An Improved E-DEEC Protocol using Periodic and Threshold-Sensitive Data Transmission in Heterogeneous Wireless Sensor Network

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Abstract

An improved energy efficient clustering routing protocol has been presented in this paper. The proposed protocol is an improvement over EDEEC and APTEEN. The new approach exploits the advantages of both the protocols and minimizes the data transmission overhead. An improved EDEEC protocol is obtained by using the periodic and threshold-sensitive data transmission. Simulation results show that performance of the proposed approach is better than DEEC, DDEEC and EDEEC.

Keywords- WSN, EDEEC, APTEEN

I. INTRODUCTION

A wireless sensor network (WSN) can be defined as a network of (possibly low-size and low-complex) devices called nodes that can sense the environment and communicate the information gathered from the monitored field through wireless links; the data is forwarded, possibly via multiple hops relaying, to a sink (sometimes called as controller or monitor) that can use it locally, or is connected to other networks (e.g., the Internet) through a gateway. Wireless sensor networks are generally deployed in remote areas like battle fields, disaster relief operations, biodiversity mapping etc. and the sensor nodes are generally battery powered devices. So it is difficult to recharge the battery at regular intervals. Hence key issues involved in wireless sensor networks are reducing energy consumption and extending network lifetime. Transmission of data is more energy consuming as compared to the processing of data. Many protocols have been proposed till now to make communication energy-effective. Clustering is one of the key techniques followed in these protocols. LEACH[1] a homogeneous protocol (because of the same initial energies of all nodes), elects cluster head based on a fixed probability assigned to each node and this probability decides after how many rounds a node can be again cluster head. But it does not always select node with high energy as the cluster head. PEGASIS[2] was proposed with the idea that if nodes form a chain from source to sink only one node in any given transmission time-frame will be transmitting to the base station. But it added overhead as a sensor node required to know the energy status of its neighbors to route its data. SEP[3] a heterogeneous protocol, considered two types of nodes- normal and advanced. Cluster head selection in SEP is done randomly on the basis of probability of each type (normal and advanced) of node as in does not support multi level heterogeneity of nodes and also the selection of cluster head is not dynamic; therefore the normal nodes will die first than the advanced nodes. DEEC[4] proposed that all the nodes of the network use the initial energy and residual energy to specify the cluster head. DEEC embeds the factor of residual energy in the heterogeneous environment thus ensuring that always high energy nodes will have more chance to become cluster head than low energy nodes. Several enhanced versions of DEEC were proposed such as DDEEC, EDEEC etc. DDEEC[5] introduces threshold residual energy and when energy level of advanced and normal nodes falls down to the limit of threshold residual energy then both type(normal and advanced) of nodes use same probability to become cluster head. EDEEC [6], which was enhanced version of DEEC proposed to insert another node in the network (super node) with the existing normal and advanced nodes which increased the heterogeneity and lifetime as well. It has been evaluated in [7] that DDEEC has low stability period, lifetime and throughput as compared to the EDEEC. So EDEEC act as motivating factor to work on and improve it further. TEEN[8] a threshold sensitive reactive protocol proposed scheme to minimize the transmission time as transmission consume more energy than processing of data at the nodes. This was done by introducing two threshold parameters, hard and soft threshold. A node only transmits when currently sensed value is greater than hard threshold and difference between current sensed and previous sensed value is greater than soft threshold. But being a reactive protocol it was not suited for proactive applications (data is required at regular intervals). APTEEN[9] was developed for the hybrid networks i.e. both reactive and proactive.

II. RELATED WORK

DEEC used the ratio of residual energy left after communication (Ei(r)) and average energy ($E_{avg}(r)$) of the nodes in election of cluster heads as:

$$Y = E_i(r)/(E_{avg}(\mathrm{r}))$$

$$(E_{avg}(r)) = \frac{1}{n} * E_{total}(1 - \left(\frac{r}{R}\right))$$

n is total no. of nodes, R is total no. of rounds (lifetime) and r is current round no. E_{total} is the total energy of the nodes.

EDEEC used three types of nodes i.e. normal, advanced and super and thus increased the heterogeneity level. The energy of advanced and super nodes are 'a' and 'b' times the normal nodes respectively. EDEEC maintain no. of cluster heads as $n*p_{opt}$ in a round. Thus

$$p_{norm} * n_{norm} + p_{adv} * n_{adv} + p_{sup} * n_{sup} = n * p_{opt}$$

Spatially located nodes have same type of data. So it is wastage of time and energy for cluster heads of network to send similar data to base station again and again and earlier research works show that transmission is the most energy consuming process.

