Geographic and Clustering Routing for Energy Saving in Wireless Sensor Network with Pair of Node Groups

Shahrokh Vahabi[1], Mahmood Lahabi[1], Mohammadreza Eslaminejad[1], and Seyed Ebrahim Dashti[2]
[1]*Information Technology Department, Zand Institute of Higher Education, Shiraz, Iran*
[2]*The Department of Computer Engineering, Jahrom Branch, Islamic Azad University, Jahrom, Iran*
shahrokhvahabi@gmail.com, 1372mahmood@gmail.com, eslami@zand.ac.ir, sayed.dashty@gmail.com
Corresponding author: shahrokhvahabi@gmail.com

Abstract- **Recently, wireless sensor network (WSN) is the popular scope of research. It uses too many applications such as military and non-military. WSN is a base of the Internet of Things (IoT), pervasive computing. It consists of many nodes which are deployed in a specific filed for sense and forward data to the destination node. Routing in WSN is a very important issue because of the limitation of the energy of each sensor node. Energy is supplied from a battery and in many situations, it impossible to change the battery of sensor nodes. With power control of each sensor node can improve energy efficiency and the network lifetime. In this paper, a method proposes for energy saving issue of routing. It uses clustering with the advance network coupling model based on a geographic method for routing. This new algorithm is based on gateway nodes to save more energy of nodes and decrease the average end-to-end delay for delivery of data packets. Simulation results clearly show that the new proposed method can improve the average energy consumption of the network by at least 32.5% and increase the network lifetime by at least 87.14% than other approaches.**

Index Terms- Wireless sensor network, routing, energy saving, network lifetime, gateway.

I. INTRODUCTION

Wireless sensor network (WSN) refers to the network with many counts of sensor nodes which are small in size and cheap in price [1, 2]. Generally, these sensor nodes include some partitions such as power unit, sensing unit(s), a processing unit, and a radio unit. The power unit includes a battery, sensing unit(s) consist(s) of sensors and Analog to Digital Converter (ADC), the processing unit includes memory and processor, and radio unit consists of the transceiver [1]. Fig. 1 illustrates common sensor node units.

Manuscript received 23-Feb.-2019 and revised 5-June-2019,
Accepted on 27-June-2019
P- ISSN: 2322-4088
E- ISSN: 2322-3936

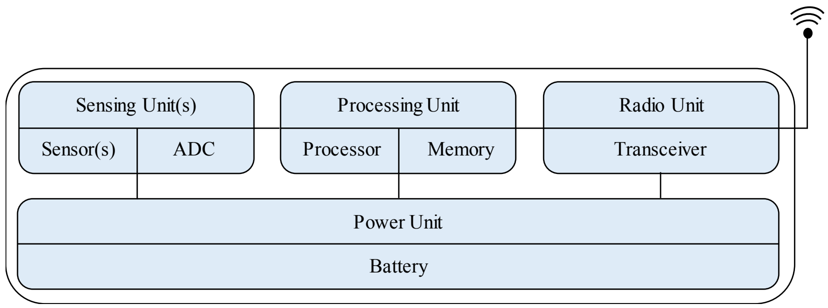

Fig. 1. Common sensor node units.

Sensor nodes are deployed in the sensing filed to sense and transmit data packets to the destination node or sink node. Then sink node collects data packets from sensor nodes and forwards them to the Base Station (BS) which is located out of the sensor filed [3, 4]. Figure 2 shows a common WSN.

There are some challenges such as energy consumption control, deployment of nodes, security, network lifetime, end-to-end delay, latency of the network, and so on exist in WSN. Most energy of nodes depletion for transmitting and receiving data packets, so routing is the supreme issue in the WSN [1, 2]. Hence, this paper focuses on the routing and also energy saving to improving the energy consumption of nodes. There are three categories of routing exist in the WSN: (1) Flat routing protocols (2) Clustering/Hierarchical routing protocols (3) Geographic routing protocols. In flat routing protocols, there are the same sensor nodes in the network and they forward their data packets by multi-hop technic. in clustering/hierarchical routing protocols, after sensor nodes deployed in the sensing field, they place in some partition called cluster. In each cluster a node with higher energy in each round is selected as Cluster Head (CH) which collects data packets from sensor nodes in its cluster. After that, CH node forwards its data packets to the next CH node until data packets reach to the sink node. Then sink node forwards data packets to the BS. In geographic routing protocols, transmitting data packets is based on the location of the sensor nodes. The location of sensor nodes is detected by Global Positioning System (GPS) or radio signal strength or another method of detecting position [5].

