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Servant-LEACH Energy Efficient Cluster-Based Routing Protocol for Large Scale Wireless Sensor Network

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***Abstract*—In wireless sensor networks (WSNs), an extension of the lifetime of the network is one of the primary concerns of every routing protocol design. A critical study on The Low Energy Adaptive Clustering Hierarchy (LEACH) revealed that the scheme uses a probabilistic approach in selecting cluster heads. This approach allows weak nodes to be chosen as cluster heads (CHs) which cannot transmit the sensed data to the Base station (BS) hence affecting the throughputs of the network. Also single hop communication method was adopted which limits the network coverage and unnecessary data transmission of the heads affecting the lifetime of the network. In this research work, a heterogeneous form of LEACH called Servant–LEACH is proposed. The new protocol modified the election probability of the nodes by considering two factors in selecting the heads. i) The distance between the nodes and the base station and ii) the residual energies of the nodes. The proposed scheme further implemented soft and hard thresholds and servant nodes concept. The simulation results of the new scheme showed that the proposed protocol outperformed Threshold Distributed Energy Efficient Clustering (TDEEC) protocol in terms of stability period, throughputs, residual energy and the lifetime of the network**

Keywords— S-LEACH; Servant nodes; Network lifetime; Residual energy; distance; Matlab simulation

I. INTRODUCTION

Wireless Sensor Network (WSN) consists of a large number of sensors. The sensor network by their nature, have low processing power, low energy consumption and short transmission range for monitoring a physical environment. WSN can be used in a wide variety of areas including environmental monitoring, health, home applications, control (object detection and tracking), and surveillance [1][2]. Generally, in order to reduce energy consumption in WSNs, the clustering method is mostly used. In this technique, the sensor nodes are put into groups called clusters in which each cluster is headed by a node called a Cluster Head (CH). The rest of the nodes in the cluster is referred to as cluster members. These cluster members are responsible for capturing data and transmitting the sensed data directly or indirectly to the Cluster Heads (CHs). The CHs then aggregate the data and send the report to the Base Station (BS) for further analysis [3].

LEACH protocol is one of the first homogeneous cluster-based routing protocols to be proposed by [4]. Several other protocols built on LEACH have also been proposed. Younis and Fahmy [5] proposed Hybrid Energy-Efficient Distributed Clustering (HEED). HEED improved the scheme of the LEACH algorithm by including remaining energy. This method balanced the load on sensor nodes and extend the lifetime of the network. The protocol also offered the guarantee that the maximum energy node will be the cluster head inside its cluster range. The protocol did not consider distance in CHs' selection. Therefore distant CHs will dissipate a lot of energy to send their data to the BS.

Ramesh et al. [6] described the modified R-LEACH protocol which allows an alternative node to get substituted in place of a node that loses its energy. This is to allow the protocol to prolong the lifetime of the entire network and avoids data loss. The results showed that the Packet Delivery Ratio (PDR) and energy level have been enhanced compared to LEACH. The challenge in this protocol is similar to HEED which distance is not considered as criteria in selecting CHs. This allows distant nodes to dissipate so much energy in order to send their data to the BS.

