Improved Developed Distributed Energy-Efficient Clustering Scheme (iDDEEC)

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Abstract:- Heterogeneous routing protocols are getting more attention in recent times due to the fact that, the protocols proved to be better than homogeneous routing protocols in terms of stability period and network lifetime. The sensor nodes used in designing these protocols have different battery energy and high processing ability. The cluster heads chosen in these protocols have higher residual energy than any other routing protocol. In this research work, the heterogeneous routing scheme, Developed Distributed Energy-Efficient Clustering scheme (DDEEC) for heterogeneous wireless sensor Networks was studied carefully. It was observed that, DDEEC protocol made some changes to average probability in DEEC protocol. The average probability now depends on the threshold residual energy value, $Threv$. This energy value makes the advanced and normal nodes to have the same probability of becoming cluster heads (CHs). However, it was realized that, distance factor was not considered in selecting the some of the advanced nodes. So distant advanced nodes will have to dissipate more energy to relay their data to the Base station. Also, unnecessary transmission of data to the Base station was noticed in this protocol which resulted into depletion of energy of the nodes hence affecting the lifetime of the network. In this paper, a new optimization scheme is proposed. The new algorithm, modified the average probability of advanced nodes whose residual energy is less than the $Threv$ to now depend on the average distance of the nodes from the Base station rather than the average energy of the network. Also, we implemented TEEN and different amplification energy levels in this protocol to conserve energy in the network. Simulation was conducted to evaluate the performance of the new scheme and the existing protocol using MatLab 2017a. The simulation results showed that, the proposed protocol performed better than the existing scheme in terms of throughputs, residual energy and network lifetime.

Keywords: *DDEEC Protocol; TEEN; Network Lifetime; Residual Energy; Different Amplification Energy; MatLab Simulation.*

I. INTRODUCTION

Wireless Sensor Network (WSN) can be explained as a system that is made up of thousands of sensor nodes developed to communicate wirelessly to each other. These nodes can collaborate with each other to monitor any hazardous environment, collect measurement data, and convey the report to another resourced node called the Base station. This kind of network does not require any fixed infrastructure and are also found useful in other areas such as health monitoring, home intelligence and many other areas [1]. However, these sensor nodes are battery operated and the rate at which energy of these batteries are depleted determines the lifetime of the network. One of major energy depletion factors that was discovered in this network is the radio communication [2]. This is the one of the main reason why designing of any routing protocol must be energy efficient. Base on the distribution of energy among the nodes, wireless sensor networks (WSNs) are categorized into heterogeneous and homogeneous networks [3]. The heterogeneous networks composed of sensor nodes with different abilities. They have more complex processing power and large memory space which enable them to execute complex algorithm better compare with the nodes in homogeneous networks. So when a heterogeneous sensor nodes are placed in the network, they enhance the throughputs and battery lifetime [4]. In literature, several heterogeneous and homogeneous routing protocols have been developed and here are few of them.

The results of Stable Election Protocol (SEP) has been discussed by Amaragdakis et al. [5]. The protocol relied on the weighted election probabilities of each node to be chosen as cluster head which also based on their respective energy. The scheme adopted two types of nodes namely, normal and advanced nodes where the advanced nodes have higher residual energy and have better chances of becoming cluster heads. Simulation showed that, SEP has improved the network life time.

Another heterogeneous routing protocol which elect cluster heads using the ratio between residual energy of each sensor node and average energy of the network, DEEC, has been presented by Qing et al.[6]. The two level nodes of DEEC is similar to that of SEP in terms of the type of nodes. The major challenge in this algorithm is the fact, the advanced nodes are usually punished when their energy drained to normal nodes levels.

Elbhiri et al.[7] developed energy efficient algorithm for heterogeneous networks which is based on DEEC protocol. The protocol, DDEEC, has been able to provide solution to the major problem identified in DEEC's scheme where the advanced nodes are penalized. However, the algorithm failed to take into account the distance between the Base station and each node in electing the cluster heads. Thus, this research work seek to enhance this particular protocol.

