Distance-Distributed Energy Efficient Clustering (D-DEEC) routing protocol for wireless sensor network

.

ABSTRACT

A wireless sensor network (WSN) composed of many tiny devices that rely on energy efficient routing protocols for extension of their lifetime. *Many cluster-based routing protocols have been proposed based on heterogeneity in recent times. Indeed, these protocols are aiming at achieving energy efficiency, throughputs and better lifetime of the networks. However, two important factors that could have helped some of these protocols to achieve the above-mentioned aims are really missing. Factors such as the distance and average distance between nodes and the Base Station (BS) in selecting a cluster head needed to be considered. These were the major challenges that were identified in the Distributed Energy Efficient Clustering (DEEC) protocol after careful study. As a result, the throughputs and the lifetime of the scheme were affected. In this paper, a* reviewedhierarchy-based heterogeneous routing protocol *called Distance-DEEC (D-DEEC) is proposed to enhance the DEEC protocol. The new algorithm took into account the residual energy, distance of the individual nodes and average distance of all the nodes from the BS in selecting the Cluster Heads (CHs). This has allowed the protocol to select a cluster head that has high residual energy, is closer to the BS and at the same time not too far from its neighbours. The scheme also employed the sleep and awake approach to reduce energy dissipation. The technique allows the Base BS to calculate the maximum energy of distant nodes and determines when such nodes can transmit their report based on a given threshold energy,* E_{th}*. The performance of the proposed algorithm was evaluated using MatLab R2018a and the outcomes showed that, D-DEEC protocol outperformed TDEEC in terms of energy consumption, throughputs and the network lifetime.*

.

Keywords*:* D-DEEC, Distance, Energy Consumption, *neighbours*, Sleep and Awake,

1. INTRODUCTION

A wireless sensor network (WSN) consists of spatially distributed tiny devices called sensor nodes which cooperatively monitor physical environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants, at different locations [1]. These nodes collect data about the environment where they are deployed and convey the report directly or indirectly to an external node called a Base Station (BS) for further examination [2]. These tiny devices rely on batteries for energy and can be recharged and even replaced. However, charging and replacing these batteries in a hostile environment will be practically impossible. Therefore, the efficient use of the limited resources of the tiny devices always helps to enhance the performance of the network [3].

Heterogeneous routing protocols have been proven to perform better than homogeneous routing schemes [4]. In these protocols, higher-energy nodes (advanced nodes) which are mostly the Cluster heads (CHs) are used to receive, aggregate and transmit information to the BS, while low-energy nodes (normal nodes) are used to sense and collect data from the environment. The collected data is relayed to the higher-energy nodes for onward submission to the BS. Some of the protocols proposed in these networks pay much attention to the residual energy of the nodes in selecting the head but fail to consider their distance to the BS. A node having higher residual energy helps a lot but if its distance from the BS is far, then its outcomes may not be appreciated. It is against this background that, this research paper presents an enhanced form of DEEC protocol.

In literature, several heterogeneous routing protocols have been proposed for WSNs. A few of them are explained below:

Authors in [5] presented an advanced form of DEEC called Developed Distributed Energy-Efficient Clustering (DDEEC) for heterogeneous wireless sensor networks. The scheme failed to incorporate distance factors in choosing the cluster managers. The work is similar to what was proposed in [6]. This protocol described the Enhanced Distributed Energy Efficient Clustering Scheme (EDEEC), for heterogeneous WSN. The scheme introduced super nodes to enhance the lifetime of the network but the gap between the nodes and the BS was not considered in selecting the heads.Threshold Distributed Energy Efficient Clustering (TDEEC) has been explained in [7]. The algorithm employed three levels of nodes with a modified probability function. The gap between nodes was not taken into account in coming out with the heads. Authors in [8] described Enhanced Developed Distributed Energy-efficient Clustering (EDDEEC) for Wireless Sensor Networks. The protocol is a merger of E-DEEC and DDEEC protocols but failed to address selecting heads based on distance from the BS. This challenge is similar to what was proposed in [9]. The scheme explained the Improved Developed Distributed Energy-Efficient Clustering (iDDEEC**)**algorithm. It modified the average probability of advanced nodes whose residual energy is less than the threshold residual energy value, $\boldsymbol{Threv}$. However, no distance between the nodes and the BS was considered. In [10], the authors proposed a heterogeneous form of Modified Low Energy Adaptive Clustering Hierarchy, Servant-MODLEACH (S-MODLEACH). The algorithm uses three levels of nodes namely, advanced, servant and normal nodes. The protocol chooses CHs based on their residual energy without considering the distance between the nodes and the BS. An enhanced form of Threshold Distributed Energy Efficient Clustering protocol (TDEEC) has been described in [11]. The new algorithm, Gateway based-TDEEC, introduced a gateway node in the middle of the sensing area and then installed the BS far away from the sensing field. The CHs relay their data to the gateway which will then aggregate the data and then send the final report to the BS. It, however, failed to consider the distance factor in choosing the heads. Researchers in [13] explained the Stable Election Protocol (SEP) for heterogeneous wireless sensor networks. The scheme uses the weighted election probabilities of each node as criteria to choose a cluster head which also depends on their respective energy. SEP utilizes two types of nodes, the normal and advanced nodes. The normal nodes have the lowest energy compared to advancednodes. The simulation results showed that the SEP protocol has extended the lifetime of thenetwork. Considering the literature reviewed, it is clear that taking into account, the distance of the nodes from the BS in choosing the CHs has not been given the needed attention. Factors such as the distance of individual nodes and the average distance of the nodes from BS can help reduce energy dissipation, delay in data transmission and reduce signal attenuation as a result of the interference.

