

Energy And Location Aware Cluster Routing Protocol For Wireless Sensor Networks (ELACRP)

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ABSTRACT

This paper proposes an ensemble protocol called Energy and Location Aware Cluster Routing Protocol (ELACRP) for wireless sensor networks. The location information model and energy consumption model are adapted. The neighbor node election operation is initiated once when the network is deployed. The cluster head selection mechanism is performed based on the residual energy of sensor nodes. The cluster head mechanism chooses the sensor node having maximum residual energy. Clustering is performed based on the nodes location information conceived from the GPS location information. The metrics number of packets delivered to the sink, energy utilization rate, the energy standard deviation and average hops are taken to compare the performance of the ELACRP with AELAR protocol [13]. Simulations are performed using NS2 and the outcome results depicts that the proposed ELACRP performs better than that of AELAR protocol [13] in terms of the chosen performance metrics.

Keywords: Energy and Location Aware Clustering; Sensor networks; relay nodes; location information model; energy consumption model.

1. INTRODUCTION

A wireless sensor network (WSN) consists of a set of sensor nodes. The sensor nodes are communicating among themselves using a shared wireless medium. Such sensor nodes are positioned in the situation to be monitored in ad hoc structure. WSN a

multi-hop network that is readily available collects data from all other sensor nodes. While a WSN is a wireless multi-hop network, is easy for deployment, the system lifetime, the data latency, and the quality of the network make a distinction that WSN are unique when compared with conventional multi-hop wireless networks. Clustering is a research problem that has the significance of offering an effectual method in order to extend the lifetime of a wireless sensor network. The recently proposed research works can be broadly classified into two types. One is selecting cluster heads with more residual energy, and the next one makes use of the cluster heads in rotation basis at regular intervals for distributing the energy consumption among the sensor nodes in each cluster for prolonging the network lifetime. Wireless sensor networks have the characteristic of lesser stern power, computation, and memory constraints. Since the sensor networks has only limited and non-rechargeable energy condition, the energy resource of sensor networks is to be maintained prudently for expanding the lifetime of sensor nodes. This research work contributes an energy and location aware clustering protocol for wireless sensor networks.

2. LITERATURE REVIEW

Many energy-efficient (hierarchical) clustering algorithms were proposed to extend the network lifetime [2 – 10]. Heinzelman et al. [11] have proposed a clustering protocol known as LEACH used for periodical data-gathering applications. LEACH protocol makes use of randomized rotation of cluster heads in order to distribute energy consumption over all nodes in the network. In the data transmission phase, each cluster head forwards an aggregated packet to the base station directly. An energy-aware variant of LEACH is proposed in [2], in which the nodes with higher energy are more likely to become cluster heads. However, the underlying routing protocol is assumed to be able to propagate node residual energy through the network. The authors have analysed trade-off between delay and energy for data aggregation. They have shown that WSN suffers with energy consumption with non-aggregation methods and WSN suffers with delay when full aggregation method is used [5]. The authors analytically determine the optimum number of cluster heads. Choi et al. [7] propose a two-phase clustering (TPC) scheme. At the cluster head electing stage, each node advertises for cluster head with a random delay, and the node who overhears others' advertisement will cancel its scheduled advertisement. After forming the initial clusters, each cluster member searches for a neighbor closer than the cluster head within the cluster to set up an energy-saving data relay link. HEED [8] introduces a variable known as cluster radius which defines the transmission power to be used for intra-cluster broadcast. The initial probability for each node to become a tentative cluster head depends on its residual energy, and final heads are selected according to the intra-cluster communication cost. HEED terminates within a constant number of iterations, and achieves fairly uniform distribution of cluster heads across the network. VCA [9] is an improvement over HEED. Sensors vote for their neighbors to elect suitable cluster heads. The authors also propose two strategies to balance the intra-cluster workload among cluster heads. It is argued that direct transmission is very easy to use, and therefore it is widely used in many applications.

Also, efficiency of direct transmission will be reduced if the geographical zone is bigger than the certain threshold [17]. The lower bound of energy-delay tradeoff and energy efficiency was proposed by authors using a realistic unreliable link model and is proposed in [18].