Another version of DEEC, EDEEC, has been presented by Saini et al. [8] for heterogeneous networks. The scheme considered three level of nodes based on their residual energy. The nodes with highest residual energy is super nodes, with the medium energy, advanced nodes and with lowest energy, normal nodes. The outcome of the experiment showed that, the scheme has been able to prolong the life time of the network compared to DEEC protocol.

Authors in [9] also described an enhanced version of DEEC protocol, TDEEC algorithm. The protocol adopted three types of nodes which are differed according to their residual energy and made slight changes to the probability function. The experimental results showed that, the scheme has enhanced the lifetime of the network significantly.

A reactive scheme, TEEN, which seek to regulate the rate of data transmission in wireless sensor network has been proposed by Manjeshwar and Agarwal [10]. The scheme introduced two thresholds namely, the hard and soft thresholds such that, the sensed data must meet the requirement of these thresholds before data can be transmitted to the Base station. This is to prevent unnecessary transmission of captured data by the sensor nodes.

Authors in [11] have explained an improved version of LEACH, MODLEACH for homogeneous networks. In this scheme, two important methods have been introduced. These are: the efficient cluster head replacement model and different amplification energy. The techniques introduced are to ensure that, if the residual energy of a cluster head is not exhausted it can be used in the next round and also to use different amplification energy levels in transmitting data within inter-cluster, intra-cluster and cluster head to sink communications.

We applied the TEEN algorithm to control data transmission and also implemented different amplification energy levels to conserve energy during inter and intra cluster communications and communication between cluster heads and the Base station.

The remainder of this research is organized as follows: **Section 2** described the methodology used, simulation results are discussed in **Section 3** and conclusion is then drawn in **Section 4.**

II. METHODOLOGY

In this section, we explained both the existing protocol and the proposed protocol.

A. The Existing DDEEC Protocol

DDEEC protocol operates similar to the technique implemented in DEEC scheme especially in calculating the average energy of the networks, $\bar{\boldsymbol{E}}(\boldsymbol{r})$, and average probability algorithm used in choosing the cluster heads. The protocol provided a solution to the challenge found in DEEC algorithm. This challenge arises when the residual energy, $\boldsymbol{E_i}(\boldsymbol{r})$, of both the advanced and normal nodes at a point in time are the same. The advanced nodes are discriminated against and continuously being punished more than the normal nodes. This deplete the energy of the advanced nodes which results into early death of the nodes. So DDEEC protocol solved this challenge by introducing a threshold residual energy value, Th_{REV} which the average probability now depends on in selecting the cluster heads. The average probability proposed in DDEEC is given by (1)

$$Pi = \begin{cases} \frac{p_{opt}\, E_i(r)}{(1+am)\bar{E}(r)} \; for\ normal\ nodes, \boldsymbol{E_i}(\boldsymbol{r}) > Th_{REV} \\ \frac{(1+a)p_{opt}\, E_i(r)}{(1+am)\bar{E}(r)} \; for\ normal\ nodes, \boldsymbol{E_i}(\boldsymbol{r}) > Th_{REV} \\ c\frac{(1+a)p_{opt}\, E_i(r)}{(1+am)\bar{E}(r)} \; for\ normal\ nodes, \boldsymbol{E_i}(\boldsymbol{r}) \le Th_{REV} \end{cases} \quad (1)$$

Where c is a reel positive variable which manages directly the clusters in the network and the value of Th_{REV} is given as $Th_{REV} = bE_0$, where $b \in [0,1]$

B. Proposed iDDEEC Protocol

The proposed scheme, iDDEEC also works similar to the existing protocol, DDEEC in terms of choosing cluster head (CH). However in iDDEEC algorithm, the cluster heads are selected according to the residual energy level of the nodes with respect to average energy of the network for normal nodes and advanced nodes whose $\boldsymbol{E_i}(\boldsymbol{r}) > Th_{REV}$. The average energy of the network for the advanced nodes whose $\boldsymbol{E_i}(\boldsymbol{r}) \le Th_{REV}$ have been replaced with average distance, $\bar{\boldsymbol{D}}(\boldsymbol{av})$ of the nodes from the Base station. This introduced distance factor in selecting some of the advanced nodes in the network. When this factor is taking into account, those advanced nodes which may meet the requirement of Th_{REV} , and are also closer to the Base station will have a better chance of becoming cluster heads than advanced nodes which may be far from the Base station. So the new average probability is given by (2).