Yassein et al. [7] developed a new Version LEACH (V-LEACH) protocol which is an improvement of the original LEACH protocol by selecting vice-CH that takes over the role of the CH in case it dies. In this protocol, when a CH dies, the cluster becomes useless because all data gathered by sensors in the cluster will never reach the sink. In addition to electing CH, the vice-CH is also selected. This approach ensures that cluster nodes data will always reach the BS and there is no need to elect a new CH each time the CH dies. This has extended the lifetime of the wireless network. However, the protocol did not consider residual energy in selecting the CH. As a result, nodes with less energy can become CHs which cannot transmit data to the BS. Cheng et.al. [8] Presented their findings on Energy Efficient Weight Clustering (EWC) protocol as an extension to LEACH protocol in which residual energy, distance, and node degree are considered as metrics to select a CH. Nodes having more neighbours or with a higher degree can serve more nodes which will save more energy. The challenge in this protocol is where CHs aggregate and transmit data at the same time. A model called LEACH-B (Balanced-LEACH) protocol was proposed by Tong and Tang [9] which is an enhancement of LEACH protocol. The protocol finds the optimal number of CHs which can be selected by using residual energy of nodes. Minimum and the optimal number of CHs are selected from the list of candidate CH nodes which are arranged in decreasing order of residual energy. This ensures cluster balancing which saves energy consumption. However, in LEACH-B algorithm, the CHs are responsible for both data aggregation and report transmission to the BS. Hence CHs loss a lot of energy. Loscrì et al. [10] came out with the two-level (TL) hierarchy protocol that reduces the energy consumption better than LEACH. TL-LEACH uses a random rotation of local cluster-based stations (primary cluster-heads and secondary cluster-heads). This allows better distribution of the energy load among the sensors in the network especially when the density of the network is higher. They evaluated the performances of the protocol with NS-2 and the results showed that their protocol outperformed the LEACH in terms of energy consumption and lifetime of the network. It is however observed that the energy of the CHs depleted with time because CHs are engaged in data aggregate and transmit data to the base station. Also, residual energy is not considered in selecting the CHs in this protocol

Qing et al. [11] also proposed a probability-based clustering algorithm called Distributed Energy-Efficient Clustering algorithm (DEEC). DEEC elects cluster heads based on the ratio between residual energy of each node and the average energy of the network. However, distance is not considered in selecting the CHs which allows distant nodes to be selected as CHs. This results in the energy depletion of the CHs.

Sharma and Verma [12] suggested the LEACH-heterogeneous system which seeks to compare two systems; the heterogeneous and homogeneous systems. They have analyzed LEACH protocol which is a homogeneous system and then studied the impact of heterogeneity. Simulation results using MATLAB shows that the proposed Leach-heterogeneous system significantly reduces energy consumption and increases the total lifetime of the wireless sensor network. The main problem identified in this scheme is the CHs are overburden with data aggregation and data transmission to the BS.

Elbhiri et al. [13] presented a model called Developed Distributed Energy-Efficient Clustering (DDEEC) for heterogeneous wireless sensor networks. It is the advanced version of DEEC and this protocol resolves the penalizing effect of DEEC protocol. However, the DDEEC has a similar problem as SEP where distance was not considered in selecting the CHs. Hence distant nodes dissipate energy to send their data to the BS.

Saini et al. [14] described an Enhanced Distributed Energy Efficient Clustering Scheme (EDEEC) for heterogeneous WSN. This is an extended version of DEEC with normal, advance and super-node classification based on node's energy. The problem identified in this protocol is similar to that of DEEC, SEP and DDEEC in which the CHs are engaged in both data aggregation and transmission to the BS. The effect of this is that the energy of the CHs is depleted over time.

The author in [15] suggested a new optimization scheme. The new algorithm modified the average probability of advanced nodes whose residual energy is less than the $\boldsymbol{Threv}$ (threshold residual energy value**)** to now depend on the average distance of the nodes from the Base station rather than the average energy of the network. The scheme further implemented TEEN and different amplification energy levels in the protocol to conserve energy in the network. The simulation results showed that the proposed protocol performed better than the existing scheme in terms of throughputs, residual energy and network lifetime.

An improved form of E-DEEC has been proposed by the author in [16]. iE-DEEC modified the election probability of the protocol in [4] by taking into account the distance of super-nodes and the average distance of all the nodes to the Base station (BS) in selecting the cluster heads (CHs). The scheme also introduced different amplification energy levels to minimize the energy consumption during the communications between the CHs and BS and also within inter and intra clusters. MatLab 2017a was used for simulation to evaluate the effectiveness of the scheme. The simulation results showed that the proposed protocol performed better than E-DEEC in terms of throughputs, residual energy and network lifetime.

Jibreel (17) 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 Base station 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. (18) described a heterogeneous form of Modified Low Energy Adaptive Clustering Hierarchy, Servant-MODLEACH (S-MODLEACH). The algorism uses three levels of nodes namely, advanced, servant and normal nodes. The protocol chooses Cluster heads based on their residual energy and assigned data aggregation role to a group of nodes called servant nodes. Simulation results showed that S-MODLEACH achieved better outcomes than MODLEACH in respect of throughputs and the network lifetime.