An improved form of E-DEEC has been proposed by the author in [14]. iE-DEEC modified the election probability of the protocol in [6] by taking into account the distance ofsuper-nodes and the average distance of all the nodes to the BS in selecting the CHs. The scheme also introduced different amplification energy levelsto minimize the energy consumption during the communications between the CHs and BS and also within inter and intra clusters.

MatLab 2017a was used for simulationto evaluate the effectiveness of the scheme. The simulationresults showed that the proposed protocol performed betterthan E-DEEC in terms of throughputs, residual energy andnetwork lifetime. Jibreel (15) discussed an extended form of Threshold Stable Election Protocol called eTSEP has been proposed. The new scheme introduces the distance and residual energy into the election probabilities of each level of the nodes. This allows nodes with high residual energy and closer to the BS to stand a better chance of becoming a cluster head. The performance of the scheme was evaluated using MatLab 2017a and compared with TSEP. The simulation results showed that, the new protocol performed better than TSEP in terms of throughputs, residual energy and the network life time. Jibreel et al. (16) presented a Gateway- Stable ElectionProtocol(G-SEP). The G-SEP scheme modified the electionprobability of selecting the CHs by considering thedistance, average distance and residual energy of the advancednodes. The algorithm further introduced a gateway node at themiddle of the network and then installed the BS outside thefield. Simulation results using MatLab R2017a showed thatthe G-SEP performs better than Zonal-Stable Electionprotocol (ZSEP) in terms of coverage, stability period,throughput and network lifetime.

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

2. MATERIAL AND METHODS / EXPERIMENTAL DETAILS / METHODOLOGY

In this section, both the existing and the proposed protocols are explained

2.1 The Existing DEEC Protocol

Authors in [12]proposed the Distributed Energy Efficient Clustering Protocol (DEEC) protocol. The scheme is a cluster-based method for both multi-level and 2 level-energy heterogeneous wireless sensor networks. In the two (2) level energy heterogeneous network, two kinds of nodes are used: normal nodes and advanced nodes. The CHs are elected by probability based on the ratio between the residual energy of each node and the average energy of the network. The nodes with high initial and residual energy (mostly advanced nodes) have a better chance of being selected as CHs than the low-energy nodes. This makes DEEC have a better stability period and also efficient in prolonging the network lifetime in heterogeneous settings. In DEEC protocol, the average probability (P_i), for both the normal node and the advanced node is given by Equations (1) and (2) respectively.

$$\boldsymbol{P_i} = \frac{P_{opt}E_i(r)}{(1+a*m)\bar{E}\,(r)}; \quad (1)$$

$if \;\; s_i \; is \; the \; normal \; node$

$$\boldsymbol{P_i} = \frac{P_{opt}(1+a)\,E_i(r)}{(1+a*m)\bar{E}\,(r)\,)}; \quad (2)$$

$(if \;\; s_i \; is \; the \; advanced \; node$

Where $\boldsymbol{p_{opt}}$ is reference value of average probability $\boldsymbol{p_i}$,$\boldsymbol{a}$, is a constant and $\mathbf{m}$is the percentage of nodes which are considered as advanced nodes. In homogenous networks, all sensor nodes have the same initial energy so they use $\boldsymbol{p_{opt}}$ to be the reference energy for probability, $\boldsymbol{p_i}$. However, in heterogeneous networks, the value of $\boldsymbol{p_{opt}}$ is different and it is based on the initial energy of the sensor node.

Also, the average energy $\bar{E}$ (r) of the network for any round r is given by Equation (3)

$$\bar{\boldsymbol{E}}\,(\mathbf{r}) = \frac{1}{N}E_{total}\left(1-\frac{r}{R}\right) \quad (3)$$

R denotes the total rounds of network lifetime and is calculated using Equation (4)

$$\boldsymbol{R} = \frac{E_{total}}{E_{round}} \quad (4)$$

$E_{(total}$ is the total energy of the network where $E_{(round\ )}$ is energy dissipated during each round.
Assuming p_i is the average probability of each sensor node s_i to become cluster head in a round. During each round, each sensor node chooses a random number between 0 and 1. If the number is less than the threshold as defined in Equation (5) below, the node is eligible to become a CH else not.

$$T(s_i) = \begin{cases} \frac{p_i}{1-p_i[rmod\frac{1}{p_i}]} & if\ s_i \in G \\ 0 & otherwise \end{cases} \quad (5)$$

Where G is the set of sensor nodes eligible to become CH at round r.