3. PROPOSED WORK

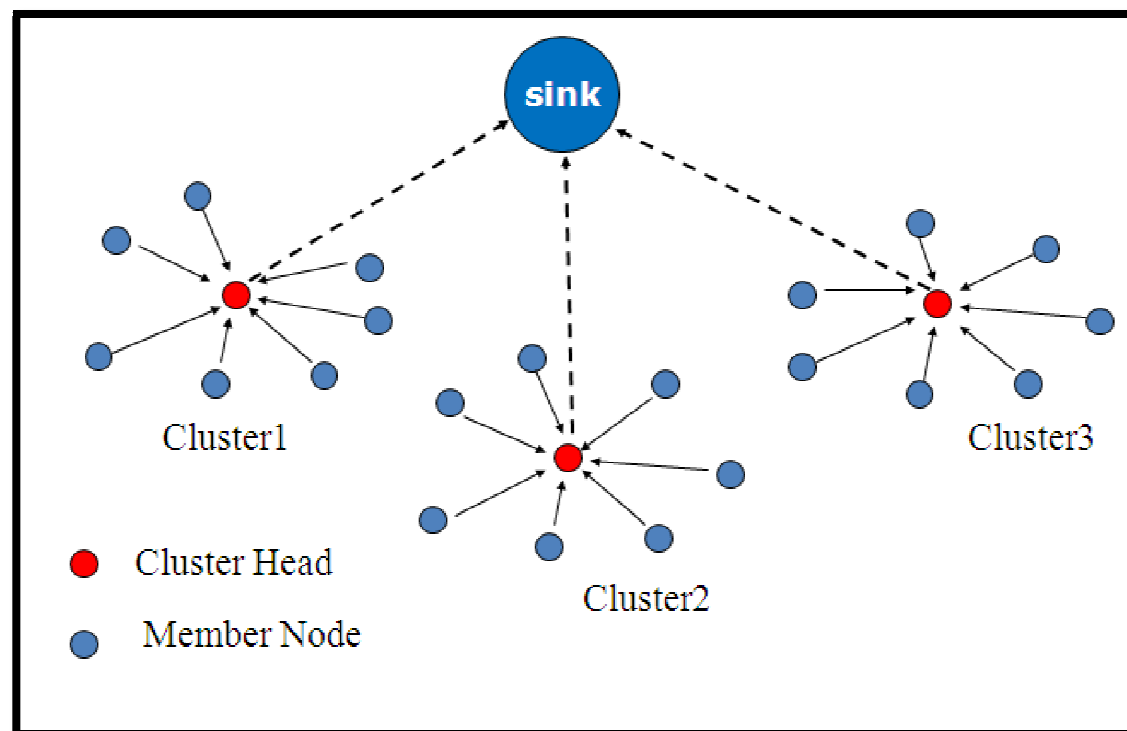


Figure 1. Clustering in Wireless Sensor Networks

3.1 Assumptions

In this research work a heterogeneous and hierarchical wireless sensor network is chosen. The hierarchical wireless sensor network system consists of three categories of devices that is to say sink node which is base station, cluster head nodes shortly termed as CH, and the sensor nodes. The system is placed in topography of two dimensional area. The algorithm for cluster formation is depicted in 3.3. It is assumed by which group of nodes called as clusters are formed and the cluster head is chosen, there happens the transfer of information in the form of messages. It is presumed that the cluster head nodes (CHs) are enabled with GPS devices, the device types exists on the network along with the residual energy (node remaining energy) for its corresponding clusters. Also it is to be noted that only one sensor node is considered as the sink node. The sink node communicates only with the cluster head nodes via wireless medium. The cluster head nodes are spread and placed around the sink node

and is capable to communicate among other cluster head nodes in direct fashion and it is known as one-hop communication. The cluster head nodes are also capable enough to communicate within the network. The cluster head mechanism depicted in 3.3 chooses the cluster head which is a device with more residual energy, than ordinary sensor nodes. Each cluster has a combination of static and homogeneous wireless sensor nodes with single omni-directional antennas that forms a multihop network. It is noteworthy to be mentioned that the sensor nodes present in the clusters are capable enough to perform computation and also communication, both in simultaneous fashion. The time synchronization is adapted from [15]. The cluster is modelled as a directed graph $G = (V, E)$, where $V = (v_1, v_2, \dots, v_n)$ represents the set of sensors and $E = (e_1, e_2, \dots, e_m)$ denotes the group of all likely communication links for the sensors. All the sensor nodes are alike with their range of communication and time taken for processing. The link used for communicating with other sensor nodes are enabled with half duplex mode by which the data at a time is capable enough to transfer in one direction that does not allow full duplex means of transmission since the channel cost for deployment is not cost effective.