An improved form of Threshold Distributed Energy Efficient Clustering protocol (TDEEC) has been proposed by Jibreel (19). The new algorithm, Gateway based-TDEEC, introduced a gateway node at the middle of the sensing area and then installed the BS far away from the sensing field. The cluster heads relay their data to the gateway which will then aggregate the data and then send the final report to the BS. The simulation results showed that, the proposed protocol performed better than the TDEEC in terms of stability period, throughput, residual energy and the network lifetime. It however, failed to consider the distance factor is choosing the heads.

The authors in (20) proposed a modified heterogeneous routing protocol called Distance-DEEC (D-DEEC). The new

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scheme took into consideration the residual energy, distance of the individual nodes and average distance of all the nodes from the Base station in choosing the cluster heads. This has allowed the protocol to select cluster heads that have high residual energy, closer to the Base station and at the same time not too far from their neighbours. The performance of the proposed algorithm was evaluated using MatLab 2017a and the outcomes showed that D-DEEC protocol outperformed DEEC in terms of energy consumption, throughputs and the network lifetime.

Jibreel et al. (21) presented a Gateway- Stable Election Protocol(G-SEP). The G-SEP scheme modified the election probability of selecting the cluster heads by considering the distance, average distance and residual energy of the advanced nodes. The algorithm further introduced a gateway node at the middle of the network and then installed the BS outside the field. Simulation results using MatLab R2017a showed that the G-SEP performs better than Zonal-Stable Election protocol (ZSEP) in terms of coverage, stability period, throughput and network lifetime.

II. MATERIAL AND METHODS

In this section, the proposed protocol is explained

A. *Proposed Protocol*

In this section, the proposed heterogeneous LEACH protocol called Servant-LEACH is proposed. The S-LEACH adopts a three-level nodes system namely, advanced nodes, servant nodes and normal nodes in the network. The proposed scheme uses a modified form of election probabilities proposed by [22]. The election probabilities in S-LEACH protocol depend on the ratio of the distance between each node and the base station to their respective individual residual energy. So the node with high residual energy and closer to the BS will have a higher chance of becoming a cluster head thereby reducing energy consumption as a result of transmission distance. Also, the special nodes called servant nodes were introduced to aggregate the sensed data from the normal nodes then forward it to its cluster head. The cluster heads then transmit to the BS if they are closer to the BS else, they will transmit the data to the heads that are closer to the BS for onward transmission to the BS. This multi-hop communication approach coupled with the reduction of tasks on the CHs by the servant nodes has reduced the energy consumption of the CHs and gives the network wider coverage. Finally, hard and soft thresholds proposed by [23] have been used in this scheme to ensure that the sensed data reaches a certain threshold before data can be transmitted by the heads. This has further reduced the energy dissipation of the heads. Figure 1 below shows the proposed S-LEACH model.

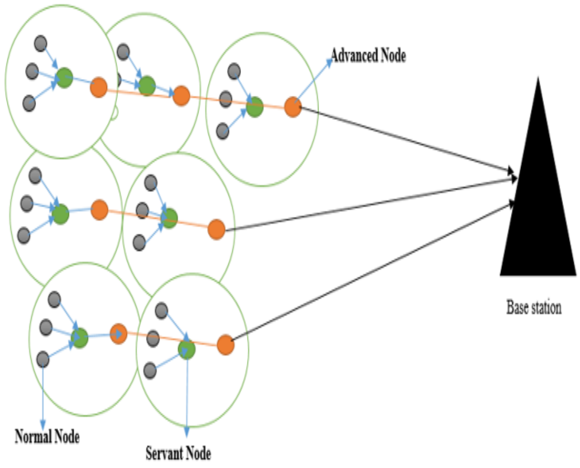

Fig. 1. S-LEACH MODEL

B. *Cluster Formation*

The protocol is made up of the following phases:

