proposed I-EECBRP performed better than EECBRP. Location base node association mechanism to cluster affected the network lifetime. After some round, EECBRP loses more energy compared to I-EECBRP, thus, I-EECBRP transmits the sensed data in an energy efficient way. Even though both routing protocols use the same technique to maintain the best route, we can see the different in throughput, this is due to the simulation end time as the throughput is based on the amount of packet of data successfully transmitted

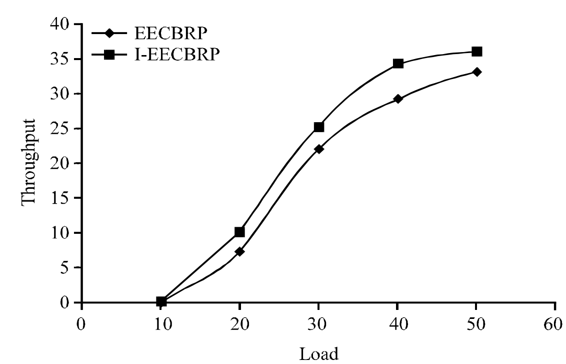

Fig. 4: Throughput vs. number of rounds

Packet dropped vs. number of rounds: Packet dropped is the number of packet data loss during the transmission to the base station. As shown in Fig. 5, the packet dropped for the two protocol are quite similar but we can see that at some point EECBRP has a higher packet dropped

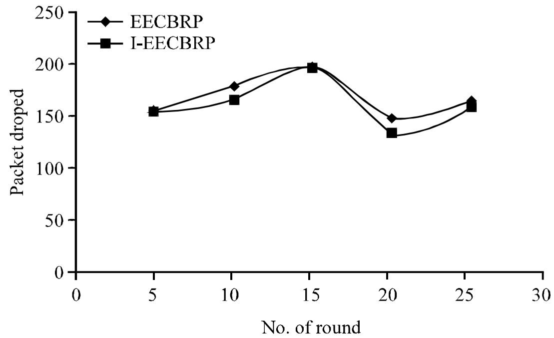

Fig. 5: Packet dropped vs. rounds

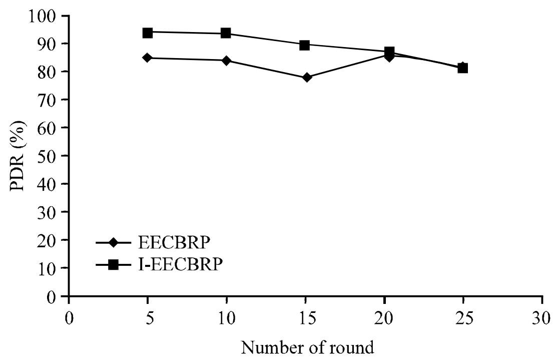

Fig. 6: Packet delivery ratio vs. number of round

compared to I-EECBRP this is due to the nodes congestion in the network. A low number of packet drop will result in high packet delivery ratio.

Packet delivery ratio vs. round: Packet Delivery Ratio (PDR) is the ratio of the number of received packet data by destination nodes and the number of packet data sent by source nodes. Better PDR value means less data loss in the network. PDR is given by the equation as:

$$\text{Packet delivery ratio} = \frac{\text{No. of received packet}}{\text{No. of packet sent}}$$

Packet delivery ratio for I-EECBRP is higher than EECBRP as shown in Fig. 6. It means that <0.1% of packets are not delivered in EECBRP regardless the number of rounds.

Average end to end delay vs. round: The average end to end delay is the average time for packet data takes to travel from source to destination. The time is measured in seconds. This metric is useful in understanding the delay caused while discovering path from source to destination. The average end to end delay result is shown in Fig. 7.

