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Hole Healing Energy Aware Algorithm For Wireless Sensor Networks

Ifrah Farrukh Khan and Muhammad Younus Javed

***Abstract*—Wireless Sensor Networks are composed of very small nodes having limited resources. One of those resources is energy available in the form of battery. Efficient use of this energy is a challenging factor in designing a routing protocol. Void areas are created due to early loss of energy of a few nodes. These void areas are routing holes. In this paper a routing algorithm has been proposed that uses the geographic information of the nodes and average of energy levels available for forwarding the packets within the network. Each node has information about its distance from its neighbor. When it receives a packet for forwarding, it takes decision about the next hop by first calculating the average energy of all the neighbors and then selecting one on the basis of this average energy and the shortest distance. When the packet reaches a routing hole area, it is redirected by first reversing the link and then again using average energy and distance. The proposed algorithm shows a high packet delivery rate and gives longer life to the network by using energy of the nodes in an efficient manner.**
[1]

***Index Terms*—Energy efficient, Routing protocol, Wireless sensor networks.**

I. Introduction

Wireless Sensor Networks (WSNs) are the simplest kind of communication network. These are composed of simple tiny nodes, called sensor nodes. Sensor nodes have very simple circuitry so they have low processing capability, small storage space and very low battery power. These nodes are capable of sensing light, sound, vibration etc. depending on the application for which they are used.

WSNs are now playing important part in many systems such as movement monitoring systems, security systems, Information systems these networks have a large number of nodes and each node has a very small storage space. That is why use of traditional addressing scheme is impossible in this scenario. A location based communication strategy is used in which all nodes are aware of their geographical positions.

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Ifrah Farrukh Khan is with College of Electrical and Mechanical Engineering, National University of Sciences and Technology, Pakistan, on leave from Quaid-i-Azam University, Islamabad, Pakistan (e-mail:ifrahkhan@ceme.nust.edu.pk).
Muhammad Younus Javed is with Computer Engineering Department of College of Electrical and Mechanical Engineering, National University of Sciences and Technology, Pakistan (e-mail:myjaved@ceme.nust.edu.pk).

Development of routing protocol depends on several factors such as low battery power where the routing protocol has to use energy in such a way that life of the network increases. Importance of data is another factor which demands successful and unchanged delivery of the packets. Application and deployment of the nodes are also important factors influencing the design of a protocol.

Different routing strategies are in use (i.e. hierarchical routing, cluster based routing, geographic routing[1],[2]). Geographic routing is most commonly used in WSNs because it is efficient and scalable. But due to inefficient use of energy it suffers a problem of void areas called holes[3],[4],[5]. When a packet reaches such a point where no more nodes are available for forwarding data then the packet is dropped, and such an area is known as routing hole. It is created due to malfunctioning nodes or energy depletion of the nodes. In this research paper, a new routing algorithm has been proposed that uses average energy and distance of the node for selection of next hop. By doing this, it can use the energy efficiently and gives longer life to the network. It also deals with the problem of routing hole by reversing the link when it reaches a point where no further node is available for forwarding the packet.

This paper has been organized as follows. Section 2 presents the related work. Section 3 describes principle, working and simulation results of HHEAA in detail and Section 4 contains the conclusion and future work of the paper.

II. Related Work

Many routing protocols have been developed for different types of applications. Yu. et al. [6] suggested a protocol that was based on geographical information of the sensor nodes named as GEAR (Geographical and Energy Aware Routing). This algorithm first forwards data to the selected region on the basis of shortest distance from the target. Secondly, it disseminates the data with in the region by using recursive geographic forwarding algorithm. When the node density is high then recursive algorithm divides the region into sub-regions and gives one copy of the packet to each region. It keeps on dividing and delivering data until only one node is left in the region. If the density of nodes is low then it uses restrictive flooding method for data dissemination. Each sensor node has the information about estimated cost that is calculated using energy level and distance. While the other cost is learning cost that is used by the algorithm to overcome the routing hole problem.