There are many applications exist to WSN same martial applications such as soldier’s surveillance, enemy detection, battlefield monitoring, enemy equipment monitoring, and civilian applications such as fire detection, forest monitoring, smart city, weather station system, airplane monitoring, health care, and many other applications [6, 7]. WSNs can use for Internet of Things (IoT), and pervasive/ubiquitous computing infrastructures. Types of WSN include terrestrial WSN, underwater WSN (UWSN), and WSN on body. Be aware the terrestrial WSN is the same WSN that work on the earth same the new proposed method in this letter. Each kind of WSN has its application.

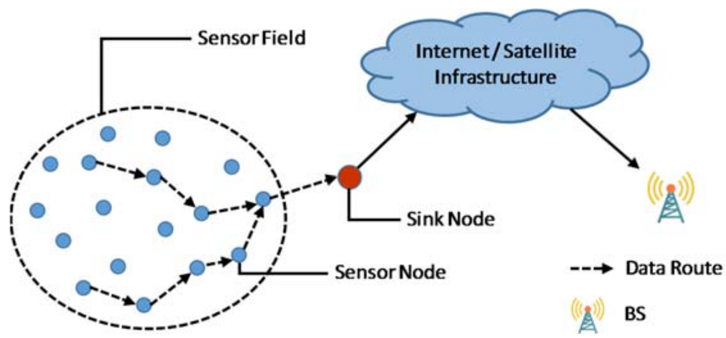

Fig. 2. A Common WSN.

II. RELATED WORKS

There are some routing protocols in WSN. In this section, some of them in the scope of geographic and clustering routing protocols are introduced. Due to the new proposed algorithm is based on a gateway, hence, two protocols are described based on the gateway for comparison.

A. Gateway-Based Energy-Aware Multi-Hop Routing Protocol (M-GEAR)

The network filed in this method is divided into some partitions via the position of each sensor node. The BS is top and out of the network. A gateway node is placed in the center of the network. Each sensor node is placed in the first partition which nearest the BS, sends its data packets to the BS directly. Also, sensor nodes in the middle partition of the network which nearest to the gateway node can transmit their data packets to the gateway node directly. There is a CH node in each partition. The big problem with this approach is each partition which is located far away from gateway node or BS has the high latency for delivery packets, and the energy of nodes around the gateway node will be finished sooner [8].

B. Energy Aware Multi-Hop Routing Protocol using Gateway

This approach is an improvement of M-GEAR protocol. All conditions in this method are the same M-GEAR, but this approach uses the hello packet from the BS to obtaining a middle point of each partition to improving transmitting data packets [9].

C. Energy Efficient Sleep Awake Aware (EESAA)

The target of this method is improving remaining energy with the pair of node groups. Sensor nodes are deployed in the sensing area randomly and every two nodes which nearest to each other are placed into a cluster. It means that, each cluster in this network includes two adjacent nodes. In each round of transmitting data packets, only one node in each cluster is active and another node is sleep to improving the energy depletion of nodes. A node in the active state can forward its data packet to the next cluster. This process continues until data reach to the sink node or destination node. If two nodes are placed too much close to each other, so, the energy of nodes depletion, and latency will be increased because of long distances of two nodes to the sink node [10].

The common big problem with three approaches mentioned above is the random deployment in the network. In the random deployment, a partition or an area or a cluster has many counts of sensor nodes and another partition or area or cluster has a few counts of sensor nodes. Therefore, a partition with the lower count of sensor nodes has the longer distance to the destination node. Hence, the latency of the network will be increased as well as the energy depletion of sensor nodes, and also the network lifetime will be decreased.

