Performance Analysis of Cluster based Routing Protocols in Heterogeneous Wireless Sensor Network

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ABSTRACT
Increasing the network lifetime is considered as one of the major issue in wireless sensor network (WSN). The network lifetime can be increased with the introduction of the heterogeneity in sensor nodes. Many heterogeneous routing algorithms in WSN are proposed. In this paper, we have analyzed the performance of distributed energy efficient clustering algorithm (DEEC), developed distributed energy-efficient clustering algorithm (DDEEC), and energy efficient heterogeneous clustered scheme for WSN (EEHC) in terms of network lifetime and number of messages received by base station.

Keywords
WSN, heterogeneous WSN, clustering algorithm

1. INTRODUCTION
WSN contains thousands of tiny sensor nodes, whose main aim is to sense the environment and forward the sensed data to base station. Forwarding the sensed data to the base station is done on proactive or reactive basis depending on the application. Most of the clustering and chain based algorithm LEACH [1], LEACH-C [2], VR-LEACH [3], TL-LEACH [4], PEGASIS [5] assume WSN as homogeneous. Node heterogeneity is one of the major challenges in WSN [6].

2. RELATED WORK
Stable Election Protocol (SEP) is developed for the two level heterogeneous WSN as advance node and normal nodes [7]. Advance nodes are provided extra energy as compared to normal nodes. Probability of selecting CH is done based on node initial energy. SEP does not work with multi-level heterogeneity.

Distributed energy efficient clustering algorithm (DEEC) is developed for two level heterogeneous WSN as advance node and normal nodes [8]. It is also shown that it works well with multi-level heterogeneity.

Developed distributed energy efficient clustering algorithm (DDEEC) algorithm has modified the clustering scheme of DEEC algorithm [9].

Energy efficient heterogeneous clustered scheme for WSN (EEHC) worked on three types of sensor nodes normal nodes, advanced nodes and super nodes [10].

In [11], authors have reviewed and compared various energy-efficient clustering algorithms for heterogeneous WSN based on various parameters.

In [12], authors have presented a survey and compared various clustering protocols in WSN.

In [13], authors have presented a survey on various heterogeneous WSN routing protocols.

3. HETEROGENOUS WSN

3.1 Distributed energy efficient clustering (DEEC) algorithm
DEEC is a distributed energy efficient clustering algorithm for heterogeneous wireless sensor networks. It is developed for two level heterogeneity namely normal nodes and advanced nodes where 'm' number of nodes is equipped with 'a' amount of extra energy. In this algorithm, cluster heads are selected based on probability using the ratio between residual energy of each node and the average energy of the network. So the sensor node with higher remaining energy has more chance to be a cluster head. The probability where each sensor node, Si elects itself to be a cluster head in each round is given Eq. (1).

$$T(s_i) = \begin{cases} \frac{p_i}{(1-p_i\, r \bmod p_i)} & if\ s_i \in G \\ 0 & otherwise \end{cases} \quad (1)$$

Where p_i is,

$$p_i = \begin{cases} \frac{p_{opt}\, E_i(r)}{(1+am)\bar{E}(r)} & if\ s_i\ is\ normal\ node \\ \frac{p_{opt}\,(1+a) E_i(r)}{(1+am)\bar{E}(r)} & if\ s_i\ is\ advanced\ node \end{cases} \quad (2)$$

Where $E_i(r)$ denotes the remaining residual energy of a sensor node at round r and $\bar{E}(r)$ denotes the average energy of the network at round r.

3.2 Developed distributed energy-efficient clustering (DDEEC) algorithm
The probability where each sensor node elects itself to be a cluster head in each round is given in Eq. (1) and (3). Initially CH are selected from the advanced nodes, later when the energy of these nodes become equal to the normal nodes then the probability of selecting CH of these advanced nodes will be same as that of normal nodes.

Where p_i is

$$p_i = \begin{cases} \frac{p_{opt}\, E_i(r)}{(1+am)\bar{E}(r)} & \text{for nomal nodes, } E_i(r) > TH \\ \frac{p_{opt}\,(1+a)E_i(r)}{(1+am)\bar{E}(r)} & \text{for advance nodes, } E_i(r) > TH \\ c\,\frac{p_{opt}\,(1+a)E_i(r)}{(1+am)\bar{E}(r)} & \text{for normal and advance nodes , } E_i(\leq \text{TH} \end{cases} \quad (3)$$

Where TH is,

$$TH = E_0\left(1 + \frac{aE_{disNN}}{E_{disNN} - E_{disaN}}\right) \quad (4)$$

3.3 Energy efficient heterogeneous clustered scheme for WSN (EEHC)

EEHC worked on three types of sensor nodes normal nodes, advanced nodes and super nodes. There are N×m×mo number of super nodes used with β times more energy than the normal node. Where N represents the total number of nodes, m and mo are the fraction of the total number of nodes. The rest N×m×(1-mo) are number of advanced nodes which are equipped with α times more energy than the normal nodes; the remaining N×(1-m) are number of normal nodes. The probability where each sensor node elects itself to be a cluster head in each round is given in Eq. (1), (5), (6) and (7).