Drawback in DEEC

Sensor nodes in most cases are randomly distributed in the deployment areas. These nodes will either be closer or very far from the BS. This makes distance an important factor in selecting CHs. The DEEC protocol, however, considered the residual energy of the nodes in selecting the heads. The effects are that, **i)** the head dissipates a huge amount of energy in conveying its report to the BS **ii)** the report delays before reaching the BS **iii)** the signals are affected by other interference and therefore may not reach the BS and **iv**) because of the head's signal strength, some of the nodes are compelled to send their data to the distant head for onward transmission to the BS. These nodes deplete so much energy. As a result, the throughputs and the lifetime of the network in DEEC algorithm are affected. Figure 1 illustrates this point.

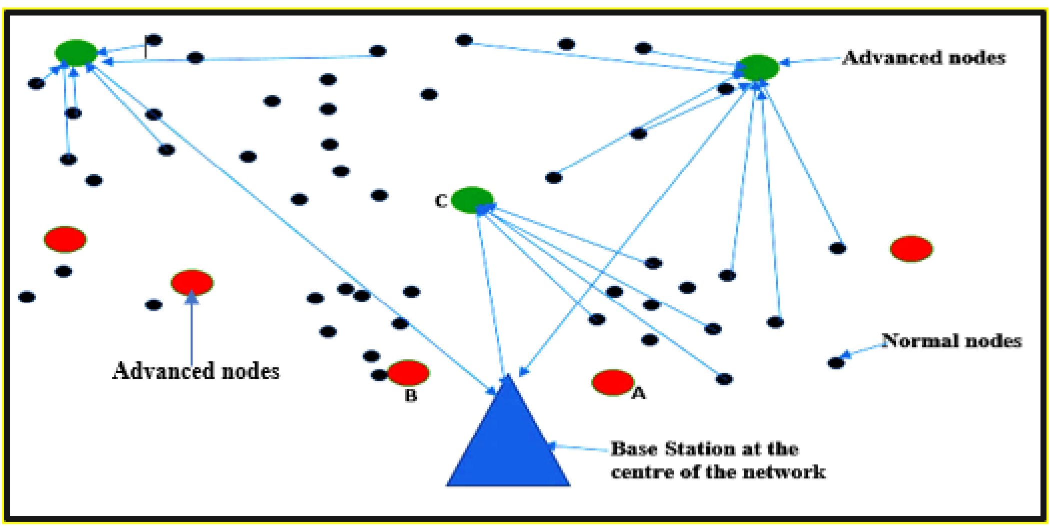

Fig. 1: DEEC protocol

Figure 1 shows a network where only the residual energy of the node is considered. For instance, when the advanced nodes (nodes with green colours) are chosen as CHs, the distant nodes are compelled to transmit their data to the distant cluster head because of its high received signal strength. This depletes a huge energy of the nodes. The chosen heads, due to the long transmission distance, also waste a lot of energy to convey the final report to the distant BS. As a result, the throughputs and lifetime of the network are affected.

2.2 Proposed Protocol

The proposed protocol, Distance-DEEC (D-DEEC), implements a similar concept as in DEEC in terms of cluster formation. However, the election probabilities of the protocol have been modified. D-DEEC introduced the ratio of two important factors which are the distance between each node $d_{(il}$ and the BS to the total average distance between all the nodes and BS. In this case, the advanced nodes which have high residual energy and are closer to the BS will have a better chance of becoming CHs than those which are far from the destination node. This has reduced the energy depletion, the death rate of the nodes and extend the lifetime of the network work as a whole. Figure 2 illustrates this point.

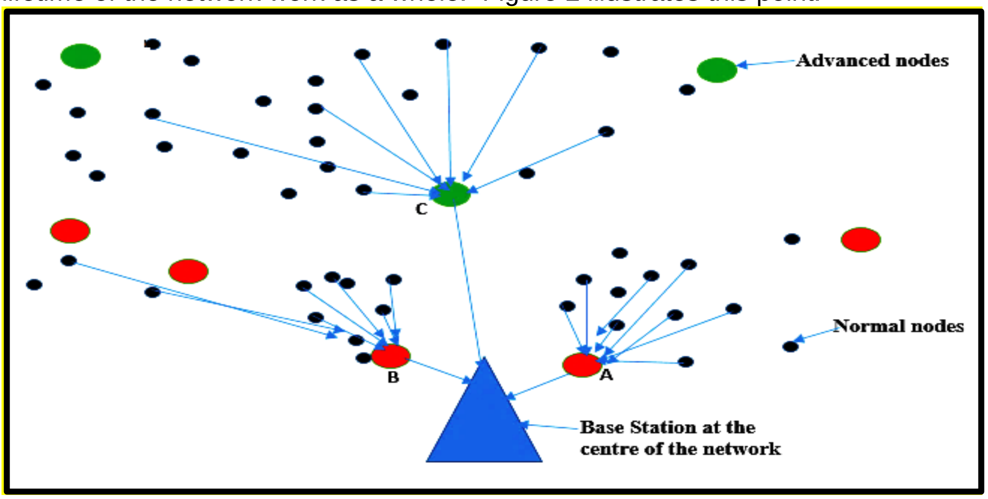

Fig. 2: Proposed Scheme (D-DEEC Protocol)