III. PROPOSED ALGORITHM

This section describes the new proposed algorithm including some phases as mentioned below. The first phase is the deployment and clustering, the second phase is the data packet transmitting, and the third phase is the energy model. Deployment, grouping, and clustering phase describes how sensor nodes are deployed in the sensor field and how grouping and clustering are done in the network. Data packet transmitting phase is about how data packets can be transmitted in the network. Actually, this phase is about data routing. Finally, the energy model phase describes a kind of energy model used in this new approach. Fig. 3 shows the general process of the new proposed algorithm.

A. Deployment, Grouping and Clustering Phase

Sensor nodes are deployed in the sensor area manually. The distance between every two nodes is 75 m. All approaches are simulated with 200, 500, and 1000 nodes. After deployment, every two neighbor nodes are placed into a group. It means that, each group consists of two nodes. After grouping, every four groups are placed in a cluster. On the other hand, each cluster includes eight sensor nodes or four groups of couple nodes. If the count of groups is less than four, the remaining groups are placed in the last cluster. Also, every cluster can be including three, and two groups which it depends on the specific application. After clustering, gateway nodes are placed in the center of each cluster. Gateway nodes are the same sensor nodes which energy of them is chargeable with solar. Chargeable gateway nodes are so cheaper than sensor nodes in cost [8]. A number of active or sleep nodes can calculate as in (1), a number of groups in the network can calculate as in (2), and a number of clusters in the network can calculate as in (3) or (4). Algorithm I shows how grouping and clustering are done in the new proposed method.

$$N_{Active\ or\ sleep}(N) = \frac{N}{2} \tag{1}$$

where $N_{Active\ or\ sleep}$ is a number of active or sleep nodes, N is the count of sensor nodes in the network. In each round, just one sensor node in each group is in the active state, and another node is

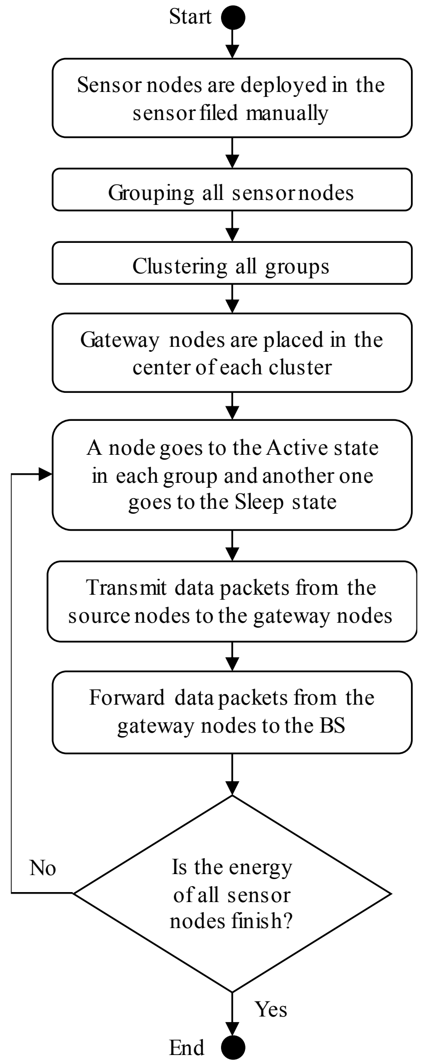

Fig. 3. The general process of the new proposed algorithm.

in the sleep state. So, half of sensor nodes in the network are in the active state and half of them are in the sleep state.

$$\mathrm{N_{Groups}(N)} = \frac{\mathrm{N}}{2} \tag{2}$$

where N_{Groups} is a number of groups for *N* sensor nodes in the network. There are two sensor nodes in each group. So, a total number of groups is half of the number of sensor nodes.

$$\mathrm{N_{Clusters}(N)} = \left\lceil \frac{\mathrm{N}}{8} \right\rceil \tag{3}$$

where $N_{Clusters}$ is the number of clusters for *N* sensor nodes in the network. Note that each cluster consists of eight sensor node or four groups.

$$\mathrm{N_{Clusters}(N)} = \left\lceil \frac{\mathrm{N_{Groups}}}{4} \right\rceil \tag{4}$$