$$Pi = \begin{cases} \frac{p_{opt}\, E_i(r)}{(1+am)\bar{E}(r)} \; for\ normal\ nodes, \boldsymbol{E_i(r)} > \ Th_{REV} \\ \frac{(1+a)p_{opt}\, E_i(r)}{(1+am)\bar{E}(r)} \; for\ normal\ nodes, \boldsymbol{E_i(r)} > \ Th_{REV} \\ c\,\frac{(1+a)p_{opt}\, E_i(r)}{(1+am)\bar{D}(av)} \; for\ normal\ nodes, \boldsymbol{E_i(r)} \le \ Th_{REV} \end{cases} \quad (2)$$

Also, the technique introduced by [11] has been used in this protocol to manage and control the unnecessary transmission of information to the Base station by the sensor nodes. Furthermore, the method suggested by [10] has been implemented to reduce energy expenditure as a result of inter and intra cluster communication and that of CH and BS in this protocol and it is given by (3)

$$\begin{cases} \boldsymbol{kE_{elect} + k\epsilon_{\frac{fs}{10}} d^2 ,\ if\ \ d > d_1} \\ \boldsymbol{kE_{elect} + k\epsilon_{\frac{mp}{10}} d^4, if\ d \le d_1} \end{cases} \quad (3)$$

Where $\boldsymbol{d} = \sqrt{\frac{\text{Efs}}{\text{Emp}}}$ and $\boldsymbol{d_1} = \sqrt{\frac{\text{Efs1}}{\text{Emp1}}}$ given that $\text{Efs1} = \frac{\text{fs}}{10}$ and $\text{Emp1} = \frac{\text{mp}}{10}$

III. SIMULATION RESULTS AND ANALYSIS

To measure the effectiveness of our iDDEEC protocol and existing scheme DDEEC, we used MatLab 2017a for simulation. In this experiment, a random network of 100 nodes is used in 100m x100m square area and the Base station was installed outside the field (50m, 150m) unlike the DDEEC scheme. The values of c and b are respectively 0.02 and 0.07. Other parameters used in the simulation are shown in the Table1.

S/N	Parameter	Values
1	E_{elect}	50nJ/bit
2	E_{fs}	10pJ/bit/m^2
3	E_{mp}	0.0013pJ/bit/m^2
4	E_0	0.5J
5	Message size, k	4000
6	n	100
7	p_{opt}	0.1
	E_{DA}	5nJ/bit/message

Table 1:- Simulation Parameters

Fig. 1 displays the number of alive nodes during each transmission round for the iDDEEC and DDEEC routing schemes. From the graph, it can be seen that, the network life time is enhanced significantly in iDDEEC compared to DDEEC. Nodes survived up to 3900 rounds in DDEEC and remain active up to 7000 rounds in iDDEEC. This shows that, nodes remain active for longer time in iDDEEC and hence better lifetime than DDEEC routing protocol. The longer lifetime of the new algorithm is as a result of the energy conserving techniques that was implemented in this protocol. The prevention of regular transmission by the TEEN algorithm, control of energy during inter and intra cluster communication and election of some advanced nodes based on their distance to the Base station.