3.2 Energy Consumption Model

The energy model used in this research work is adopted and described precisely in this section [1]. E_{comp} is denoted for energy consumption due to the processes in execution on the server. The energy consumption of executing N clock cycles with CPU speed f as

$$E_{comp}(V_{dd}, f) = NCV_{dd}^2 + V_{dd} \left(I_0 e^{\frac{V_{dd}}{nV_T}} \right) \left(\frac{N}{f} \right) \dots \quad (1)$$

$$f \approx K(V_{dd} - c) \dots \quad (2)$$

Where V_T denotes the thermal voltage and C, I_0, n, K, C are processor-dependent parameters. It is considered that a sensor node will consume different energy within its communication range, $E_{tx}(l, d)$ and $E_{rx}(l)$ where l denotes the data size and the distance is denoted by d . The duty cycle and sleep cycle of sensor nodes is followed as per the above said energy consumption model, where sensor nodes changes to sleep mode in order to reduce energy. The sleep mode will be get activated on the sensor nodes when there is no communication and also during no computation tasks are allocated for them. The model also will purge the energy consumption of a radio during the rest of the likely states (e.g., idle listening) in sensor nodes.

3.3 Energy and Location Aware Cluster Routing Protocol (ELACRP)

The assumptions and the energy consumption model for the proposed research work is given in section 3.1 and section 3.2 respectively. This section proposes the working mechanism for development of energy and location aware clustering routing protocol

(ELACRP). As the name implies the devices in the wireless sensor network system are enabled with GPS in order to get the location information and we named the protocol as location aware. The proposed algorithm works in turns and each of the turns are divided into two stages and each stage consists of one mechanism. Stage 1 has cluster setup mechanism and stage 2 has steady state mechanism. Before the execution, at first neighbor discovery operation is performed.

3.3.1 Neighbor node discovery operation

The neighbor discovery is initiated by the sink node. It is done by sending a hello packet which consists of sender id, hop-count and euclidean distance to arrive at the sink and location of the sender. The euclidean distance offers the shortest path between nodes which gives higher reliability by forwarding and makes the transmission of packets between the sensor nodes. The euclidean distance can be calculated [16] by,

$$d(a,b)=d(b,a)=\sqrt{(b_1-a_1)^2+(b_2-a_2)^2+...+(b_n-a_n)^2}=\sqrt{\sum_{i=1}^n(b_i-a_i)^2} \quad (3)$$

Where a,b are the location coordinates received from the GPS. d refers to the distance and n refers the number of location coordinates and i refers the number of iterations to be calculated for the distance. The hop-count and euclidean distance are used to measure distance from the sink. Receiving nodes of hello packet add sender as its neighbor and record information like sender id, hop-count and location, and then send hello reply to the sender. Each intermediate nodes will also forward the hello packet by allocating its id as sender id, location parameter and both distances hop-count and euclidean distance, to arrive at the sink. Whenever any node is having its energy less than threshold T, it will broadcast itself as a inactive node by sending the inactive message. The threshold will be calculated using the formula

$$T=\frac{1}{5}\times IE \dots \quad (4)$$

where IE stands for the initial energy of the sensor node. The receiving nodes will update its neighbor table once it receives the inactive messages. This neighbor node discovery operation is performed only during the time of network construction.