ALGORITHM I. Clustering Algorithm

N is nodes count and must be even
Groups_Count ← 0
for *index = 0 to N* **do**
    $Group_{index}$ ← every two adjacent node
    Groups_Count ++
end for
for *index = 0 to* Groups_Count **do**
    if *Groups_Count* ≥ 4 **then**
        $Cluster_{\mathrm{Groups\_Count}}$ ← every four Groups
    end if
    if *Groups_Count* < 4 **then**
        $Cluster_{\mathrm{Groups\_Count}}$ ← remaining Groups
    end if
end for

B. Transmitting data packets Phase

First, BS sends the location of all sensor nodes to the gateway nodes via GPS just once. Then each gateway node in each cluster sends the position of each node which is placed in its cluster to sensor nodes. With this information, each sensor node knows its adjacent node as well as its gateway node in its cluster. Also, each gateway node knows its sensor nodes in its cluster. In each round, each sensor node in every group is in the active state and another sensor node is in the sleep state. It means that, in every round, half of the sensor nodes in the network is in the sleep state and the energy consumption of each node will much improve. A node with the higher remaining energy is selected as the active node in each round. Each sensor node which is selected as the active node, forwards its data packet to the gateway node in its cluster. Each gateway node collects data packets from its cluster, then gateway nodes send their data packets to the BS directly via internet or satellite. This approach has a minimum one hop and maximum two hops to transmitting a data packet from the source node to the destination node. The low count of hops will cause to decrease in the average end-to-end delay. Fig. 4 illustrates the new proposed algorithm network model.

C. Energy model Phase

The new proposed approach uses an energy model used in [7, 11] to transmitting (Tx) a k-bit data packet with distance (d) and receiving (Rx) k-bit data packet in the network. You can see the energy for Tx as in (5) and also the energy for Rx as in (6).

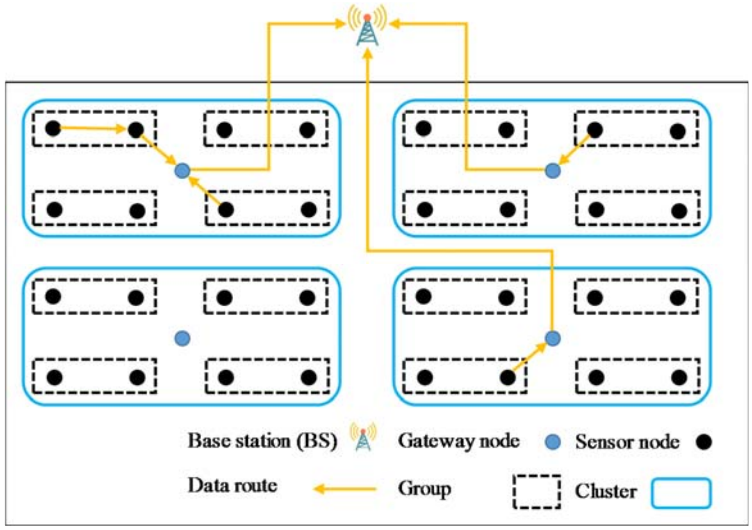

Fig. 4. A network model of the new proposed algorithm.

$$E_{Tx}(k,d) = \begin{cases} k^*E_{elec} + k^*E_{fs}{}^*d^2 & d < d_0 \\ k^*E_{elec} + k^*E_{amp}{}^*d^4 & d \geq d_0 \end{cases} \quad (5)$$

where $\boldsymbol{E_{elec}}$ shows the electronics energy, and $\boldsymbol{E_{fs}} * \boldsymbol{d^2}$or $\boldsymbol{E_{amp}} * \boldsymbol{d^4}$, represents the amplifier energy for the distance (*d*). Also, $\boldsymbol{d_0}$ is the threshold and its value can be calculated as in (7).

$$E_{Rx}(k) = k * E_{elec} \quad (6)$$

$$d_0 = \sqrt{E_{fs}/E_{amp}} \quad (7)$$

The energy consumption of the new proposed algorithm can calculate as in (8).

$$Energy_{New\_Algorithm} = \sum_{Cluster=1}^{Cluster=N} \sum_{Group=1}^{Group=4} E_{Tx} \quad (8)$$

As the energy of gateway nodes are chargeable, therefore, there is no energy consumption calculating for these nodes. Also, there will not be energy consumption for receiving data from the source node to the gateway node in each cluster because since mentioned before the battery of the gateway nodes are chargeable with solar.