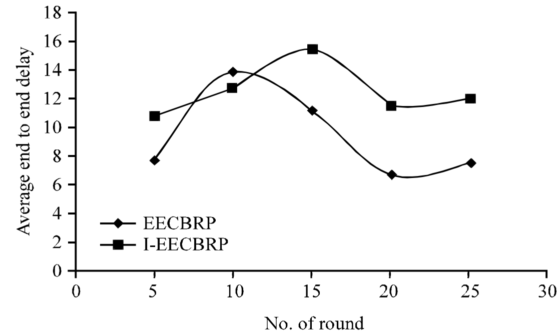

Fig. 7: Average end-to-end delay vs. number of rounds

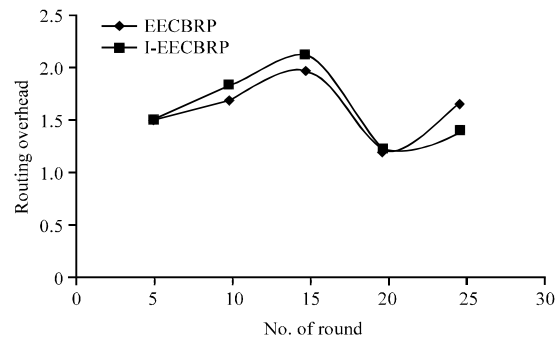

Fig. 8: Routing overhead vs. rounds

This metric is given by the following:

$$\text{Average end to end delay} = \frac{\text{Time received-Time sent}}{\text{Total packet receiver}}$$

Routing overhead vs. number of rounds: Routing overhead is the ratio of routing and control packets transmitted per data packets delivered to April 3, 2018 the destination. As shown in Fig. 8, routing overhead for I-EECBRP is quite similar to EECBRP. DSDV is slightly higher at 10 and 15 nodes but slightly lower at round 25.

CONCLUSION

We used one of the most common techniques adopted by different algorithms for wireless sensor network which is clustering technique. Many clustering based routing protocol were designed in different features and the result was analyzed and compared in many aspects to demonstrate the performance. Location based association node mechanism used in this project, allow the nodes to select the cluster head with the shortest distance to them. This mechanism is convenient for wireless sensor network as the sensed data is transmitted to the base station is an energy efficient way. Moreover, wireless sensor network consists of micro-electromechanical sensor nodes which are operated by battery power and it is difficult to recharge their battery as there are installed in a remote place so a power efficient routing protocol is required for a longer network lifetime. In this study, we used Linux environment together with virtual machine software. The performance analysis and comparison were all done in this area but a dedicated UNIX-based workstation to run the Network Simulator NS 2 can be used for bigger RAM size in future development.

SUGGESTIONS

There are some suggestions for future enhancement of this project: cluster head selection can be improved further using other parameters such as distance to base station, load along with residual energy and number of adjacent nodes. Performance can be improved further by selecting the routers located in the direction of sink node for data transmission.

REFERENCES

Al-Karaki, J.N. and A.E. Kamal, 2004. Routing techniques in wireless sensor networks: A survey. IEEE Wireless Commun., 11: 6-28.

Attea, B.A. and E.A. Khalil, 2012. A new evolutionary based routing protocol for clustered heterogeneous wireless sensor networks. Applied Soft Comput., 12: 1950-1957.

Guo, W. and W. Zhang, 2014. A survey on intelligent routing protocols in wireless sensor networks. J. Network Comput. Appl., 38: 185-201.

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.

Kour, H. and A.K. Sharma, 2010. Hybrid energy efficient distributed protocol for heterogeneous wireless sensor network. Int. J. Comput. Appl.., 4: 1-5.

Kumar, D., T.C. Aseri and R.B. Patel, 2009. EEHC: Energy efficient heterogeneous clustered scheme for wireless sensor networks. Comput. Commun., 32: 662-667.

Nikolidakis, S.A., D. Kandris, D.D. Vergados and C. Douligeris, 2013. Energy efficient routing in wireless sensor networks through balanced clustering. Algorithms, 6: 29-42.

Pal, V., G. Singh and R.P. Yadav, 2012. SCHS: Smart cluster head selection scheme for clustering algorithms in wireless sensor networks. Wireless Sens. Network, 4: 1-8.

Roy, S. and A.K. Das, 2014. Energy Efficient Cluster Based Routing Protocol (EECBRP) for Wireless Sensor Network. Proceedings of the 2014 1st International Conference on Networks and Soft Computing (ICNSC), August 19-20, 2014, IEEE, Kolkata, India, ISBN:978-1-4799-3486-7, pp: 25-29.

Tyagi, S. and N. Kumar, 2013. A systematic review on clustering and routing techniques based upon LEACH protocol for wireless sensor networks. J. Network Comput. Appl., 36: 623-645.