3.3.2 Cluster setup mechanism and routing

Clustering is the mechanism of partitioning the wireless sensor nodes into small units called as clusters. These clusters consists of one cluster head and some ordinary nodes as its members. The cluster head selection is primarily based on the residual energy (RE) of the sensor nodes in the cluster. The number of sensor nodes present in the WSN are deemed as

$$NoN = \{N_1, N_2, N_3, \dots, N_n\}. \dots \quad (5)$$

Where NoN represents the number of nodes. The cluster head node will be preferred based on the below said criteria,

$$CH = \text{MAX} [\text{RE}\{\text{NoN}\}] \dots \quad (4)$$

It is common fact that when the clusters nearer to the base station have smaller cluster sizes, they will consume less energy. This will happen during the intra-cluster data processing. Also, it will conserve a few more energy for the inter-cluster relay traffic. Smaller cluster sizes are supported by the cluster heads that are located closer to the base station, and it is to be noted that more number of clusters are require to be formed nearer to the base station. The cluster head that has the maximum received signal strength is being chosen by the ordinary nodes followed up with informing the cluster head by sending a join cluster message (JCM).

The process of routing begins when the nodes want to transmit the data to the sink node. The cluster heads will surrender the data to the base station. This is performed during the cluster head at first collects the data cumulatively from its members of the clusters. A single hop path is chosen to send the packet to the base station via intermediate cluster head nodes. Each cluster head will send a beacon message to the whole network at a fixed power and this process will be performed before selecting the next hop node. A beacon is a node aware of its location (e.g. equipped with GPS) along with node_id, residual energy and distance to reach the base station. A threshold T is used for taking transmission decision whether to transmit packets or not. When a node's distance to the base station is smaller than T, it will send the data directly to the base station. When a node's distance to the base station is greater than T a relay node will be found in order to send its data to the base station. The value of T is always smaller than the residual energy since the residual energy is less than the initial energy.

4. SIMULATION SETTINGS AND PERFORMANCE METRICS

The simulation has been done using the NS-2 Simulator. The WSN nodes were uniformly deployed with varied node density of 600 to 1100. The packets are allowed to transfer in constant bit rate fashion. It is assumed that all sensor nodes are homogeneous that have the same ability of communication and also know their neighbor nodes and their own location information by GPS [12]. The performance metrics taken are number of packets delivered to the sink, energy utilization rate, the energy standard deviation and average hops. The aim of the simulation is to determine the performance of the ELACRP with AELAR [13]. The simulation parameters are shown in Table 1.

Table 1. Simulation Settings

Parameter Name	Value
Number of nodes	600 nodes to 1100 nodes
Initial energy / node	50 joules
Simulation time	1500 seconds
Baseline node power	6mW
Simulation runs	10
Packet size	300 bytes

5. RESULTS AND DISCUSSION

AELAR [13] proposes a novel method of dividing routing request zone and construct a select equation which can enlarge the energy awareness as network time goes on. AELAR makes use of the routing request zone and chooses the changing equation factor in automatic fashion. The proposed ELACRP is compared with AELAR protocol.