In Figure 2, A, B, and C are advanced nodes that are chosen as the CHs because, they have high residual energy, are closer to the BS and at the same time not far from their neighbours. The CHs which are far from the BS are allowed to transmit based on the sleep and awake technique. The technique allows the BS to check and calculate the energy required by the distant CHs to transmit their report to the BS. If the energy level of the CH is greater or equal to the given energy threshold, E_{th} then the head transmits its data to the BS else it will move into sleep mode to conserve energy. The energy threshold, E_{th} suggested in [17] is given by Equation (6).

$$\boldsymbol{E_{th}} = ((\boldsymbol{E_{TX}} + \boldsymbol{E_{DA}}) * \boldsymbol{k} + \boldsymbol{E_{amp}} * \boldsymbol{k} * \boldsymbol{d^4}) \quad (6)$$

Where $\boldsymbol{E_{TX}}$, the energy consumed in the $\boldsymbol{k}$ -bit message transmission over a distance, $\boldsymbol{d}$, $\boldsymbol{E_{DA}}$, the energy consumed in data aggregation and, $\boldsymbol{E_{amp}}$ is the energy dissipation in the power amplifier,

With this approach, energy is conserved by the heads, the nodes and throughput are also enhanced.

The new election probabilities of the normal and advanced nodes are given by Equations (7) and (8) respectively.

$$\boldsymbol{P_i} = \frac{P_{opt}\, E_i(r)}{((1+a*m)\bar{E}\,(r))} * \frac{d_i}{D_{avg}} \quad (7)$$

Where d_i is the distance of individual nodes from the BS and D_{avg} is the average distance of all nodes from the BS.

$$\boldsymbol{P_i} = \frac{P_{opt}(1+a)\, E_i(r)}{(1+a*m)\bar{E}\,(r)\,)} * \frac{d_i}{D_{avg}} \quad (8)$$

The average distance which is obtained from Equation (2) is given by using Equation (9)

$$\boldsymbol{D_{avg}} = \frac{1}{n}\sum_i^n \boldsymbol{d_i} \quad (9)$$

Each non-cluster-coordinator used energy in relaying $\boldsymbol{k}$-bits data to the cluster head (CH) and is given by Equation (10).

$$\boldsymbol{E_{non-CHd}} = \boldsymbol{E_{TX}}(\boldsymbol{k}, \boldsymbol{d_{to\ CH}}) \quad (10)$$

where $d_{to\ CH}$ is the intervals from the non- CHs to the CH.

The total energy spent by each cluster-manager in reporting k-bits data to the BS is given by Equation (11)

$$E_{CHd} = \left(\frac{n}{c} - 1\right) kE_{elect} + E_{TX}(k, d_{to\ BS}) \quad (11)$$

where $d_{to\ BS}$ is the intervals from the CH to the BS, n is the number of nodes, c is the number of clusters in the network and E_{elect} is the energy used due to running of radio electronics

The energy used in a group per round is given by Equation (12).

$$E_{cluster}\ d \approx \left(\frac{n}{c} - 1\right) E_{non-CHd} + E_{CHd} \quad (12)$$

The total energy spent by the system is given by Equation (13).

$$E_{total} = cE_{cluster}\ d$$

$$E_{total} = c\left(E_{TX}\left(k, d_{to\ CH}\right) + kE_{elect}\left(\frac{n}{c} - 1\right) + k\frac{n}{c}E_{DA} + E_{TX}\left(k, d_{to\ BS}\right)\right) \quad (13)$$

Therefore, the proposed scheme that gives less energy dissipation in transmitting data to the BS in D-DEEC is given by Equations (7), (8) and (13).

Algorithm : selection of cluster head(CH) and data transmission

step 1: *for all the nodes in N, BS do*

– *N is the number of nodes in the network*

step 2: *choose CH from heterogeneous nodes*

step 3: *compute* d_i *and* D_{avg}

step 4: *if* $d_i < d_{max}$ *and* $D_{avg} < D_{max}$ *and* $E_i(r) > E_{max}$ *then*

d_{max} *is the maximum distance of nodes from the BS and*

E_{max} *is the maximum energy of nodes*

D_{max} *is the maximum average distance of all the nodes from the BS*

step 5: *compute CH using Equation* (8)

step 6: *send Data to BS*

step 7: *else*

step 8: *apply sleep and wake technique*

step 9: *if* $E_i(r) > E_{th}$, E_{th} *is the minimum energy threshold*

step 10: *CH is in active mode, send Data to BS*

step 11: *else*

step 12: *CH is in sleep mode, do not send data to BS*

3. RESULTS AND DISCUSSION

In this section, the performance of TDEEC and the proposed routing protocol D-DEEC for heterogeneous wireless sensor networks are evaluated using MATLAB R2018a. The experiment performed consisted of 100 nodes randomly deployed in a field of dimension 100m x 100m and a BS located away from the centre. All nodes are stationary after deployment and energy loss due to signal collision and interference between signals of different nodes is ignored. Table 1 defines the Simulation Parameters used in this research work.