1) Set up Phase

The cluster head selection process is similar to [19]. Assuming m is a percentage of the population of sensor nodes equipped with a times more energy resources than the normal sensor nodes in the network called advanced nodes and n is the number of nodes in the network. E_0 is the initial energy of each normal node and q is a fraction of the population of sensor nodes equipped with b times more energy resources than the normal sensor nodes in the network called servant nodes. It means the initial energy for normal nodes is E_0, advanced nodes, E_{adv} = $(1 + a)E_0$ and servant nodes, E_{svt} = $(1 + b)E_0$, where $b = a/2$ .The total initial energy of the system is increased by the introduction of both advanced and servant nodes:

$$n.E_0\,(1 - m - q)\; + n.m.E_0\,(1 + a)\; + \; n.q.E_0\,(1 + b)$$

The overall energy of the network is increased by a fraction **of** $1 + am + bq$ and the new epoch of the system must now be equal to $1/P_{opt}$ **$(1 + am + bq)$**.

P_{nrm} **,** P_{svt} **and** P_{adv} are represented as election probabilities of becoming cluster head in normal, servant and advanced nodes respectively and are given in Equations(9-11). Their respective thresholds are also given in Equations (12—14):

$$P_{nrm} = \left(\frac{P_{opt}}{(1+am+bq)}\right) * \frac{distanc(i)}{E(i)} \qquad (9)$$

$$P_{svt} = \left(\frac{P_{opt}(1+b)}{(1+am+bq)}\right) * \frac{distanc(i)}{E(i)} \qquad (10)$$

$$P_{adv} = \left(\frac{P_{opt}(1+a)}{(1+am+bq)}\right) * \frac{distanc(i)}{E(i)} \qquad (11)$$

$$T(n_{nrm}) = \begin{cases} \dfrac{P_{nrm}}{1 - P_{nrm}\left(r \bmod \left(\frac{1}{P_{nrm}}\right)\right)} & if\; n_{nrm} \in G \\ 0, & otherwise \end{cases}$$

(12)

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where **G** is the set of normal nodes that has not become cluster head in the past $\frac{1}{P_{nrm}}$ rounds of epoch.

$$T(n_{svt}) = \begin{cases} \frac{P_{svt}}{1-P_{svt}(r \bmod (\frac{1}{P_{svt}}))} & if\ n_{svt} \in G^1 \\ 0, & otherwise \end{cases} \quad (13)$$

where G^1 is the set of servant nodes that has not become cluster head in the past $\frac{1}{P_{svt}}$ round of epoch

$$T(n_{adv}) = \begin{cases} \frac{P_{adv}}{1-P_{adv}(r \bmod (\frac{1}{P_{adv}}))} & if\ n_{adv} \in G^{11} \\ 0, & otherwise \end{cases} \quad (14)$$

where G^{11} is the set of servant nodes that has not become cluster head in the past $\frac{1}{P_{adv}}$ round of epoch.

When Cluster Heads at various levels are selected, the Servant Cluster Head (SCH) generates a Time Division Multiple Access (TDMA) schedule to assign time slots to the normal sensor nodes (NSNs).

2) Steady State

Once the clusters are formed, the NSNs send the sensed data to the corresponding SCH. The SCH aggregate the data and forwards the data to their respective Cluster Heads which then send the aggregated data to the base station.

The total energy dissipated by each cluster head is given by Equation (15)

$$E_{CH} = E_{TX}(k, d_{to\ BS}) \quad (15)$$

where $d_{to\ BS}$ is the distance from the CH to the BS.

The energy dissipated by the servant cluster head in transmitting aggregated k bits of data to the respective cluster heads is given by Equation (16)

$$E_{SCH} = kE_{elect}\left(\frac{n}{c} - 2\right) + \left(\frac{n}{c} - 1\right)kE_{DA} + E_{TX}(k, d_{to\ CH}) \quad (16)$$

where $d_{to\ CH}$ is the distance from the SCH to CH.