IV. SIMULATION RESULTS

We used NS3 version 3.26 for simulations. Performance of M-GEAR, Energy Aware Multi-Hop Routing Protocol using Gateway, EESAA, and the new proposed approach are appearing in this section and all approaches are compared with each other. All parameters of the simulations are the same and detail of these parameters are shown in Table I. Count of nodes in the network for all

Table I. Parameters of Simulations

Symbol	Description	Value
N	Count of nodes	200, 500, 1000
S	Size of sensor field	200, 500, 1000 m^2
D	Data packet size	4000 bits
d	Distance between nodes	75 m
E_0	Initial energy of each node	0.1 Joule
E_{elec}	Transmitting circuit loss	50 nJ/bit
E_{fs}	Power amplification for $d < d_0$	10 pJ/bit/m^2
E_{amp}	Power amplification for $d \geq d_0$	0.0013 pJ/bit/m^4
M	MAC layer	IEEE 802.11
R	Number of runs	10 times

methods is 200, 500, and 1000. The size of the sensor filed are considered 200, 500, and 1000 $\boldsymbol{m^2}$ for 200, 500, and 1000 counts of nodes respectively. The size of each data packet is 4000 bits or 500 bytes. The distance between each sensor node is 75 m, the initial energy of each node is considered 0.1 J. The MAC layer used in all simulations is IEEE 802.11. All simulations run until 30000 round.

A. Average energy depletion

This metric is the average energy depletion of nodes during 30000 rounds for 10 times runs. Fig. 5 shows this metric for all approaches. The new proposed algorithm for using of gateway nodes in each cluster and also because of uses of half sensor nodes in each round can save more energy of nodes comparing to other approaches. In M-GEAR because of having just one gateway node which is placed at the middle of the network and also, because of having random deployment of nodes, has the worst saving energy of nodes than others. The improvement of M-GEAR, Multi-hop routing are better than M-GEAR, and EESAA. But does not better than the new proposed algorithm.

The new proposed approach can lessen the energy consumption by at least 32.5% in 200 nodes, 60% in 500 nodes, and 60.87% in 1000 nodes than other approaches. With keep, low consumption energy of each sensor node in the network can increase the average network lifetime and it caused having a longer network in time. With the longer lifetime can reach to the higher throughput of the transmitting data packets. In other words, we can transmit more data packets through the network.

B. Average data packets delivery

This metric is calculated the count of data packets which are reached successfully to the destination node. It means that this metric does not calculate the data packets which is lost or does not reach successfully to the destination node. Fig. 6 illustrates this metric for all approaches. As can be seen in Fig. 6, the new approach for the manual deployment and because of existing gateway nodes in each

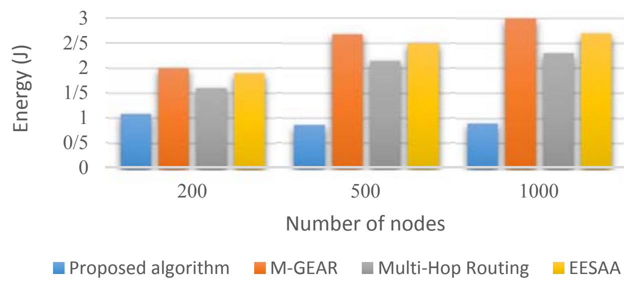

Fig. 5. Average energy depletion.