Table I: Simulation Parameters

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,	4000
6	n	100
7	p_{opt}	0.1
	E_{DA}	5nJ/bit/message

Network performance parameters taken for analyses were as follows:

i. Network Lifetime
ii. Stability Period
iii. Packets to BS
iv. Residual energy

Figure 3 below shows the number of alive nodes during simulation per round in TDEEC and D-DEEC routing protocols. From the graph, it was observed that the network lifetime was enhanced significantly in D-DEEC compared to TDEEC. Nodes were alive up to 3800 rounds in TDEEC whilst remaining alive up to 5100 rounds in D-DEEC. This means that in D-DEEC scheme, more alive nodes stayed longer than in TDEEC routing protocol hence making the proposed protocol have a better life time than the existing scheme. This is as a result of the distance factor that was taken into account in selecting the CHs. The nodes with greater residual energy and closer to their neighbours as well as to the Sink conserved energy better than the nodes that far and also far from their neighbours. The sleep and awake technique for distance nodes has helped in improving the lifetime of the network.

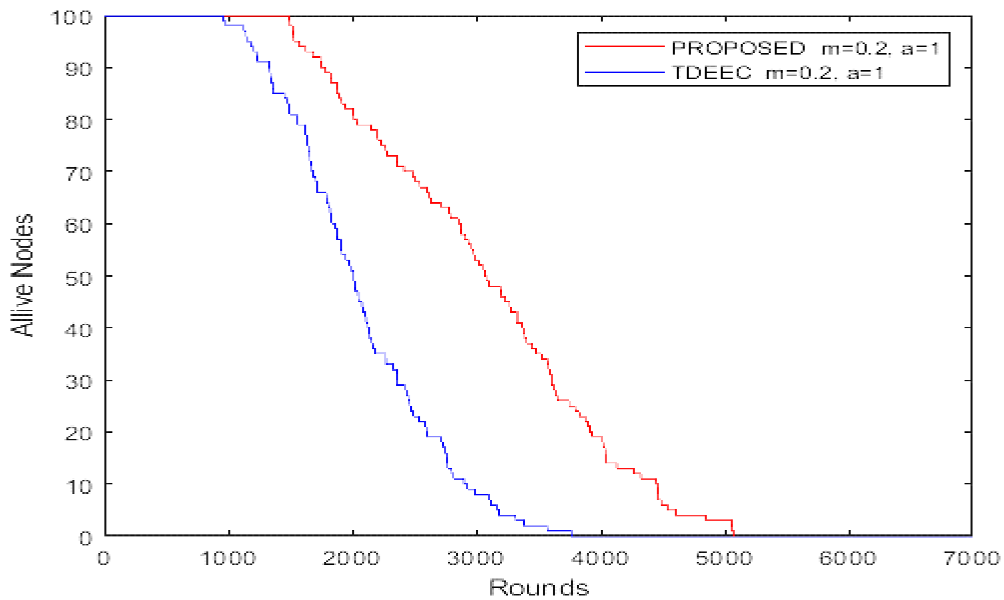

Fig. 3: Number of Alive Nodes per round

Figure 4 also shows the number of dead nodes per round in TDEEC and D-DEEC routing protocols. It was noticed from Figure 4 that the proposed routing protocol has a slight better stability period than the TDEEC protocol. That is, the first node dies at 1000 rounds in TDEEC whilst in D-DEEC scheme, it vanished at 1500 rounds which is 60% improvement of the exiting protocol. Also, all the nodes are dead at 3800 rounds in TDEEC while in D-DEEC, all the nodes died out at 5100 rounds which also constitute 57% enhancement of the existing schemeas shown in Figure 4. This indicates that, the new scheme has effectively minimized the death rate of nodes. This resulted into a lengthier lifespan of the system noticed in the D-DEEC routing scheme.