Each non-cluster head dissipated energy in transmitting k bits data to SCH and is given by Equation (17).

$$E_{non-CH} = E_{TX}(k, d_{to\ SCH}) \quad (17)$$

The energy dissipated in a cluster per round is given by Equation (18).

$$E_{cluster} \approx E_{CH} + E_{SCH} + \left(\frac{n}{c} - 2\right)E_{non-CH} \quad (18)$$

The total energy consumed by the network is given by Equation (19).

$$E_{total} = c\,E_{cluster}$$

$$E_{total} = c(E_{TX}(k, d_{to\ SCH}) + kE_{elect}\left(\frac{n}{c} - 2\right) + \left(\frac{n}{c} - 1\right)kE_{DA} + E_{TX}(k, d_{to\ CH}) + E_{TX}(k, d_{to\ BS})) \quad (19)$$

III. RESULTS AND DISCUSSION

To evaluate S-LEACH and TDEEC protocols for comparison, MATLAB R2017a was used for simulation. In this experiment, a random network of 200 nodes is used in a 200m*200m square area, and the BS was installed outside the field (100,250). Let us initialize the P_{opt} = 0.1 and assume that 40% of the sensor node will be advanced nodes (m=0.2) and 20% servant nodes (q=0.1). Other parameters used in the simulation are shown in Table1.

TABLE I: SIMULATION PARAMETERS

Parameter	Values
E_{elect}	50nJ/bit
E_{fs}	10pJ/bit/m^2
E_{mp}	0.0013pJ/bit/m^2
E_0	0.5J
k	4000
n	200
p_{opt}	0.1
m	0.2
q	0.1
e	1
b	0.5
E_{DA}	5nJ/bit/message

A) *Performance Metrics*

The following metrics are adopted to access the performance of all clustering protocols involved:

1. Stability period
2. Network lifetime and
3. Throughputs
4. Remaining energy

Figure 2 shows the number of alive nodes during each transmission round for the TDEEC and S-LEACH routing protocols. From the graph, it is clear that the network lifetime is enhanced significantly in S-LEACH compared to TDEEC. Nodes alive up to 180 rounds in LEACH and remained alive up to 10000 rounds in S-LEACH. This means that nodes live longer in S-LEACH than in TDEEC and therefore making the proposed protocol have a better lifetime than TDEEC protocol. The extension of the lifetime that was observed in S-LEACH is, as a result, of the multi-hop communication among the normal, servant and advanced nodes which has reduced the number of transmission of the nodes straight to the BS. Also, the hard and soft thresholds that were implemented conserved the energy of the heads and hence more alive nodes.

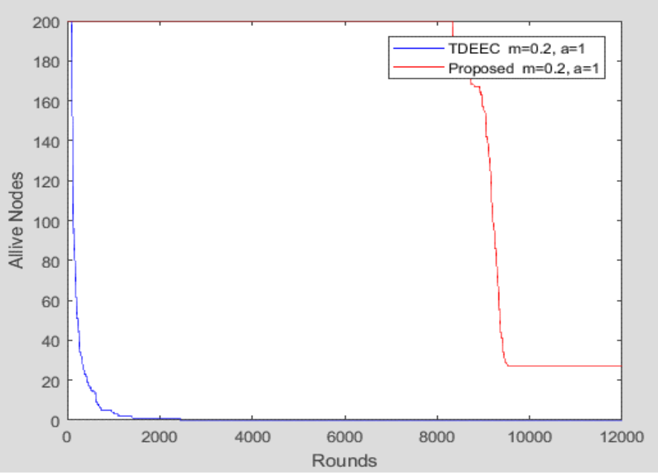

Fig. 2. Number of the Alive Nodes Per Round

Figure 3 shows the number of dead nodes during each round in both routing protocols. It was observed that the death rates in S-LEACH are lower compared to that of TDEEC as seen in figure 3. As early as 400 rounds, some nodes begin to die in TDEEC protocol but in the case of the proposed protocol nodes begin at 8100 rounds. Also, all the nodes are dead in 2000 rounds in the case of TDEEC while in S-LEACH, it is after 10200 round that all the nodes disappeared as shown in figure 3. This again shows that the proposed algorithm has effectively reduced the number of dead nodes. It has also resulted in better stability period and the network lifetime observed in the proposed protocol.