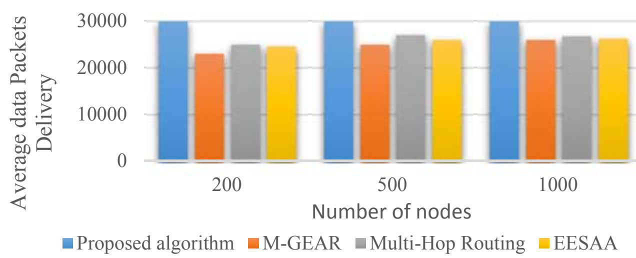

Fig. 6. Average data packets delivery.

cluster, and also for grouping the sensor nodes, can deliver more data packets than other methods. Three other approaches approximately the same in this metric.

C. Average network lifetime

Network lifetime consists of the round which first sensor node in that dies [7]. Each sensor node which is lost 99% of its initial energy, it's a dead node. According to the routing method of each approach, this metric is become different in result. This issue is so important for the network and it's one of important challenges in the routing. whatever the network lifetime be longer, it can more work and can deliver more data packets to the destination node. You can see the average network lifetime in Fig. 7. The new algorithm has the balance in the overall of the network for being gateway nodes and also for use of half sensor nodes in each round. Therefore, the network lifetime in an exponential fashion increase. The new proposed approach can increase the average network lifetime by at least 88.46%, 87.14%, and 88.15% for 200, 500, and 1000 nodes respectively comparing to other approaches.

D. Average number of dead nodes

The balance of the energy consumption in the overall of the network is so important for the average energy saving of sensor nodes, network lifetime, and a number of dead nodes. Whatever more count of dead nodes in the network, the average network lifetime will much more decrease. Fig. 8 shows the average dead nodes in the network during 30000 rounds of transmitting data packets. The new

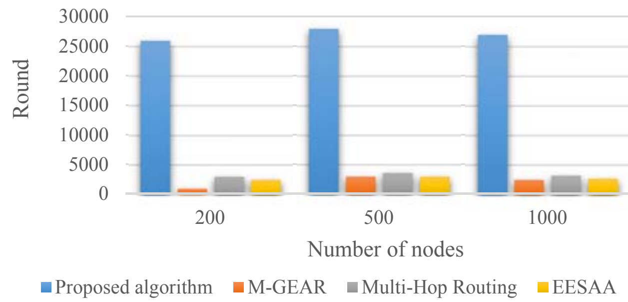

Fig. 7. Average network lifetime.

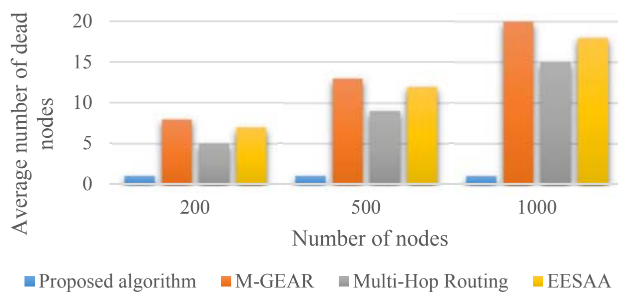

Fig. 8. Average number of dead nodes.

algorithm has the minimum count of dead nodes because of the balancing energy depletion in the overall network than others. The multi-hop method which is an improvement of M-GEAR after the new proposed approach has the minimum count of dead nodes.

E. Average end-to-end delay

This metric is the time between the transmit and deliver data packet successfully. Fig. 9 shows this metric during 30000 rounds and for 10 times runs of simulations for 200, 500, and 1000 number of nodes for all protocols. The new proposed algorithm because of a maximum two hops for transmitting data packet to the destination node, has the minimum average end-to-end delay for delivery data packets than others. Whatever the count of hops is less, so the average end-to-end delay will decrease.

V. CONCLUSION

This letter proposed the new approach for routing in WSN with energy saving by the geographic and hierarchical method. In the newly proposed algorithm sensor nodes are deployed manually in the sensor filed. Every two adjacent nodes after the deployment are placed into a group. Then every four groups are placed in a cluster. There is a gateway node in the center of each cluster and it chargeable with solar. Each gateway node collects data packets from its cluster. In each round, just one node in each group is in the active state, and another one is in the sleep state to save more energy of sensor