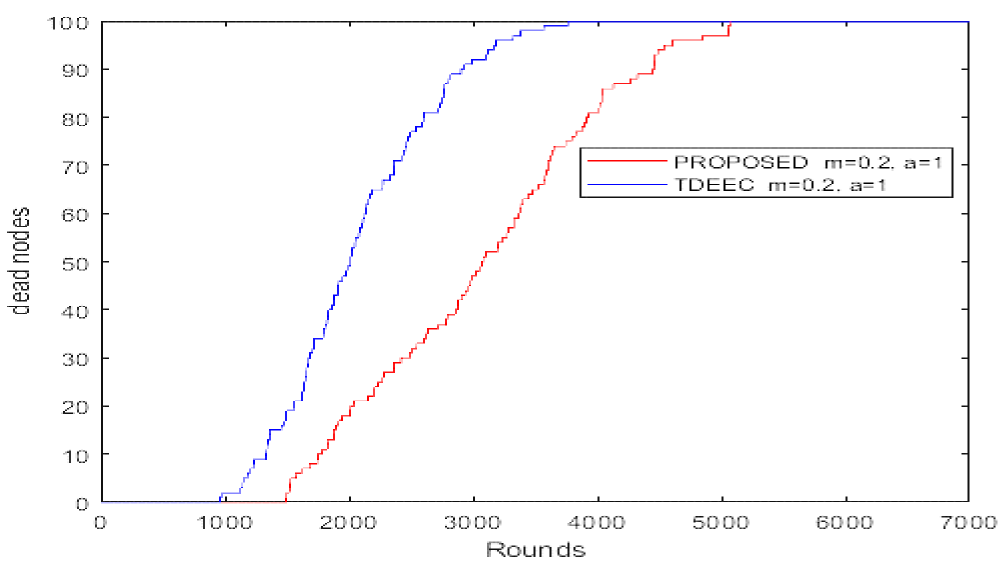

Fig. 4: Number of Dead Nodes per round

The tables 2 and 3 respectively shown the enhanced stability period and the lifetime of the proposed algorithm.

Table 2: Round vs Node stability period during simulation process

Protocol	Stability period	Round
DEEC	Death of first node	1000
D-DEEC	Death of first node	1500

Table 3: Round vs Node Death count during simulation process

Protocol	Death count	Round
DEEC	50	2000
	100	3800
D-DEEC	50	3500
	100	5100

Figure 5 shows the number of packages transmitted to the BS in both the proposed and existing routing protocols. It was realized that the amount of data transmitted to the BS by the TDEEC protocol rises from 0 to 3000 rounds and then remains stable throughout the simulation period. Thus, transmitting less quantity of data to the BS as shown in Figure 5. In the case of the new algorithm, a large quantity of reports was forwarded to the BS from 0 to 4200 rounds and then remained stable. The better performance showed in the new routing protocol is a result of i) the energetic and closer CHs that were selected to transmit data to the BS and ii) the sleep and awake technique that was employed for the distant CHs.

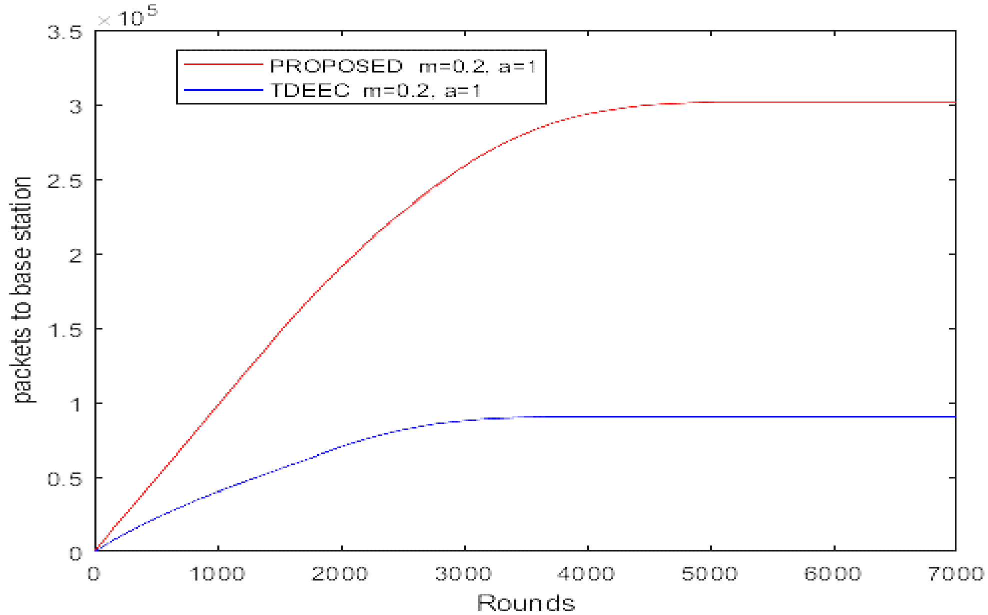

Fig. 5: Packets to the Base Station

Figure 6 shows the number of packets actually received by the BS in both the TDEEC and D-DEEC protocols. Sometimes, more data may be transmitted to the BS but a small amount of it may be received by the destination node. This may be due to interference or collision or less energy of the signals during the transmission. It was observed that, a smaller number of packets has been received in TDEEC protocol whilst in the case of the new protocol, a large amount of data was actually received. This constitutes 77% improvement of the existing protocol as seen in Figure 6. This again showed a better performance of the new algorithm in terms of the quantity of report received by the BS.