Another energy aware algorithm is EAGR (Energy Aware Greedy Routing)[7]. It is a location based energy aware algorithm that combines energy level of the nodes and average distance of the neighbors for selection of the next hop. In this algorithm, initially a table is created in which it stores location information of all the nodes. Then average distance from the neighbor nodes is calculated. Next node is selected whose distance is less than or equal to this average distance and has maximum energy amongst the neighbors. This process is repeated until the packet reaches to the destination node. This algorithm equivalently distributes the data-forwarding load amongst the nodes giving longer life to the network.

REAR (Reliable Energy Aware Routing) was proposed by Hassanein et. al. [8]. This algorithm provides energy efficiency as well as reliability of data delivery. There are three types of nodes in this algorithm, which are network sink, intermediate nodes and target source. Working of REAR is divided in four parts. First is the Service Path Discovery (SPD). It reserves an energy efficient path on the request of the Sink node which is confirmed by the source node and the energy level required for data transfer is reserved until the transfer is complete. No other node can claim this reserved energy until it is released. Second part is Backup Path Discovery (BPD), the process is same as SPD. The only difference is that the nodes already selected in SPD cannot be used in BPD. Third part is reliability of transmission which is achieved by storing data at the source node until acknowledgement is received. Fourth part is release of reserved energy. In case of link failure, a message is transmitted to the neighbors for releasing the reserved energy for the path.

III. HHEAA: Hole Healing Energy Aware Algorithm

Advantages of location based routing are used in an efficient manner besides dealing with problem of routing holes.

A. *Principle of HHEAA*

Hole Healing Energy Aware Routing (HHEAA) works on average energy and distance of nodes for giving longer life to the network. If only shortest distance is considered, nodes nearest to the destination will be selected repeatedly resulting in their early energy loss. If only the nodes having maximum energy are selected, then longer path may be followed that may result in delayed delivery of packets. Therefore, a combination of average energy and distance is used. First the average energy of the neighbor is calculated, and then the nodes having energy level greater than or equal to this average energy are selected. Packet is forwarded to the node which is at the shortest distance amongst these selected nodes. If a packet reaches a node whose all the neighbors are dead, then the link is reversed . Packet is sent back to the previous node for selecting some alternate path by using average energy and shortest distance. By doing this, the packet dropping rate decreases. The proposed algorithm selects the next hop in utilizing energy in an efficient manner and also deals with the problem of routing holes.

B. *HHEA Algorithm*

Initialize the network; //with specific number of nodes

1) Get Location; //Location of node in the network
2) Get Neighbors; //Check the neighbors of the node and create a table
3) Find neighbor distance;// Get the distance of each neighbor and store it in the table.

//Transmission

4) For each node
   If the node is alive // Energy greater than threshold
   a) Calculate average energy of neighbors
      - Find neighboring nodes having energy >= average energy.
      - Determine node with minimum distance.
      - Send packet to the node at minimum distance.
   b) Deduct energy used for processing .
      // Hole Healing
   Else if node is dead
      Reverse link; // Send packet to previous node.
      Go to step 4;
5) If all nodes are dead
   Drop Packet;

C. *Flow chart of HHEAA*

Fig. 1 shows the flow chart of HHEAA. First of all, the network is initialized and after that location of each node is stored and then distance of each neighbor is checked and stored. Packet is then generated and to forward it, it is checked whether the node is alive. Average energy of all the neighbors is calculated and packet is forwarded to the neighbor whose energy level is greater than or equal to their average energy. If more than one such nodes exist, then distance is compared and the packet is sent to the node at the shortest distance and processing energy is deducted from the available energy of the node. It is checked that whether the packet has reached to the destination or not. If yes, then the next packet is generated. Otherwise the process is repeated. If packet reaches to a dead node, then it is sent back to the previous node, where again the comparison is performed on the basis of average energy and distance and the packet is transmitted through the alternate path. If all the nodes in path are dead, then the packet is dropped.

IV. Simulation

Simulation for HHEAA has been developed using Omnet++ and executed for different number of nodes. For monitoring performance of the proposed algorithm, nodes were placed randomly. Two algorithms (i.e. HHEAA and greedy algorithm) have been simulated for checking the performance.