TEEN eliminates this problem by introducing two thresholds- hard threshold and soft threshold. Since it is a reactive protocol it act by checking significance of data and decide to transmit or not. But if thresholds are not reached, the nodes will never communicate and the user will not get any data from the network at all and will not come to know even if all the nodes die. Also TEEN is not suited for applications where the user needs to get data at regular basis.

To overcome these problems APTEEN is used.

Attribute(A): Parameter about which data is to be gathered.

Hard Threshold(H_T): CH will transmit data beyond this absolute value of sensed attribute.

Soft Threshold(S_T): The smallest sensed value at which the nodes switch on their transmitters and transmit.

Count Time(T_C): Time period between two successive reports if threshold is not reached. Time period is taken in terms of the number of rounds. After certain rounds value of effective sensed value (SV) threshold is reset to ensure that even if the threshold is not reached, data is transmitted.

APTEEN combines both reactive and proactive protocols. Also the energy consumption can be controlled by the count time and threshold values.

III. SYSTEM MODEL

A. Network Model

In network model a square field with N sensors deployed in it is considered. Some of the assumptions made about the network and the nodes are:

1. Sensor nodes are deployed randomly and uniformly in entire sensor field.
2. Sink and all other nodes are stationary after the deployment.
3. Nodes need not be equipped with GPS capable units to determine the location.
4. All nodes have similar processing capabilities.

B. Radio Model

Radio hardware energy Dissipation Model is used similar to as shown in [1]. Both the free space (d^2 power loss) and the multi-path fading (d^4 power loss) channel models are used in the model, depending on the distance between the transmitter and receiver. The energy spent for transmission of a *l*-bit packet over distance *d* is:

$$E_{Tx}(l,d) = E_{Tx\text{-}elec}(l) + E_{Tx\text{-}amp}(l,d)$$
$$= \begin{cases} lE_{elec} + l\,\varepsilon_{fS}\,d^2,\ d<d \\ lE_{elec} + l\,\varepsilon_{mP}\,d^2,\ d<d_0 \end{cases} \quad (1)$$

and to receive this message, the radio expends energy:

$$E_{Rx}(l) = lE_{elec} \quad (2)$$

d_0 is the threshold distance calculated as follows:

$$d_0 = \frac{\varepsilon_{fs}}{\varepsilon_{amp}} \quad (3)$$

A sensor node also consumes E_{DA} (nJ/bit/signal) amount of energy for data aggregation.

IV. PROPOSED APPROACH

Considering the research gap analysis and the limitations of EDEEC, an improved EDEEC protocol (PTEDEEC) is proposed by applying the optimization protocol APTEEN on EDDEC in which nodes sense the environment continuously and only those nodes which sense a data value at or beyond the hard threshold transmit. Once a node senses a value beyond hard threshold, it next transmits data only when the values of that attribute changes by an amount equal to or greater than the soft threshold. If a node does not send data for a time period equal to the count time, it is forced to sense and transmit the data. Three types of nodes are used same as used in EDEEC. Energy level of these nodes is as follows:

normal nodes: E0

advanced nodes: E0(1+x)

super nodes: E0(1+y)

If normal nodes are initially equipped with energy E0, advanced nodes have ‘x’ times more energy than the normal nodes and super nodes have ‘y’ times more energy than the normal nodes. Node distribution is done according to the constants m and m_0, where N is the total number of nodes:

normal = (1-m) * N;

advanced = (1-m_0) * m * N;

super = m_0 * m * N;

Total energy of the network in a round is

$$E_0 * (1-m) * N + E_o(1+x) * (1-m_0) * m * N + E_0(1+y) * (m_0 * m * N) = N * E_0(1+m *(a+m_0y)); \quad (4)$$

Cluster heads are elected according to the probability p_{opt} so that a node becomes eligible for cluster head after 1/p rounds as in LEACH. But since we are using three types of nodes, so probabilities of different nodes are:

$$P_i = \begin{cases} \frac{p_{opt} * E_i(r)}{(1+m(a+m_0b)*E_{avg}(r)} & \text{if node is normal} \\ \frac{p_{opt} *(1+x)* E_i(r)}{(1+m(a+m_0b)*E_{avg}(r)} & \text{if node is advanced} \\ \frac{p_{opt} *(1+y)* E_i(r)}{(1+m(a+m_0b)*E_{avg}(r)} & \text{if node is super} \end{cases} \quad (5)$$

Now, threshold for cluster head selection is calculated as follows:

$$T(s_i) = \begin{cases} \frac{p_i}{1-p_i(r \bmod \frac{1}{p_i})} & \text{if } p_i \quad H' \\ \frac{p_i}{1-p_i(r \bmod \frac{1}{p_i})} & \text{if } p_i \quad H'' \\ \frac{p_i}{1-p_i(r \bmod \frac{1}{p_i})} & \text{if } p_i \quad H''' \end{cases} \quad (6)$$

Where H’ is the set of normal nodes that have not become cluster heads in the last 1/p_i rounds and s_i is the set of normal nodes. Similarly H’’ and H’’’ are sets of advanced and super nodes that have not become cluster heads in the last 1/p_i rounds.