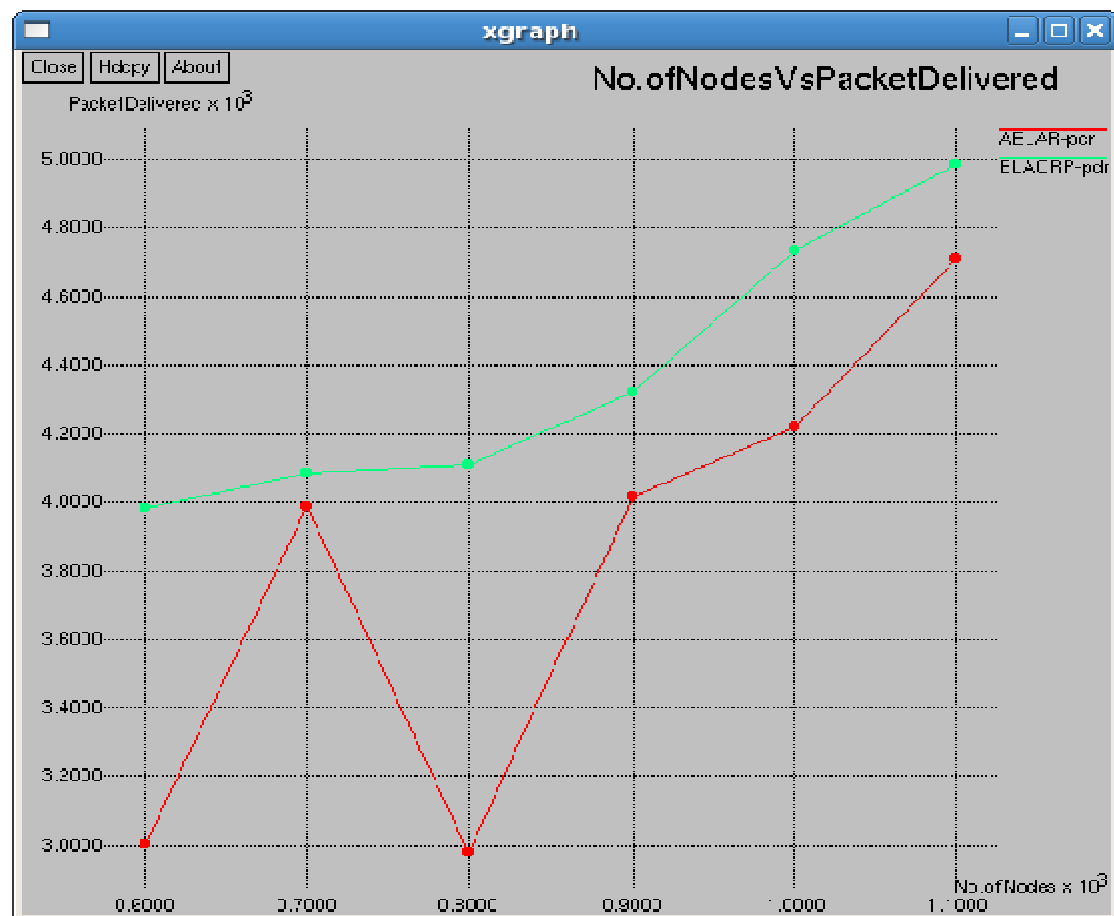


Figure 2. Number of Nodes Vs Packet Delivered to the Sink

Figure 2 shows the number packets delivered successfully to the sink node. Even when more number of nodes are added in the network, the performance is getting better due to the efficiency of the proposed work that depends on find the euclidean distance