A. *Simulation Model for 10 Nodes and its working*

Nodes are randomly placed and are static. Initially, each node is assigned energy equal to 1 joule, which decreases

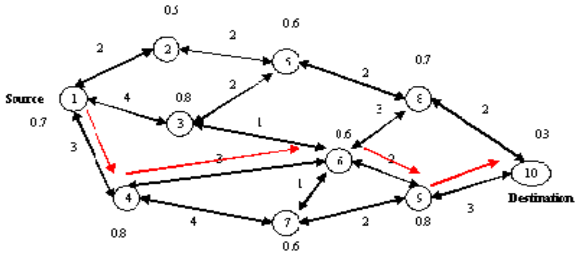

Fig. 2: 10 Nodes Wireless Sensor Network

When the packets are forwarded. When the energy of a node decreases down to the preset threshold, it is considered dead (i.e. it cannot forward packets anymore). Destination node is fixed while source can be changed. Fixed length packets are generated by the source nodes.

Fig. 2 shows a network of 10 nodes. Each node is assigned a specific identification. Different energy levels

and distances are assigned for the clarification of working of the proposed algorithm. In the Fig., circles represent the nodes and their identity is mentioned within the circle. Energy level of the node is represented here as real numbers adjacent to the circle. Distance between the nodes is written along with the edges. Red arrows represent the path taken by the packet.

B. Working

When the packet is at node 1, average energy is calculated first, which is equal to 0.7. Here two nodes, node 3 and node 4 have the energy greater than 0.7. So, the distances of these nodes are compared. Distance of node 4 < Distance of node 3, hence node 4 is selected for receiving the packet. Energy used for processing (i.e. 0.001 joule) is deducted from node 1. Now at node 4, again the average energy is calculated which is equal to 0.6. In the above mentioned network, nodes 6 and 7 have energy equal to 0.6 but the distance of node 6 is less than the distance of node 7. So, the packet is sent to node 6 and energy is deducted from node 4. At node 6 average energy is calculated which is equal to 0.7. Nodes 8 and 9 have energy equal to or greater than 0.7 but as the distance of node 9 is less than that of node 8 so the packet is sent to node 9 and energy is deducted from node6. There is only one neighbor of node 9, so the packet is transferred to node 10 which is a destination node.

C. Hole Healing

During packet forwarding, energy is deducted from the nodes. So, after some time some nodes start losing their energy and become dead resulting in a routing hole. When a packet reaches to such a node whose all the neighbors are dead, it is sent back to the previous node from where it takes an alternate path. This process is represented in Fig. 3 and Fig. 4.

Case 1

In Fig. 3, red circles represent the dead nodes. Red arrows shows the first path taken by the packet and green arrows show the alternate path taken by the packet after reaching the routing hole. Source node generates a packet and sends it to node 2. At node 2, average energy is calculated of its neighbors (i.e. 0.4). When energy and distance of neighbors are compared node 5 is selected. Considering that 0.01

energy is used for processing it is deducted from node 2 . Energy of node 2 becomes 0.49. At node 5, all the neighbors are dead so node 5 sends the packet back to node 2 and energy of node 5 is reduced to

0.39. At node 2, average energy is recalculated which is now 0.39. Node 3 is selected after comparing average distance and energy of the neighbors. Neighbors of node 3 are alive so the packet is forwarded via node 6, node 11 and node 12 respectively and it successfully reaches to the destination node 16

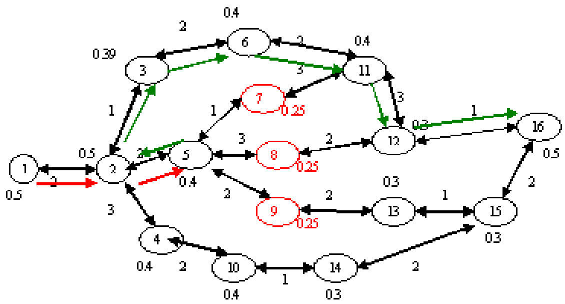

Fig. 3: Hole Healing

Case 2

In Fig. 4, red nodes are dead nodes. Source node (i.e. node 1) generates a packet and is sent to node 2. At node 2, average energy is 0.39. After comparing the average energy and distance, node 3 is selected, represented by red line. Energy of node 2 is reduced to 0.49. But the node 6 is dead so the packet is sent back to node 2 represented by green line. Energy of node 3 becomes 0.38 .