V. METHODOLOGY

A. Performance Criteria Used

Performance criteria used to evaluate the performance are:

- Stability period: The round in which first node get dead.
- Lifetime: It is the maximum no of rounds in which nodes are alive.
- Number of dead nodes per round.
- Number of alive nodes per round.
- Throughput: This is no. of packets send per round from cluster heads to base station.

B. Algorithm

Input: Nodes

Output: No. of dead nodes, No. of alive nodes

Algorithm:

Step 1: Cluster head election is done according to the defined threshold T(i) depending upon the node.

Step 2: Node-cluster head communication is done.

Step 3: If current value of sensed data (CV) is greater than the hard threshold and CV differs from the effective sensed

value (SV) by an amount equal to or greater than the soft threshold, go to step 4 else go to step 5.

Step 4: Cluster head - base station communication is done.

Step 5: If time period between two successive counts greater than the Count Time (T_c), go to step 4 else go to step 6.

Step 6: Drop the packet and wait for further data.

Step 7: End of round.

VI. SIMULATION AND RESULTS

MATLAB is used for simulation. Simulation is performed for different cases by varying the proportion of normal, advanced and super nodes i.e. m and m_0. Also the energy levels of three types of nodes i.e. x and y are varied to test the results of the proposed protocol in various scenarios. Comparison of the performance of the proposed protocol PTEDEEC is done with the existing DEEC, DDEEC and EDEEC protocols. DEEC embeds the factor of residual energy in the heterogeneous environment. DDEEC introduces threshold residual energy and when energy level of advanced and normal nodes falls down to the limit of threshold residual energy then both type (normal and advanced) of nodes use same probability to become cluster head. EDEEC increased the heterogeneity level.

TABLE 1: List of Parameters

Parameters	Value
Area	100*100
BaseStation	(50,50)
No. of nodes	100
Rounds	10000
E_0	0.5J
E_{elec}	50nJ/bit
E_{fS}	10nJ/bit/m^2
E_{mP}	0.0013pJ/bit/m^4
p_{opt}	0.1
Hard Threshold	100
Soft Threshold	2

A. Case Studies

Following case studies have been enumerated. In case 1 and case 2, x and y are kept constant and values of m and m_0 are varied i.e. fractions of energy level of advanced and super nodes are kept constant and fraction of number of advanced and super nodes are varied. While in case 3 and case 4, m and m_0 are kept constant and values of x and y are varied.

TABLE 2: Case 1

x = 1.5 y = 3 m = 0.5 m_0 = 0.4	First Node Dead	Tenth Node Dead	Last Node Dead	Packets to the base station/round
DEEC	1118	1475	4536	12
DDEEC	1414	1710	3625	9
EDEEC	1423	1575	9689	35
PTEDEEC	3285	3810	10000+	32

TABLE 2: Case 2

x = 1.5 y = 3 m = 0.8 m_0 = 0.5	First Node Dead	Tenth Node Dead	Last Node Dead	Packets to the base station/round
DEEC	1138	1490	4688	11
DDEEC	1394	1680	3556	8
EDEEC	1425	1644	8925	45
PTEDEEC	3264	3778	10000+	40

TABLE 3: Case 3

x = 1.5 y = 2 m = 0.5 m_0 = 0.4	First Node Dead	Tenth Node Dead	Last Node Dead	Packets to the base station/round
DEEC	1187	1468	4600	11
DDEEC	1361	1752	3639	8
EDEEC	1359	1476	6618	30
PTEDEEC	3149	3532	10000+	31

TABLE 4: Case 4

x = 1.5 y = 2 m = 0.8 m_0 = 0.5	First Node Dead	Tenth Node Dead	Last Node Dead	Packets to the base station/round
DEEC	1214	1408	5017	11
DDEEC	1417	1636	3552	8
EDEEC	1390	1654	6765	35
PTEDEEC	3126	4181	10000+	40

B. Results

Simulation results have been shown for case 3 (Fig. 1-3) i.e. when x=1.5, y=2, m=0.5 and m_0=0.4. Fig. 1 shows the network stability i.e. the time when the first node dies in the network and also number of nodes dead during each round. It can be clearly seen that PTEDEEC has higher stability period as compared to the other protocols. Fig. 2 shows the network lifetime i.e. the time when the last node dies and also the number of nodes alive in each round. Clearly, PTEDEEC surpass all other protocols in terms of network lifetime also. Fig. 3 shows the throughput i.e. the number of packets sent to the base station in each round. PTEDEEC has almost same throughput as EDEEC in most of the cases. Throughput varies due to the hard and soft thresholds used in PTEDEEC. Hence proposed approach shows better results as compared to DEEC, DDEEC and EDEEC protocols.