measure which provides the shortest route. AELAR protocol has no such euclidean distance mechanism and the performance is fluctuating due to that. Figure 2 clearly shows that ELACRP delivers more number of packets to the sink than that of AELAR.

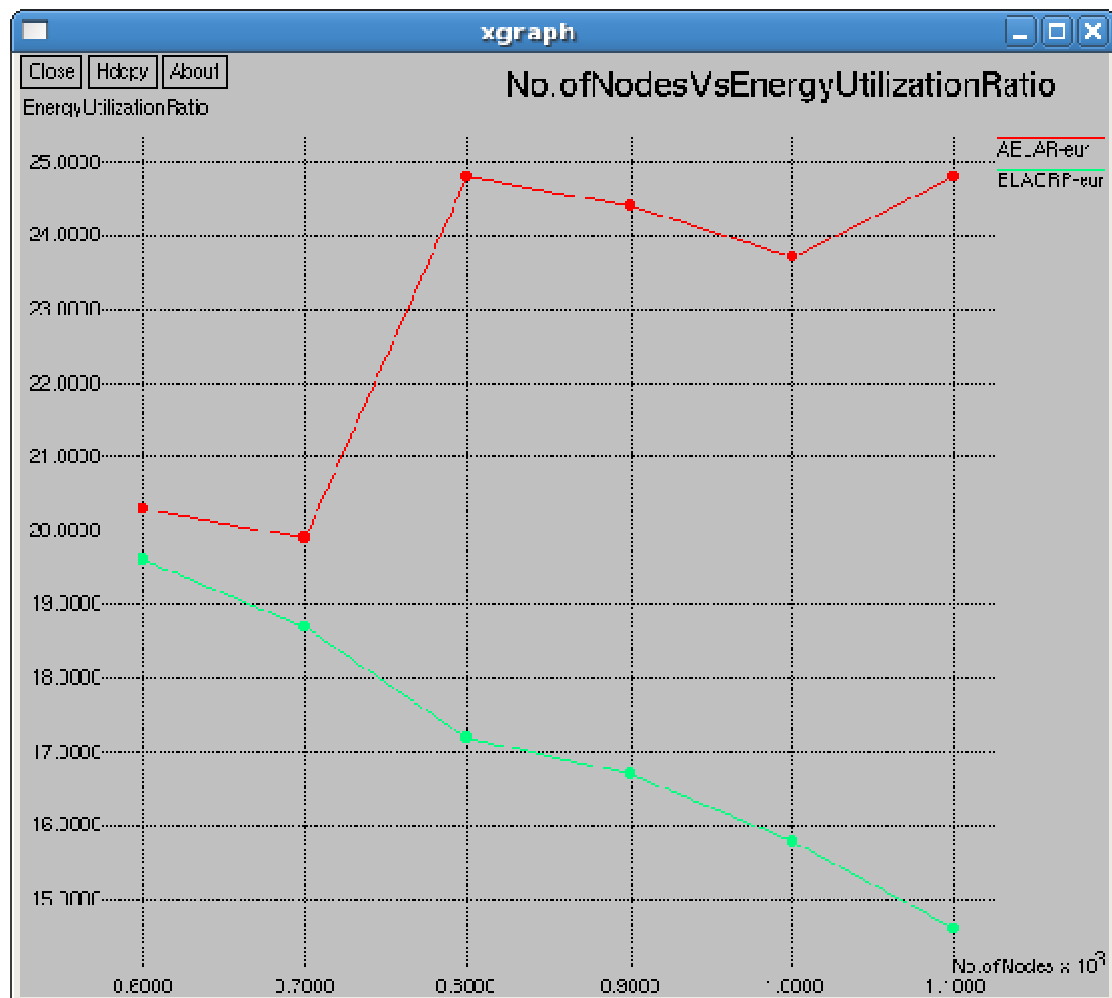
**Figure 3. Number of Nodes Vs Energy Utilization Ratio**