Average energy is recalculated at node 2 which is again 0.39. Comparison of energy and distance resulted in selection of node 5. Energy of node 2 becomes 0.48. Neighbors of node 5 are dead so the packet is sent back again to node 2,it is represented by blue line energy of node 5 reduced to 0.38. At node 2, average energy is calculated again and node 4 is selected after comparison of distance and energy. All the neighbors of node 4 are alive so the packet is forwarded towards destination via node 10, 14 and 15 respectively.

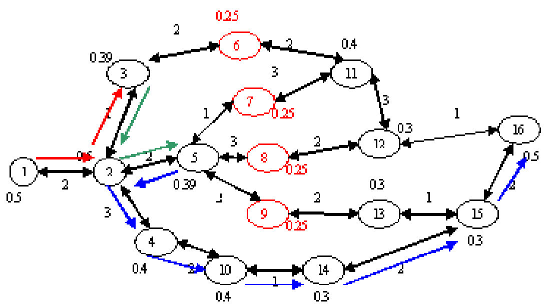

Fig. 4: Hole Healing Case 2

V. Results and Comparison

A. Performance Criteria

Greedy algorithm and HHEAA have been compared on the basis of packets delivered successfully, packets dropped, percentage of successful packets, number of alive nodes , number of dead nodes and percentage of alive nodes.

B. Comparison of HHEAA and Greedy algorithm for 10 nodes.

At the start of simulation, all the nodes were assigned equal energy. The nodes were placed randomly. In greedy algorithm, packet was forwarded to the next node using the shortest distance from the destination. It was noted that greedy algorithm worked efficiently for smaller number of nodes. Results in Table 1 show that all the packets were delivered successfully and only one node was dead at the end of simulation. Packet success rate was 100% and 90% nodes were alive. In HHEAA, packet was forwarded to the node having energy level greater than or equal to average energy and was at the minimum distance. As shown in Table 1, the proposed algorithm works efficiently for 10 nodes as the packet success rate is 100% and also 100% nodes are alive. In HHEAA, energy is consumed equivalently by all the nodes thus giving longer life to the network.

TABLE 1: Comparison for 10 nodes

	HHEA Algorithm	*Greedy Algorithm*
Delivered Successfully	5000	5000
Packets Dropped	0	0
Percentage Delivered	100%	100%
Alive Nodes	10	9
Percentage alive	100%	90%

C. Comparison of HHEAA and Greedy algorithm for 80 nodes.

When Greedy algorithm was tested for 80 nodes the performance degraded, packet delivery success rate became 69.4% and 2 nodes were dead at the end of simulation. It is obvious from the results shown in Table 2 that the performance of HHEA algorithm is much better than the greedy algorithm as the packet success rate is 78.7% for HHEAA that is better than 69.4%. Only one node is dead in case of HHEAA.

TABLE 2: Comparison for 80 nodes

	HHEA Algorithm	*Greedy Algorithm*
Delivered	31498	26562
Packets Dropped	8502	13438
Percentage Delivered	78.7%	66.40%
Alive Nodes	79	78
Percentage alive	98.7%	97.5%

HHEAA was tested for 10, 20, 30, 40, 50, 60, 80, 90 and 100 nodes. Summary of the results is shown in Table 3. It provides the clear picture of efficiency of the proposed algorithm. It is evident from the results that performance of HHEAA improves as the number of nodes increases. It

utilizes energy efficiently so the number of dead nodes is also less as compared to greedy algorithm. Fig. 5 shows the number of packets successfully delivered in both the algorithms it can be noted that performance of HHEAA algorithm improves with the increase in number of nodes.

