Advance Stable Election Protocol in Wireless Sensor Networks

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***Abstract*—Wireless sensor network (WSN) is an emerging research field. There are large numbers of sensors that collect and send data to base station. Saving energy by using various routing techniques is a challenge. Clustering is main technique used for this. Various protocols like SEP (Stable Election Protocol) and ESEP (Extended Stable Election Protocol) are clustering based heterogeneous aware protocols. In this paper, a new protocol ASEP (Advance Stable Election Protocol) has been proposed based on SEP. This is based on changing more efficiently and dynamically the cluster head election probability. Performance of this protocol has been evaluated in MATLAB and graphical results have been shown. The performance of ASEP is better than SEP in form of first node dies and total number of packets delivered.**

Keywords: WSN, Clustering, LEACH, SEP, ASEP

I. INTRODUCTION

Wireless Sensor Networks (WSNs) have been considered as the very important technologies used in this world from last two to three decades. There is lot of advances in wireless communication technologies that gives us the small, smart and cost effective sensors. These sensors can be deployed anywhere and connected through wireless links [1].

There is large number of sensor nodes in wireless sensor network. These can be deployed inside any field or near that field where the sensing has to be done. A sensor node mainly consists of five components:

1. Sensing
2. Memory
3. Processor
4. Transceiver (transmitter and receiver)
5. Battery [5]

In wireless sensor network (WSN), there are number of sensor nodes that send their data to the sink or base station. Base station is a powerful node or device that can receive the data from the sensor nodes. If the base station or sink is in the radio range of the node then data can be send directly otherwise the other sensor nodes can be used [3].

II. ROUTING IN WIRELESS SENSOR NETWORKS

Energy is the first and foremost consideration for the routing protocols used in Wireless Sensor Networks. According to the application of the network routing protocols can be different [8].

The characteristics of wireless sensor network are different from other networks like cellular networks or Mobile Ad-Hoc networks. So, routing process is also different. As we know that sensor network have large number of sensor nodes, so traditional IP based schemes cannot be applied here [7],[8].

III. HIERARCHICAL NETWORKS ROUTING

The major design attribute of wireless sensor networks is Scalability, similar to other communication networks. As we know that there is large number of sensor nodes. So, single tier can cause latency due to overload of Gateway. Due to this and wide area covered by nodes, long distance communication is difficult and single tier network does not work efficiently. Here comes the concept of clustering. In clustering, network is divided into clusters. [8]. There is Concept of cluster head used to reduce the work done by normal sensor nodes. Normal nodes sense the data to cluster heads and cluster heads aggregate the data and send it to base station. [7]. There are various protocols that use the concept of clustering. Like LEACH, SEP, ESEP, HEED, DEEC, etc. Our work is based on SEP (Stable Election Protocol) which is a heterogeneous aware protocol. Heterogeneous means nodes have not same initial energy. Some nodes have more initial than other nodes in these protocols. The detail of SEP is given below.

A. Stable Election Protocol

Stable Election Protocol uses the basic techniques of the LEACH protocol like cluster hierarchy, choosing optimal number of clusters, energy model used and optimal probability of a node to become the cluster head. In SEP, nodes are heterogeneous in nature means nodes have not same initial energy. SEP have the fraction of advanced nodes (m) (nodes which have more energy than the normal nodes, where m is the percentage of advance nodes in total nodes) and the additional energy factor between advanced and normal nodes (α). In this, advanced nodes have to become cluster heads more often than the normal nodes. This new heterogeneous setting (with normal and advanced nodes) has no effect on the spatial density of the network. But, the total energy of the system changes. Suppose if E_0 is the energy of each normal sensor node. The energy of each advanced sensor node will be $E_0 \cdot (1 + \alpha)$. The total energy of this new heterogeneous setting is equal to: [11]

$$n\,(1 - m)\,E_0 + n\,m\,E_0 \cdot (1 + \alpha) = n\,E_0\,(1 + \alpha\,m) \quad (1)$$

where, n= No. of nodes in sensor network

α= Energy factor between advance and normal nodes

m=Percentage of advance nodes in network

So, the total energy of the system is increased by $(1+\alpha.m)$ times

According to the additional energy in the advance nodes, the probability density function of the protocol also changes. The probability of various nodes to become cluster heads is given

$$p_{nrm} = \frac{p_{opt}}{1+\alpha.m} \quad (2)$$

$$p_{adv} = \frac{p_{opt}}{1+\alpha.m} \times (1+\alpha) \quad (3)$$

Where p_{nrm} is the probability of the normal nodes to becomes the cluster head and p_{adv} is the probability of the advance nodes to becomes the cluster head [11].