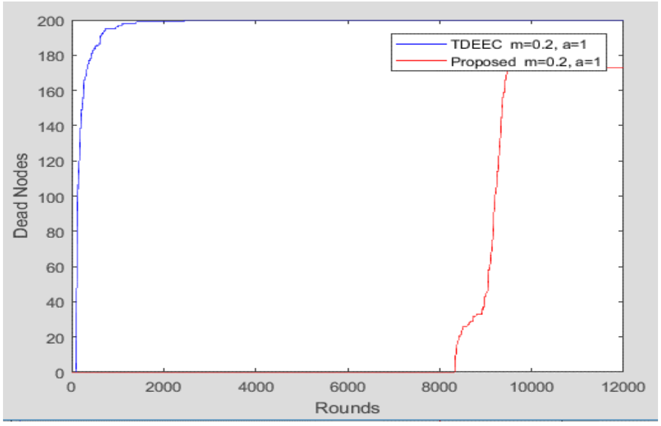

Fig. 3. Number of the Dead Nodes Per Round

Figure 4 also shows the amount of data sent to the BS per round in TDEEC and S-LEACH protocols. It can be noticed that the amount of data sent to the BS by the TDEEC protocol increases from 0 to 200 and remains stable throughout the simulation period. Thus sending less amount of data to the BS. The new algorithm, though started with less amount of data but improved after 4000 rounds and sent a large amount of data to the BS. This performance is a result of the residual energy and distance factor that was considered in electing the cluster heads. The 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 are able to transmit more data with less energy consumption. Furthermore, the Servant nodes are made to aggregate the data rather than the CHs which has also enhanced the performance of the CHs. This has reduced energy depletion of the heads and hence better data transmission to the BS.

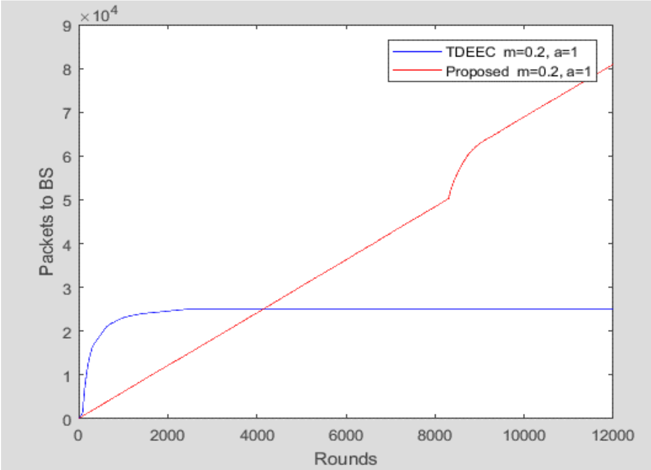

Fig. 4. Number of Packet to the Base Station Per Rounds

Figure 5 shows the energy dissipation of the network in both routing protocols. Though the two protocols decreased linearly, TDEEC exhausted its energy at 500 rounds. S-LEACH, on the other hand, sustains its energy beyond 6000 rounds as seen in figure 5. This shows that S-LEACH consumes less energy in transmitting its data to the BS.

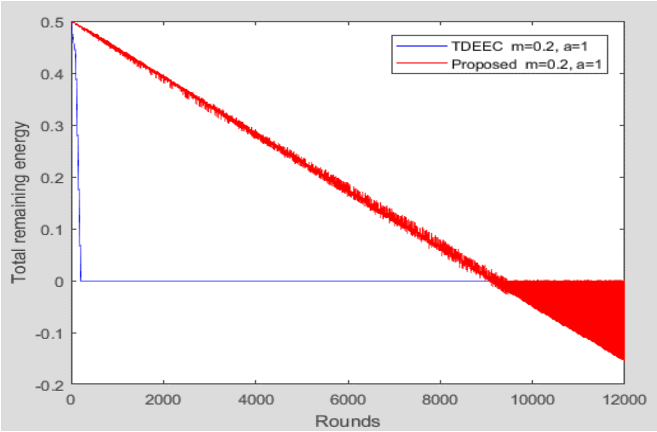

Fig. 5. Remaining Energy Per Round

IV. CONCLUSION

In this work, a heterogeneous LEACH protocol called S-LEACH is proposed. In S-LECH protocol, the election probability of the nodes in each level has been modified to consider both the distance of each node from the Base station and their respective residual energies. The new protocol makes the nodes with high residual energy and also closer the BS to have a better chance of becoming heads. This has reduced energy consumption in the nodes which have resulted in better throughputs and longer lifetime of the network. Furthermore, the protocol used Servant nodes to aggregate the data from the normal nodes to the Cluster Heads. This has reduced the energy depletion of the cluster heads thereby enhancing their data transmission to the Base station. The S-LEACH further utilized the hard and soft thresholds which reduce the unnecessary data transmission by the heads. This has helped to conserve the energy of the heads and that has also resulted in a longer lifetime of the network. So, we can