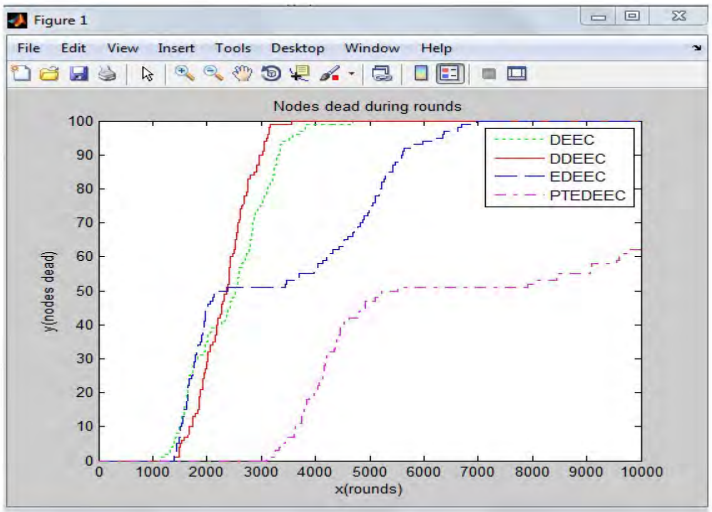

Fig. 1. Network stability (first node dead)

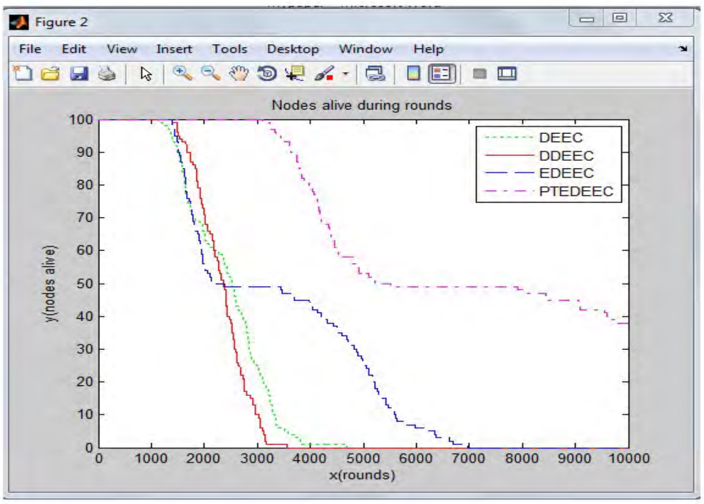

Fig. 2 Network lifetime (last node dead)

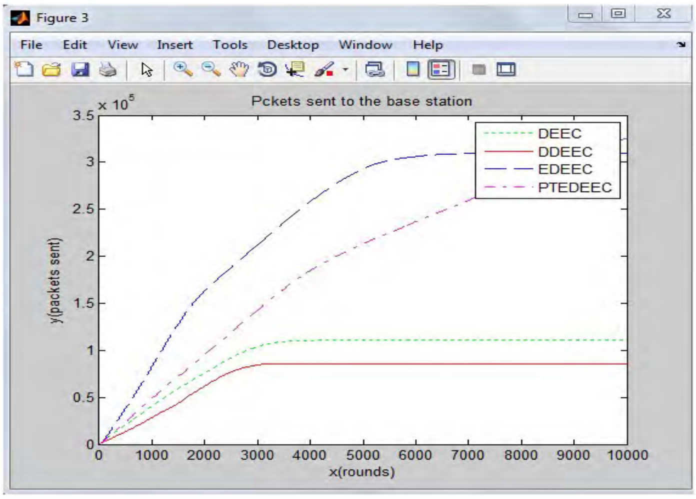

Fig. 3 Throughput (packets to BS/round)

VII. CONCLUSION

This paper presents an improved E-DEEC protocol (PTEDEEC) using the periodic and threshold-sensitive data transmission approach. Thus it is suitable both for reactive and proactive protocols. Simulation results show that proposed approach improved the stability, network lifetime and throughput of the EDEEC protocol.

VIII. REFERENCES

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