As now it is known that advance nodes with more initial energy have more chances to be a cluster head. So it increases the network lifetime due to its heterogeneous aware algorithm. But after some time, when the energy of the advanced and normal nodes remains same, it again chooses advance nodes increasing times than normal nodes. Due to this, energy of advanced nodes depletes more quickly than normal nodes. It decreases lifetime of network. So ASEP (advance stable election protocol) has been proposed in which advance nodes are selected as cluster head in starting rounds, when energy depletes upto a certain level after that the probability of both advance and normal nodes will be same.

B. Advance Stable Election Protocol the Details of ASEP is given Below

1) Heterogeneous WSN model used

In this section, the model of wireless sensor networks will be described. Nodes are heterogeneous in the initial amount of energy. Particularly, the setting of Wireless Sensor Networks and energy model used is presented. It also tells us that how the optimal clusters can be computed. There is some percentage of nodes with extra amount of energy than other nodes. There are p and k percentage of nodes equipped with a and b times more energy than other nodes. These nodes are called advance and moderate nodes. All these sensor nodes are distributed uniformly over the sensor field [11][12].

2) Creation of a cluster

In this setting, wireless sensor network is hierarchically clustered. LEACH (Low Energy Adaptive Clustering Hierarchy) is a protocol that uses same type of clustering hierarchy. In LEACH, the concept is repeated in each round. Round has two phases: cluster creation phase and steady state phase. clusters are re-established in each round and new cluster heads are chosen in each round. Due to this, load is well distributed among the nodes of the network. In this type of cluster hierarchy, each node transmits to closest cluster head and this cost of communication is very-very less than the cost of sending directly to the base station. Only the head nodes communicate directly with the base station. This expends large amount of energy but each node do this periodically. In LEACH protocol, there is optimal percentage of nodes (p_{opt}) from total nodes that has to become cluster head in a round. This percentage is determined priori and it is assumed that nodes are distributed uniformly in the field.

In LEACH, nodes are homogeneous. It means that all the nodes have same initial energy. It guarantees that each and every node will become cluster head exactly once in every $\frac{1}{p_{opt}}$ rounds. It is also assumed as the epoch of the network.

In start, every node has the probability equal to $\frac{1}{p_{opt}}$ to become cluster head. In a epoch, when one node becomes cluster head once, it can-not become cluster head in same epoch. All the nodes that has not became cluster head yet belongs to set G. After each round in same epoch, the probability of each node increases which belongs to set G. each node belongs to set G chooses a random number between 0 and 1. If less than a threshold value, this node becomes cluster head in that round. This threshold equation is

$$T(n) = \frac{p_{opt}}{1 - p_{opt}\left(r \bmod\left(\frac{1}{p_{opt}}\right)\right)} \quad \text{if } n \in G \quad (4)$$

Here r is the current number .at the end of the round, all nodes send data to cluster heads [11][12].

C. Optimal Number of Clusters

In all the previous protocols, nodes are assumed uniformly distributed and the optimal probability of the node to become cluster head is the function of spatial density. The optimal clustering mainly depends on the energy model used. Same energy model is used as in LEACH and SEP protocol.

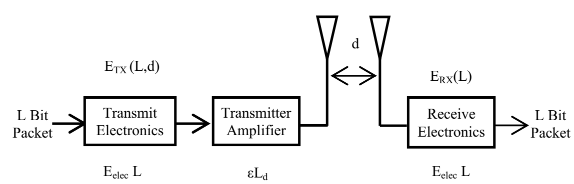

Fig. 1 Radio Energy Model Used [11]

As shown in above figure's radio energy dissipation model, in transmitting an L bit message over a distance d and to achieve an acceptable signal-to-noise ratio, the energy expended by radio is given by:

$$E_{Tx}(l,d) = \begin{cases} L \cdot E_{elec} + L \cdot \epsilon_{fs} \cdot d^2, if\ d < d_0 \\ L \cdot E_{elec} + L \cdot \epsilon_{mp} \cdot d^4, if\ d \geq d_0 \end{cases} \quad (5)$$