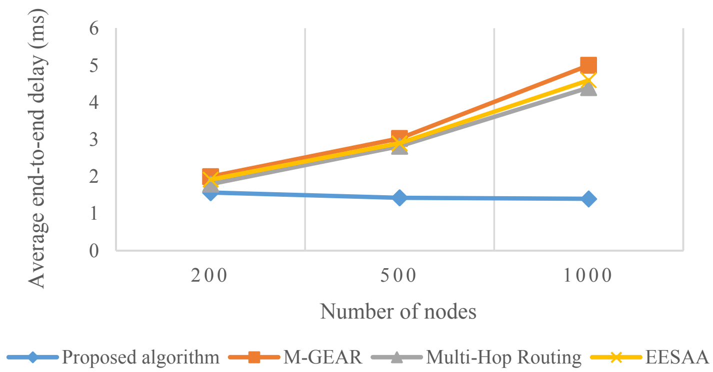

Fig. 9. Average end-to-end delay.

nodes and therefore increase the network lifetime. All approaches which are introduced in this paper simulated in NS3 version 2.36 software with the same parameters. Simulations results clearly show that the new proposed approach can decrease the average energy consumption by at least 32.5%, 60%, and 60.87% in 200, 500, and 1000 nodes respectively than other approaches. Also, the new proposed algorithm can increase the average network lifetime by at least 88.46%, 87.14%, and 88.15% for 200, 500, and 1000 nodes respectively than other protocols.

REFERENCES

[1] Y. K. Tamandani and M. U. Bokhari, "SEPFL routing protocol based on fuzzy logic control to extend the lifetime and throughput of the wireless sensor network," *Wireless Netw.,* vol. 22, no. 2, pp. 647-653, Feb. 2016.

[2] P. G. V. Naranjo, M. Shojafar, H. Mostafaei, Z. Pooranian and E. Baccarelli, "P-SEP: a prolong stable election routing algorithm for energy-limited heterogeneous fog-supported wireless sensor networks," *The Journal of Supercomputing.*, vol. 73, no. 2, pp. 733-755, Feb. 2017.

[3] P. S. Mann and S. Singh, "Energy-Efficient Hierarchical Routing for Wireless Sensor Networks: A Swarm Intelligence Approach," *Wireless Personal Communications*, vol. 92, no. 2, pp. 785-805, Jan. 2017.

[4] H. K. D. Sarma, R. Mall and A. Kar, "Energy-Efficient and Reliable Routing for Mobile Wireless Sensor Networks," *IEEE Systems Journal*, vol. 10, no. 2, pp. 1-6, Jun. 2010.

[5] H. Singh and D. Singh, "Taxonomy of routing protocols in wireless sensor networks: A survey," *2nd International Conference on Contemporary Computing and Informatics (IC3I),* Dec. 2016.

[6] M. M. Warrier and A. Kumar, "Energy Efficient Routing in Wireless Sensor Networks: A Survey," *International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET)*, Mar. 2016.

[7] R. Yarinezhad and A. Sarabi, "Reducing delay and energy consumption in wireless sensor networks by making virtual grid infrastructure and using mobile sink," *AEU - International Journal of Electronics and Communications*, vol. 84, pp. 144-152, Feb. 2018.

[8] Q. Nadeem, M. B. Rasheed, N. Javaid, Z. A. Khan, Y. Maqsood and A. Din, "M-GEAR: Gateway-Based Energy-Aware Multi-hop Routing Protocol for WSNs," *Eighth International Conference on Broadband and Wireless Computing, Communication and Applications*, Oct. 2013.

[9] S. Kumar, "Energy Aware Multi-Hop Routing Protocol for WSNs Using Gateway," *International Research Journal of Engineering and Technology (IRJET)*, vol. 05, no. 06, Jun 2018.

[10] T. Shah, N. Javaid and T. N. Qureshi, "Energy Efficient Sleep Awake Aware (EESAA) intelligent Sensor Network routing protocol," *15th International Multitopic Conference (INMIC*), Dec. 2012.

[11] N. Mittal, U. Singh and B. S. Sohi, "A stable energy efficient clustering protocol for wireless sensor networks," *Wireless Networks*, vol. 23, no. 6, pp. 1809-1821, Aug. 2017.