TABLE 3. Summary of Results

	Packets Delivered				**Packets Dropped**		**Alive Nodes**			
							HHEAA		**Greedy**	
of Nodes	**HHEAA**	**HHEAA %age**	**Greedy**	**Greedy %age**	**HHEAA**	**Greedy**	**Alive**	**Percentage**	**Alive**	**Percentage**
10	5000	100	5000	100	0	0	10	100	9	90
20	10000	100	9251	92.5	0	749	20	100	19	95
30	13500	90	10338	70	1500	4662	29	96.7	28	93.3
40	18000	90	16520	87.5	2000	3480	39	97.5	38	95
50	22618	90.47	18262	73.8	2382	6738	46	92	44	88
60	24524	81.7	24436	81.4	5476	5564	58	96.7	57	95
80	31500	78.7	26562	69.41	8500	13438	79	98.7	78	97.5
90	36615	81.4	26252	57.8	8385	18748	86	95.5	85	94.4
100	41499	83	32124	64.5	8501	17876	96	96	95	95

Fig. 6 shows the number of packets dropped in each case. It is evident from the graph that number of packets dropped in HHEAA are lesser than Greedy algorithm. This demonstrates improved efficiency of the proposed algorithm in case of data delivery. Fig. 7 shows the energy efficiency of HHEAA and Greedy algorithm. The Fig. clearly indicates that number of alive nodes in HHEAA is higher than Greedy Algorithm. Thus, the proposed algorithm gives longer life to the network. So, the greedy algorithm works well for few number of nodes but its performance starts depreciating as the number increases. It is, therefore, not suitable for the networks having large number of nodes. HHEAA has shown better performance for the network having any number of nodes. Packet delivery success rate is higher in the proposed algorithm so it is more reliable than the greedy algorithm. The proposed algorithm successfully deals with routing hole problem in an efficient manner. Consumes energy on selection of nodes for the chosen paths so it gives longer life to the network.

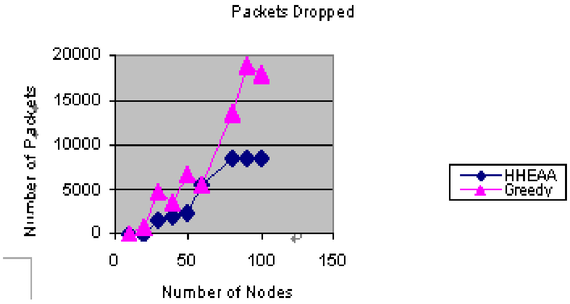

Fig. 5: Packets Delivered Successfully

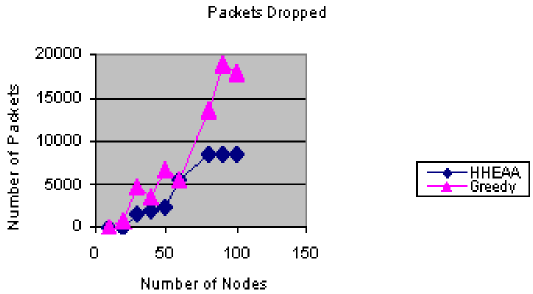

Fig. 6: Packets Dropped

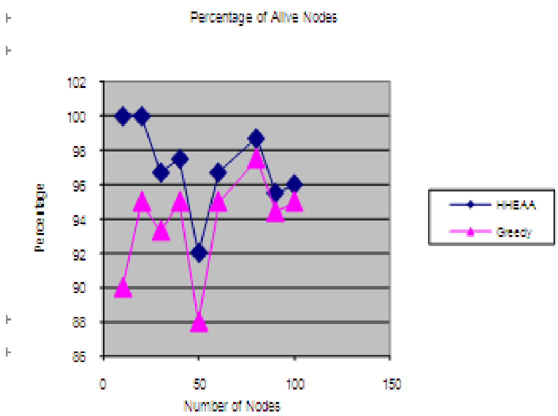

Fig. 7: Percentage of Alive nodes

VI. Conclusion And Future Work

Geographical routing is a very efficient routing strategy but its efficiency is greatly affected by the dead nodes. Dead nodes create routing holes due to which the packets are dropped. In HHEAA (the proposed algorithm) geographical routing is used along with energy awareness and it also deals with the routing hole problem. It is evident from the results that this combination works very efficiently. By using the proposed algorithm, the number of successful packets and life time of the network are increased, while the packet drop rate remain very low.

To further improve the performance of HHEAA in terms of efficiency, network life and awareness of energy the following methodologies are suggested for implementation. It can also be tested for mobile nodes. Buffer size is considered infinite in this implementation. It can be implemented with fixed buffer size so that effect of queuing and overflow can be monitored. Variable size packets can be used to check its effect on energy consumption.