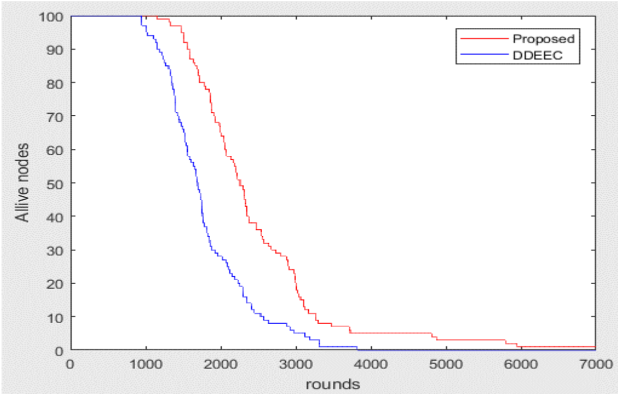

Fig. 1:- Number of the Alive Nodes per Round

Fig. 2 shows the number of dead nodes during each round in both routing protocols. It was noticed that the death rates in iDDEEC is lesser compare to that of DDEEC as seen in fig. 2. As early as 4000 rounds all the nodes are dead in case of DDEEC while in iDDEEC, it is after 7000 round that all the nodes vanished as shown in fig. 2. This again shows that the proposed algorithm has effectively minimized the number of dead nodes thereby resulted into better stability period and the network lifetime in new protocol.

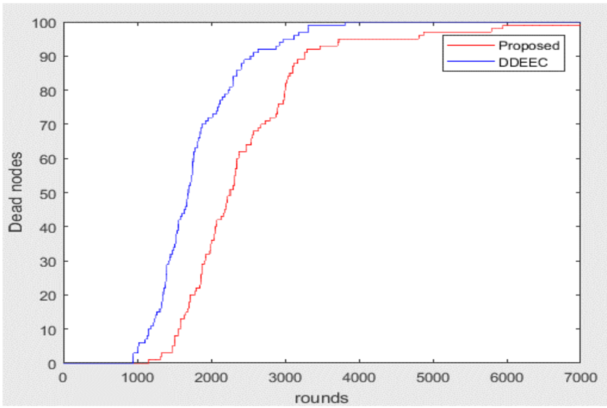

Fig. 2:- Number of the Dead Nodes per Round

Fig. 3 also shows the quantity of data sent to the BS per round in both iDDEEC and DDEEC protocols. It can be observed that, the quantity of data sent to the BS by the existing protocol increases from 0 to less than 20000 and remains constant throughout the simulation period. Thus sending small amount of data to the BS. In the new scheme, large amount of data was conveyed to the BS which is more than 20000. This performance is as result of the average distance factor that was considered in electing some of the advanced nodes as cluster heads. Some of the advanced nodes which are closer to the BS are elected as the Cluster heads. These nodes used less energy to transmit data to the BS. So they transmit more data with less energy consumption.

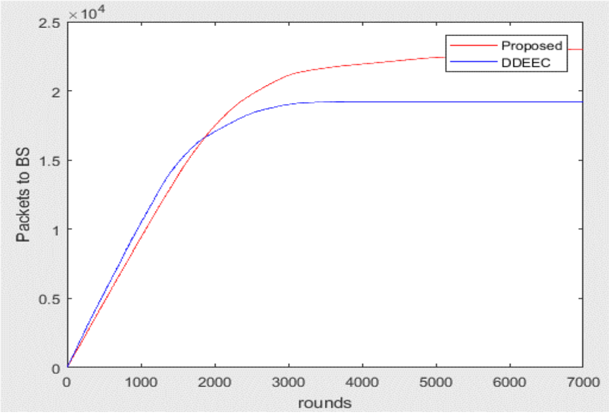

Fig. 3:- Number of Packet to the BS per Rounds

Fig. 4 shows energy dissipation of the network in both routing protocols. Though the two protocols decreased linearly, DDEEC drained its energy before 200 rounds. iDDEEC on the other hand exceeded 200 rounds before its energy was exhausted as seen fig. 4. This shows that iDDEEC consumes less energy in transmitting its data to the BS.