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conclude that S-LEACH is more effective and efficient than TDEEC in terms of stability period, throughputs, residual energy and network lifetime. Hence, S-LEACH can be used in heterogeneous networks where large coverage area may be required

REFERENCES

[1] D. Estrin, R. Govindan, J. Heidemann, & S. Kumar, "Next century challenges: scalable coordination in sensor networks, in: Proceedings of the 5th Annual ACM/IEEE", International Conference on Mobile Computing and Networking, Seattle, Washington,USA, 1999, pp. 263-270.

[2] H. Yang, and B. Sikdar, "Optimal Cluster Head Selection in the LEACH Architecture", IEEE International Conference on Performance, Computing, and Communications, 2007, pp. 93-100.

[3] F. Jibreel, "Improved- Gateway-Based Energy-Aware Multi-Hop Routing Protocol for WSNs", International Journal of Innovative Science and Research Technology, 2018, 3(12), pp. 626-630.

[4] W. Heinzelman, A. Chandrakasan, & H. Balakrishnan, "*Energy-efficient communication protocol for wireless sensor networks", In the Proceeding of the Hawaii International Conference System Sciences,* 2000, pp. 1 -10

[5] O. Younis, & S. Fahmy, "HEED: A hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks" IEEE Transaction on Mobile Computing, 2004, 3(4), pp. 366 -379.

[6] R. Ramesh, R.M.D. Charaan, N.T.M Kumar, & E. Uma, " Implementation of Load Balancing in Leach Protocol for Wireless Sensor Networks", 2nd International Conference on Emerging Trends in Engineering and Technology (ICETET'2014), London (UK), 2014, pp. 80-84.

[7] M.B. Yassein, A. Al-zou'bi, Y. Khamayseh, & W. Mardini, "Improvement on LEACH protocol of wireless sensor network (VLEACH)", International Journal of Digital Content Technology and its Applications, 2009, 3(2), pp. 132-136.

[8] L. Cheng, D. Qian, & W. Wu, "An energy efficient weight-clustering algorithm in wireless sensor networks", In Frontier of Computer Science and Technology, FCST'08. Japan-China Joint Workshop on, 2008, pp. 30-35

[9] M. Tong, & M. Tang, "LEACH-B: an improved leach protocol for wireless sensor network" WiCom, 2010 , 23(25), pp. 1–4

[10] V. Loscrì, G. Morabito, & S. Marano, "A two levels hierarchy for low energy adaptive clustering hierarchy (TL-LEACH)", Vehicular Technology Conference, 2005, vol. 3, pp. 1809-1813

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

[12] N. Sharma, & V. Verma. "Heterogeneous LEACH Protocol for Wireless Sensor Networks", Int. J. Advanced Networking and Applications, 2013, 5(1), pp. 1825-1829

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

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

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

[16] F. Jibreel, "Improved Enhanced Distributed Energy Efficient Clustering (iE-DEEC) Scheme for heterogeneous Wireless Sensor Network", International Journal of Engineering Research and Advanced Technology (IJERAT), 2019, 5(1), pp. 6-11.

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

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

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

[20] F. Jibreel, M.I. Daabo, & K.A. Gbolagade," Distance-Distributed Energy Efficient Clustering (D-DEEC) Routing Protocol", *The 13th International Multi-Conference on ICT Applications,* Volume XII, 2019. pp. 49-53

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

[22] F.A. Aderohunmu, & J.D. Deng, " An Enhanced Stabel Election Protocol (SEP) for Clustered Heterogeneous WSN", Discussion Paper Series, No. 2009/07, Department of Information Science, University of Ontago, Dunedin New Zealand, 2009, pp. 1-16.

[23] A. Manjeshwar, & 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.