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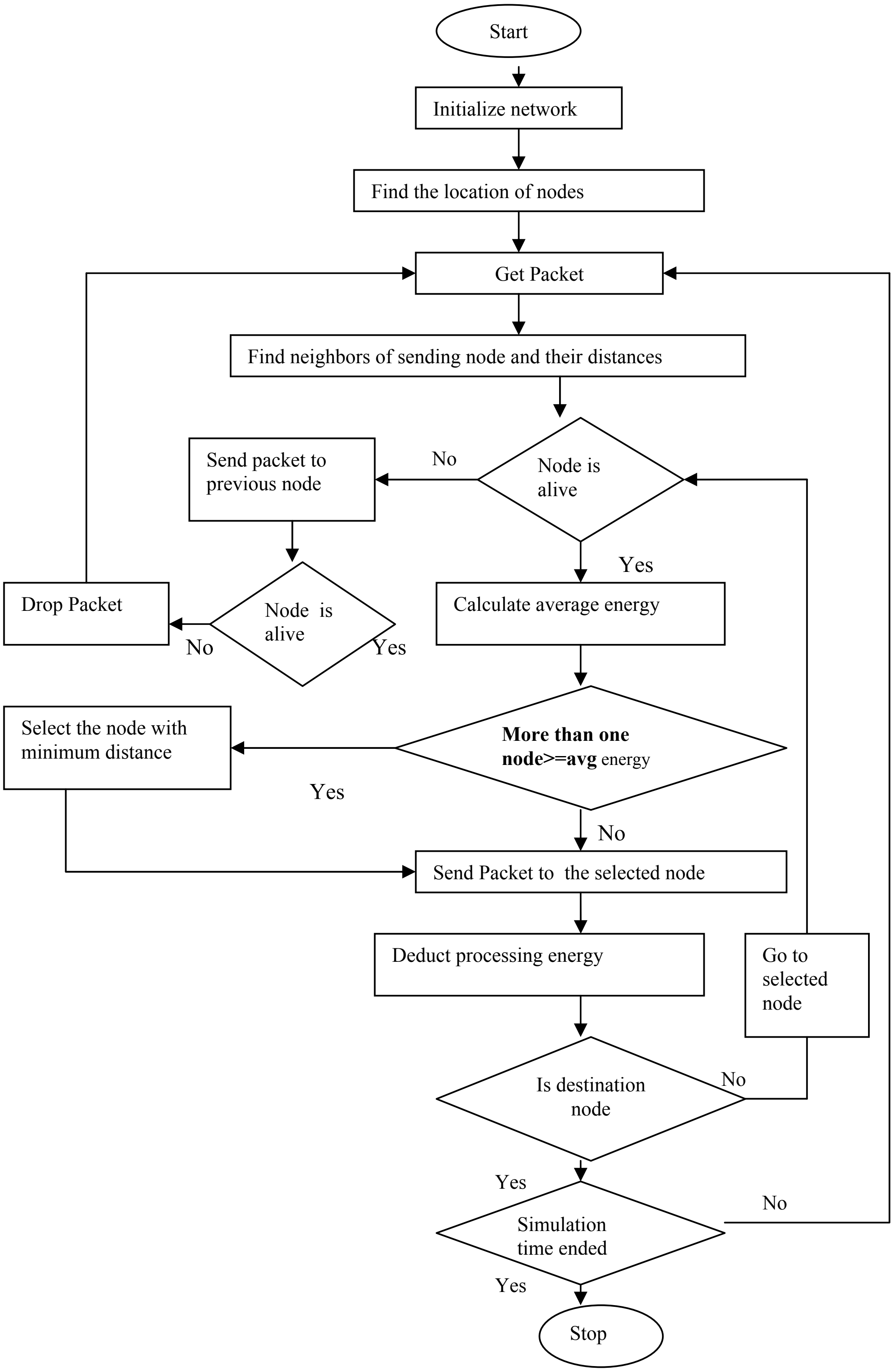

Fig 1: Flow chart of HHEAA