Where d is the distance between sender and receiver node, L is the size of the packet, E_{elec} is the energy dissipated per bit to run the receiver circuit or transmitter, ϵ_{fs} and ϵ_{mp} depend on the transmitter amplifier model used. When the equation given above is equated at d = d_0, the value comes $d_0 = \sqrt{\frac{\epsilon_{fs}}{\epsilon_{mp}}}$. So to receive an L bit size message, it expends the energy as $E_{Rx} = L \cdot E_{elec}$. By taking all the basic assumptions and if the distance of any node to the base station or sink <= d_0 then the energy dissipated in a round by the cluster head node is given below:

$$E_{CH} = L \cdot E_{elec}\left(\frac{n}{k} - 1\right) + L \cdot E_{DA}\frac{n}{k} + L \cdot E_{elec} + L \cdot \epsilon_{fs} \cdot d_{toBS}^2 \quad (6)$$

Where d_{toBS} is the distance from sink or base station to base station, k is the total number of clusters and E_{DA} is the aggregation cost of a data bit per signal. The energy used by a non cluster head node is given below:

$$E_{nonCH} = L \cdot E_{elec} + L \cdot \epsilon_{fs} \cdot d_{toCH}^2 \quad (7)$$

Where d_{toCH} is the distance from any cluster node to its cluster head. So the total energy dissipated in a single cluster per round is given below:

$$E_{cluster} \approx E_{CH} + \frac{n}{k}E_{nonCH} \quad (8)$$

So the total energy dissipated in the network is given below:

$$E_{tot} = L \cdot \left(2nE_{elec} + nE_{DA} + \epsilon_{fs}\left(k.d_{toBS}^2 + n\frac{M^2}{2 \cdot \pi \cdot k}\right)\right) \quad (9)$$

When differentiation of E_{tot} has done with respect to k and result is equated to zero, the optimum clusters constructed comes that are given below:

$$k_{opt} = \sqrt{\frac{n}{2\pi}}\frac{M}{d_{toBS}} = \sqrt{\frac{n}{2\pi}}\frac{2}{0.765} \quad (10)$$

Where the average distance from base station or sink to any cluster head is given below :

$$E[\,d_{toBS}\,] = \int_A \sqrt{x^2 + y^2}\frac{1}{A}dA = 0.765\frac{M}{2} \quad (11)$$

So p_{opt}, the optimal probability of a node to become cluster head is given below:

$$p_{opt} = \frac{k_{opt}}{n} \quad (12)$$

In the LEACH protocol this is shown that if these clusters are not made by optimal way i.e. more or less than this optimal then the consumption of energy increases exponentially [11],[12].

The working of ASEP and SEP is same and only difference is in the probability density function. As it is clear from the equations (2) and (3) that advance nodes have more probability in the whole lifetime of the network. It surely increases the lifetime of the network than LEACH as the advance nodes are selected cluster head more often than normal nodes. There comes a time when there remains same energy in both advance and normal nodes but the advance nodes are selected as cluster head with same probability as before. It drains the energy of advance nodes more quickly than normal nodes. so the probability density function for advance nodes must be changed after attaining that particular energy level. To calculate that value, energy dissipated by both advance nodes and normal must be calculated, that is given below

3) How to calculate that energy value

The probability of advance nodes is higher, so there is possibility that advance nodes can become the cluster head in each round. So energy decreased from each advance node in a round is given below:

$$E_{AN} = L\left[\frac{n}{k} \cdot (E_{elec} + E_{DA}) + \epsilon_{fs} \cdot d_{toBS}^2\right] \quad (13)$$

Here E_{CH} is the energy that is dissipated by each advance node in a round. Then number of rounds possible for a cluster head with initial energy equal to $(1 + \alpha)\ E_0$

$$NR_{AN} = (1 + \alpha)E_0/E_{AN} \quad (14)$$

By this method, energy dissipated by normal node in a round can also calculated

$$E_{NN} = L\left[E_{elec} + \epsilon_{fs} \cdot d_{toCH}^2\right] \quad (15)$$

Number of rounds possible for a normal node is

$$NR_{NN} = E_0/E_{NN} \quad (16)$$

After some rounds, advance and normal nodes will have same residual energy but the probability of advance nodes will have more than the normal nodes. so it will be selected more times than normal nodes and energy of advance nodes drain more quickly than normal nodes. there must be change in probability density function after nodes dissipate a particular amount of energy. this value of energy can be calculated by equation given below [13]

$$E_{level} = E_0\left(1 + \frac{\alpha E_{NN}}{E_{NN} - E_{AN}}\right) \quad (17)$$