Where p_i is

$$p_n = \frac{p_{opt}}{(1+m\times(\propto+m_0\times\beta))} \quad (5)$$

$$p_a = \frac{p_{opt}}{(1+m\times(\propto+m_0\times\beta))} \times (1+\propto) \quad (6)$$

$$p_s = \frac{p_{opt}}{(1+m\times(\propto+m_0\times\beta))} \times (1+\beta) \quad (7)$$

4. SIMULATION RESULTS

In this section, we evaluate the performance of DEEC, DDEEC, and EEHC based on parameters like first node dead, last node dead and number of messages received at base station (To the best of our knowledge none of the work has shown the performance comparison between these three protocols). A WSN with heterogeneous sensor nodes are randomly distributed in 100×100 network field. The first order radio model parameters used in our simulation are given in Table 1 [1]. Based on the distance between transmitter and receiver, each sensor node consumes ETX amount of energy to transmit a l bit packet over a distance d and ERX amount of energy for receiving l bit packet as shown in Eq. (8) and Eq. (9) [1].

$$E_{Tx}(l,d) = \begin{cases} lE_{elec} + l\varepsilon_{fs}d^2, & \text{if } d < d_0 \\ lE_{elec} + l\varepsilon_{mp}d^4, & \text{if } d \geq d_0 \end{cases} \quad (8)$$

$$E_{Rx}(l,d) = lE_{elec} \quad (9)$$

Where E_{elec} is energy dissipated in circuit, ε_{fs} and ε_{mp} are free space and multipath fading channel parameter.

Table 1. Simulation parameters

Parameter	Value
Network Size	100×100 m
Sink node	(50,50)
Number of sensor nodes (N)	100
Percentage of cluster head	5%
EDA	5nJ/bit/message
ε_{fs}	10pJ/bit/m^2
ε_{mp}	0.0013 pJ/bit/m^4
E0	0.4J
m	0.4
m_0	0.4
$\propto$	1.5
β	3

4.1 Stability period

Stability period indicates the first node death (FND) which is the time interval where the first node in the network field depletes all of its energy and stability period is considered as a major measure of network lifetime.

Number of alive nodes per round is the number of sensor nodes which are not yet depleted all of its energy. Fig 1. shows the number of nodes alive in each consecutive round using DEEC, DDEEC and EEHC protocols. In this experiment, FND occurs at round 854, 1238 and 1118 using DEEC, DDEEC and EEHC protocols respectively.

4.2 Instability period

Instability period is the last node death (LND) which is the time interval where the last node in the network field depletes all of its energy.

If a sensor node is assigned a large sensing range then a single node can cover almost the whole area of the network field so instability period is also an important factor

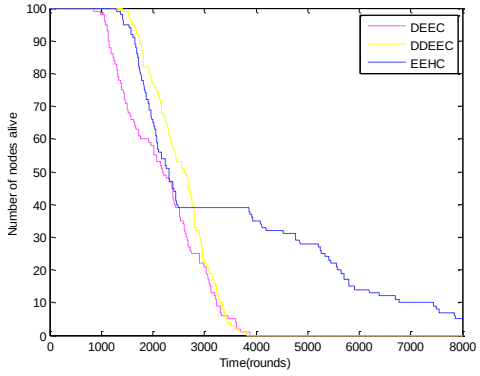

Fig 1: Number of alive nodes in DEEC, DDEEC and EEHC

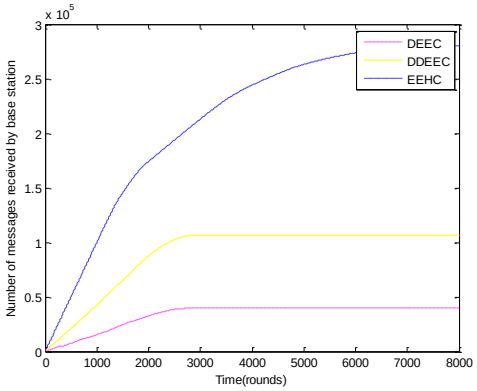

Fig 2: Number of messages received by base station DEEC, DDEEC and EEHC

The LND occurs at round 2797, 3224 and 7627 using DEEC DDEEC and EEHC algorithms respectively. So the instability period of EEHC has improved over DEEC by 172% and DDEEC by 136%.

4.2.1 Number of packets sent to sink node

Fig 2. shows that the total number of messages received by base station are 39619, 106861, and 279976 using DEEC, DDEEC and EEHC respectively. The number of packets sent to the sink node using EEHC has improved over DEEC by 606% and TDEEC by 162%.

Thus EEHC is more efficient in terms of increasing the network lifetime (LND) and number of packets received are high as compared to DEEC and DDEEC.

5. CONCLUSION

In this paper, routing protocols of heterogeneous WSN are discussed. In this paper, we have analyzed the performance of distributed energy efficient clustering algorithm (DEEC), developed distributed energy-efficient clustering algorithm (DDEEC), and energy efficient heterogeneous clustered scheme for WSN (EEHC) in terms of network lifetime and number of messages received by base station.

6. REFERENCES

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