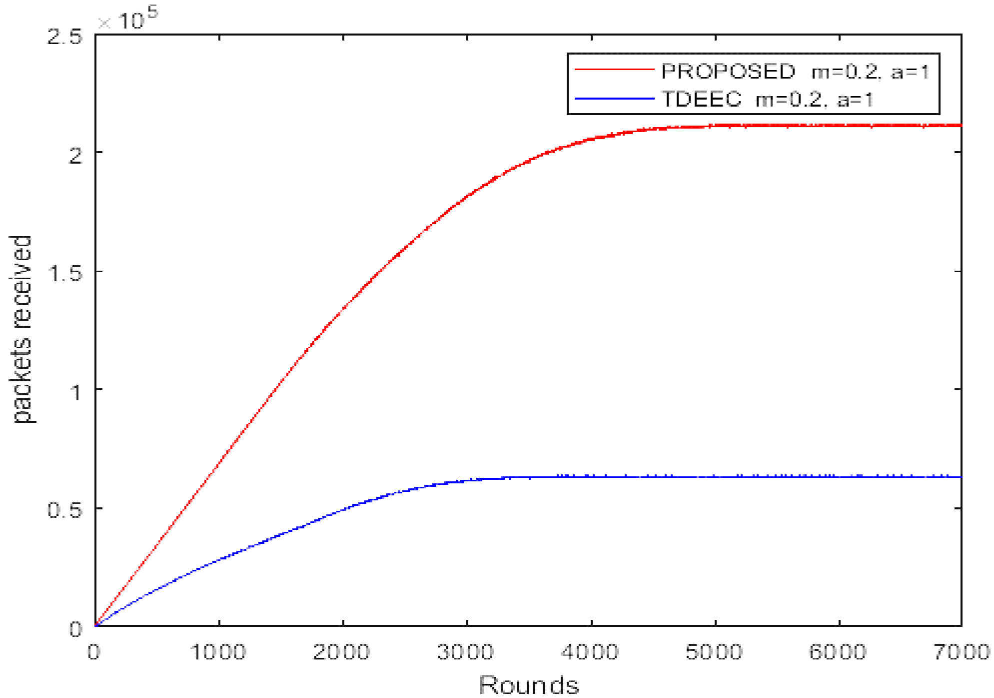

Fig. 6: Packets received by the Base Station

Figure 7 shows a comparison between the residual energy of the existing scheme and that of the proposed scheme. In the existing protocol, it is observed that the energy dissipation is high compelling the protocol to exhaust its energy immediately after 2000 rounds while in the proposed protocolat4000 rounds before the energy got exhausted.That is, the new scheme has improved the energy utilization by 62% as compare to the existing scheme. This is as a result of energy-efficient mechanisms in the new scheme. The CHs with high residual energy at the same closer to the BS are selected first and the sleep and wake technique is also applied to the distance CHs. This approach has helped reduce the energy depletion of the nodes and hence appreciable residue energy as seen in Figure 7.

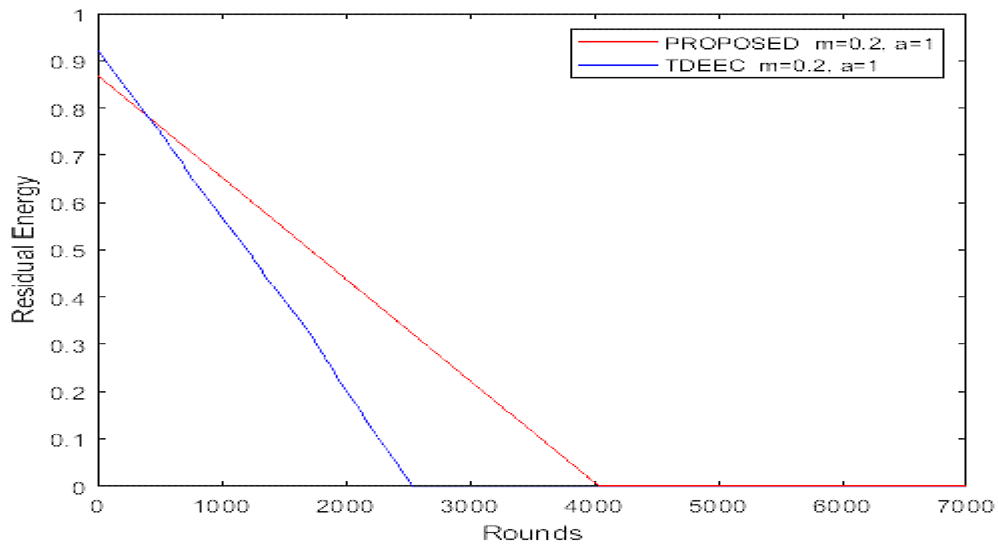

Fig. 7: Residual energy

The effective utilization of energy in the proposed scheme is shown in Table 4

Table 4: Round vs Residual energy during simulation process

Protocol	Round	Residual energy
DEEC	200	0.2
	2500	0.0
D-DEEC	200	0.48
	4000	0.0

4. CONCLUSION

A new hierarchicalheterogeneous routing protocol called Distance-DEEC (D-DEEC) is proposed in this research work. The proposed scheme modified DEEC protocol by introducing the distance of the individual nodes and the average distance of all the nodes from the BS and their neighbours in its election probabilities. The approach has minimized the energy depletion of the nodes and made the nodes stay alive longer than in the existing scheme. The new scheme also appliedthe sleep and awake approach to determine when distant CHs from the BS can transmit or move towards the sleep mode. This has also helped in conserving the energy of the network. The simulation was conducted to evaluate the performance of the new scheme and the simulation results showed that the D-DEEC protocol outperformed TDEEC protocol in terms of stability period, throughputs, residual energy and lifetime of the network.