Probabilty Density Function of ASEP

$$p_{nrm} = \frac{p_{opt}}{1+\alpha.m} \text{ for nml nodes, energy} > E_{level} \quad (18)$$

$$p_{adv} = \frac{p_{opt}}{1+\alpha.m} \times (1 + \alpha) \text{ for advance nodes, energy} > E_{level} \quad (19)$$

$$p_{an} = d\frac{p_{opt}}{1+\alpha.m} \times (1 + \alpha) \text{ for nml, adv nodes, energy} < E_{level} \quad (20)$$

Where E_{level} = G. E_0

It is assumed that all advance nodes will be cluster heads in all rounds but in reality it is not the case. Also normal nodes will become cluster heads for some rounds. So the exact value of G cannot be find, but through various simulations with random topologies, nearest value of G can be found. For the best result of protocol in terms of first node die and total packets delivered to base station, the value of G has come 0.7.

d is the variable which is used to control the cluster head number. If the number of cluster head will be more then the nodes will lose their energy very rapidly and die. If the number of cluster heads will be less then it will be difficult to gather data from the field. Through various simulations with random topologies, the nearest value of d can be found. For the best results of d in terms of first node die and total packets delivered, the value of d has come 0.05.

IV. Simulation and Results

A. Simulation Parameters

These are the basic parameters used for simulation. The main parameters are sensor area, base station position, number of nodes used in simulation, initial energy of the normal nodes, optimal probability of node to be cluster head and data aggregation cost [11].

TABLE I SIMULATION PARAMETERS

Parameters	Values
Sensor Field	(100 × 100)
Sink Position	(50, 50)
N	100
Packet Size	4000bits
ε_{fs}	10pj/bit/m^2
ε_{mp}	0.0013pj/bit/m^4
p_{opt}	0.10
E_{DA}	50nj/bit
E_0	0.5j
M	0.1
α	1
d_0	87.7m

A. Performance Metrics

1) First node dies

This parameter tells us about the round when first sensor node dies. It is also called the stable region of the network. If this region is long, then the nodes will send more useful information about the environment to be sensed to base station.

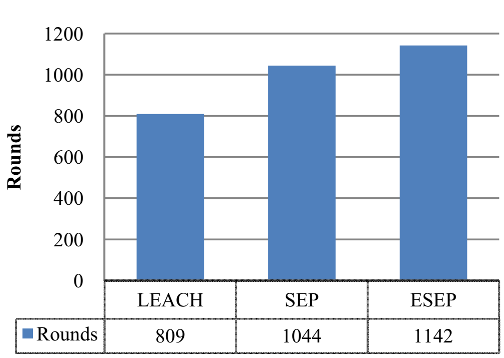

Fig. 2 First Node Dies

The stable region of the network in LEACH protocol is around 809 rounds. In SEP and ASEP, it is near 1044 and 1116. The performance of network is increasing from SEP to ASEP due to changes done in probability function of the SEP protocol.

2) Total number of packets delivered

The main work of the wireless sensor network is to send data to base station. This parameter tells us the number of packets that is sent to the base station from cluster heads. The performance of ASEP protocol is more than SEP protocol.

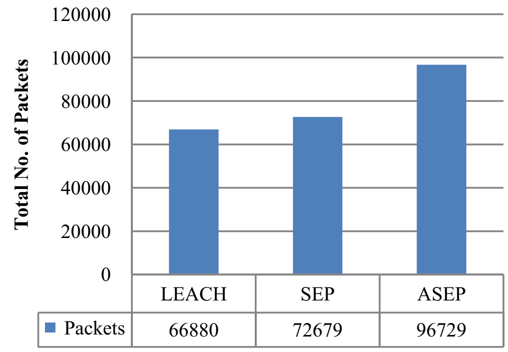

Fig. 3 Total Packets Delivered

Conclusion

Basics of wireless sensor network and heterogeneous aware protocol (Stable Election Protocol) have been discussed. The ASEP (Advance Stable Election Protocol) has been proposed which is based on SEP. it changes the probability function of the Stable Election Protocol and adds the point at which the energy of advance nodes remain same to the normal nodes. It increases the performance of network in terms of first node dies and total number of packets delivered to the base station.

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