Figure 3 shows the energy utilization ratio. The proposed protocol ELACRP adapts energy consumption model and hence the energy utilization ratio is reduced when compared with AELAR. The important factor is that the energy will be utilized based on the distance and the size of the data. The energy standard deviation is also

shown in figure 4 which can be inferred that the proposed ELACRP consumes less energy than that of AELAR protocol.

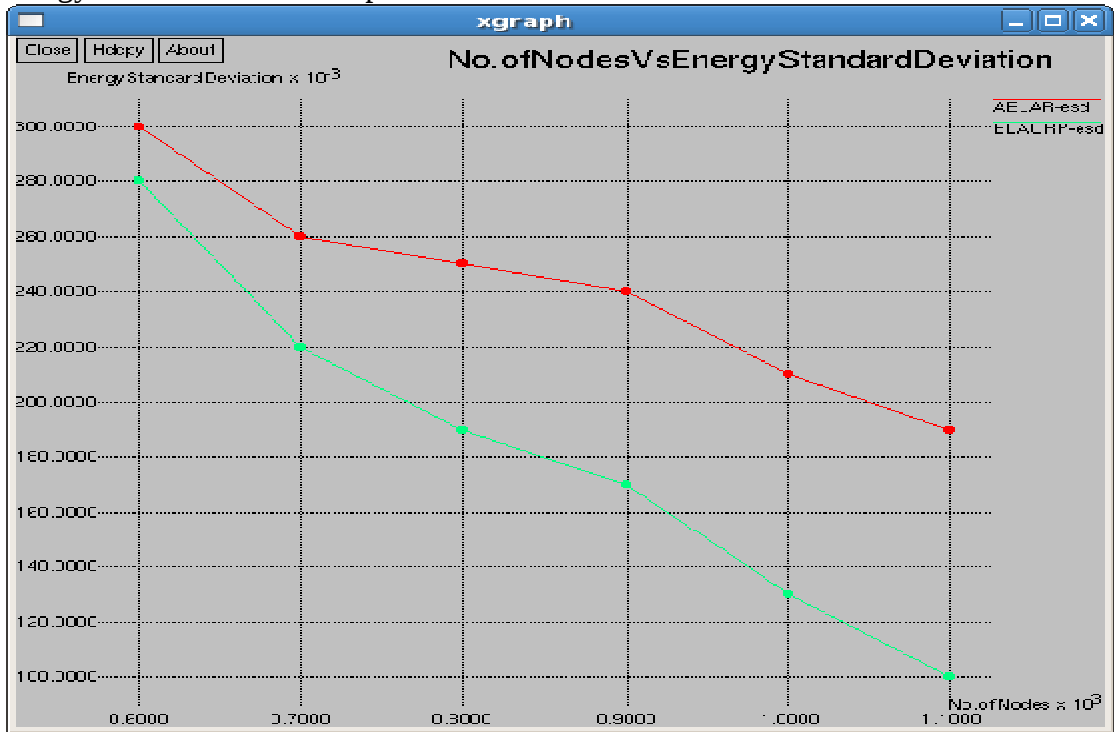


Figure 4. Number of Nodes Vs Energy Standard Deviation

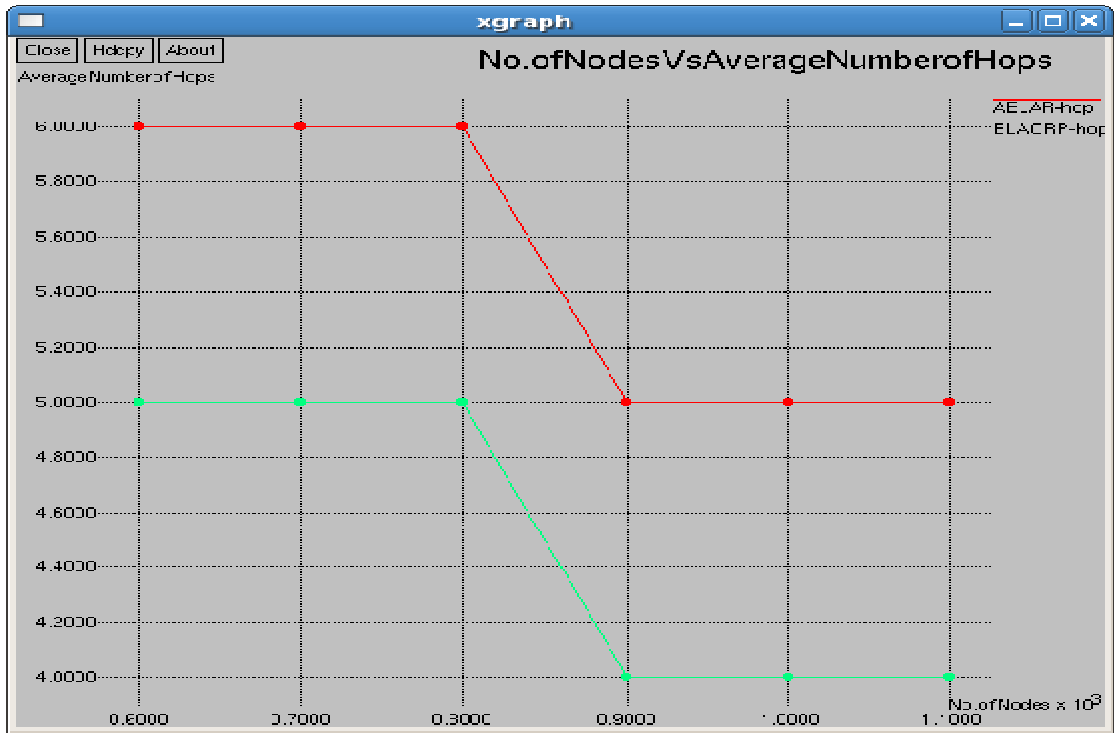


Figure 5. Number of Nodes Vs Average Number of Hops

Figure 5 depicts that the ELACRP makes use of less number of hops than that of AELAR. The proposed ELACRP follows hierarchical clustering model and hence the number of hops are reduced. Hence, from the simulation results it is proved that the ELACRP outperforms AELAR in terms of packet delivery, energy consumption, energy standard deviation and average number of hops.

6. CONCLUSION

The research work proposes an Energy and Location Aware Cluster Routing Protocol (ELACRP) for wireless sensor networks. By adapting the location information model and energy consumption model the cluster head selection mechanism is performed based on the residual energy of sensor nodes. The metrics such as number of packets delivered to the sink, energy utilization rate, the energy standard deviation and average hops are taken to compare the performance of the ELACRP with AELAR protocol. ELACRP is based on location, energy consumption model which provides effective clustering strategy and the simulation results proved that ELACRP outperforms AELAR.

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