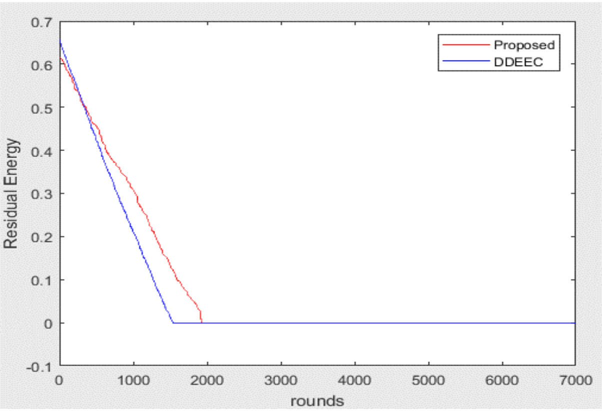

Fig. 4:- Remaining Energy per Round

IV. CONCLUSION

In this article, a heterogeneous protocol called improved DDEEC (iDDEEC) is proposed. In the new protocol, the average probability of the advanced nodes whose residual energy is less than the threshold residual energy value has been modified to consider the average distance of the nodes in the network from the Base station rather than average energy of the network as suggested in DDEEC. This makes such advanced nodes with high residual energy and also closer the BS to have better chance of becoming heads. As a result, it has reduced the energy consumption in those advanced nodes which has also led to better throughputs and longer lifetime of the network. Furthermore proposed protocol utilized 1) the different amplification energies to conserve energy during inter and intra cluster communications and 2) soft and hard thresholds to control the wastage of energy as a result of unnecessary transmission of data. All have also resulted into longer lifetime of the network. So, we can conclude that iDDEEC is more effective and efficient than DDEEC in terms of stability period, throughputs and network lifetime.

REFERENCES

[1]. [C. Fu, Z. Jiang, W. Wei and A. Wei, “An Energy Balanced Algorithm of LEACH Protocol in WSN”, IJCSI International Journal of Computer Science Issues, Vol. 10, Issue 1, No 1, 2013, pp. 354-359

[2]. V. Raghunathan, C. Schurgers, S. Park and M. B.Srivastava, “Energyaware Wireless Microsensor Networks”, IEEE Signal Processing Magazine,Vol. 19, Issue 2, 2002, pp. 40-50.

[3]. L. J. Jeevan P. Mangalore, and D. H K. Manjaiah, “Modified Distributed Energy Efficient Clustering Routing Protocol for Wireless Sensor Networks”, *International Journal of Computer Applications (0975 – 8887) Volume 81 – No 19, 2013* , PP. 38-42

[4]. M. Yarvis, N. Kushalnagar and H. Singh,. A. Rangarajan†, Y. Liu†, S. Singh Exploiting heterogeneity in sensor networks, IEEE INFOCOM, 2005,pp. 1-14.

[5]. G. Smaragdakis, I. Matta, and A. Bestavros, “SEP: A stable election protocol for clustered heterogeneous wireless sensor networks”, Proc of the Int’l Workshop on SANPA, 2004, pp. 251-261.

[6]. L. Qing, Q. Zhu,., and M. Wang, “Design of a distributed energy-efficient clustering algorithm for heterogeneous wireless sensor networks”, Computer Communications, vol. 29, no.12, 2006, pp.2230-2237.

[7]. B. Elbhiri, R, ,Saadane, S. El Fkihiand and D. Aboutajdine, “Developed Distributed Energy-Efficient Clustering (DDEEC) for heterogeneous wireless sensor networks”, I/V Communications and Mobile Network (ISVC), 5th International Symposium on, vol., no., 2010, pp.1-4

[8]. P. Saini and A. K. Sharma, “E-DEEC- Enhanced Distributed Energy Efficient Clustering Scheme for heterogeneous WSN”, 1st International Conference on Parallel, Distributed and Grid Computing,2010, pp. 205-210

[9]. P. Saini, and A. K. Sharma, “Energy Efficient Scheme for Clustering Protocol Prolonging the Lifetime of Heterogeneous Wireless Sensor Networks”, International Journal of Computer Applications 6(2),2010, pp. 30-36.

[10]. D. Mahmood, N. Javaid,, S. Mehmood, S. Qureshi, A.M. Memon., and , T. Zaman,” MODLEACH: a variant of LEACH for WSNs”26th IEEE Canadian Conference on Electrical and Computer Engineering (CCECE2013)”, Regina, Saskatchewan, Canada, 2013, pp. 1-6.

[11]. A. Manjeshwar and D. P. Agarwal, "TEEN: a routing protocol for enhanced efficiency in wireless sensor networks", In 1st International Workshop on Parallel and Distributed Computing Issues in Wireless Networks and Mobile Computing, 2001, pp. 2009-2015.