ACKNOWLEDGEMENTS

The study is not sponsored

COMPETING INTERESTS

No competing interest exists.

AUTHORS' CONTRIBUTIONS

'Author A' designed the study, developed the model, wrote the protocol,simulated the protocol andwrote the first draft of the manuscript. 'Author B' and 'Author C' managed the analyses ofthe study. 'Author C' managed the literature searches…… All authors read and approved the final manuscript."

REFERENCES

[1] Sharma, S., & Rani, M. (2014). A Survey and Comparative Study of Routing Protocols in Wireless Sensor Network. *International Journal of Engineering and Computer Science, 3(5): 6008-6012*

[2] kumar, L., & Sudan, M. (2014). Advancement in Single Node Data Transfer Energy Protocol Using Gateways in Wireless Sensor Network. *International Journal of Advanced Research in Computer Science and Software Engineering, 4(6): 106-113*

[3] Jibreel, F., Tuyishimire, E., Daabo, M.I. (2022). An Enhanced Heterogeneous Gateway-Based Energy-Aware Multi-Hop Routing Protocol for Wireless Sensor Networks. *Information*, *13*, 166: 1-15.

[4] Jibreel, F.; Gbolagade, K.; Daabo, M. (**2018).** Servant-LEACH Energy Efficient Cluster-Based Routing Protocol for Large Scale Wireless Sensor Network. *Int. J. Eng. Res. Technol. (IJERT)*, *9*, 171–176.

[5] Elbhiri, B., Saadane, R., El Fkihiand S., &Aboutajdine, D. (2010). Developed Distributed Energy-Efficient Clustering (DDEEC) for heterogeneous wireless sensor networks. *I/V Communications and Mobile Network (ISVC), 5th International Symposium on, pp.1-4*

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

[7] Saini, P. & Sharma, A. K. (2010). Energy Efficient Scheme for Clustering Protocol Prolonging the Lifetime of Heterogeneous Wireless Sensor Networks. *International Journal of Computer Applications 6(2): 30-36.*

[8] Javaid, N., Qureshi, T.N., Khan, A.H., Iqbal, A., Akhtar, E., & Ishfaq, M. (2013). EDDEEC: Enhanced Developed Distributed Energy-efficient Clustering for Wireless Sensor Networks. *Procedia Computer Science, 19: 914-919.*

[9] Jibreel, F. (2018). Improved Developed Distributed Energy-Efficient Clustering Scheme (iDDEEC**).** *International Journal of Innovative Science and Research Technology, 3(12): 564-567.*

[10] Jibreel, F., Daabo, M.I., Yusuf-Asaju, A.W., &Gbolagade, K.A. (2018). Servant-MODLEACH Energy Efficient Cluster Based Routing Protocol for Large Scale Wireless Sensor Network. *The 12th International Multi-Conference on ICT Applications, 12: 1-6*

[11] Jibreel, F. (2019). Gateway–based Threshold Distributed Energy Efficient Clustering (G-TDEEC). *International Journal of Computer Applications (0975 – 8887) , 182(42): 43-46.*

[12] Qing, L., Zhu, Q., & Wang, M. (2006). Design of a distributed energy-efficient clustering algorithm for heterogeneous wireless sensor networks. *Computer Communications, 29(12): 2230-2237.*

[13] Smaragdakis, G., Matta, I., &Bestavros, A. (2004). SEP: A stable election protocol for clustered heterogeneouswireless sensor networks. *Proc of the Int'1 Workshop on SANPA, pp. 251-261.*

[14] F. Jibreel, "Improved Enhanced Distributed Energy EfficientClustering (iE-DEEC) Scheme for heterogeneous Wireless SensorNetwork", International Journal of Engineering Research andAdvanced Technology (IJERAT), 2019, 5(1), pp. 6-11.

[15] F. Jibreel" Extended Threshold Stable Election Protocol forWireless Sensor Networks", North American Academic Research,2(3), 2019, pp. 131-140

[16] F. Jibreel, M.I. Daabo, & K.A. Gbolagade. " Gateway-stableElection Protocol for Heterogeneous Wireless Sensor Network",Asian Journal of Research in Computer Science, 5(1), 2020, pp.40-48

[17] Rasheed, *M. B. Javaid‡, N. Khan, Z. A., Qasim, U., Ishfaq*, *M.* (2013). E-Horm: An Energy-Efficient Hole Removing Mechanism in Wireless Sensor Networks**.** *COMSATS Institute of Information Technology, Islamabad, pp. 1-4*