

Performance Evaluation of LEACH Protocols in Wireless Sensor Networks

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ABSTRACT

In recent years, researchers have focused on wireless sensor networks (WSNs). Because there are a lot of applications we used. The wireless sensor network consists of many small sensor nodes that contain a small and self-charged battery. Sometimes it is possible to change the power source of the node battery but sometimes it is impossible to do so, and this varies depending on the nature of the network environment so, the wireless sensor network may be destroyed over time. This makes the process of increasing the lifetime of the wireless sensor network a major challenge for researchers. There are a lot of WSN protocols to improve the lifetime of WSN, one of these protocols and some of its modified versions.

In this paper, LEACH is used to investigate wireless sensor networks (WSN) by evaluating LEACH, LEACH-C, LEACH-B (balanced leech), MOD-LEACH, I-LEACH, and Multi-hop LEACH. Moreover, The LEACH, LEACH-C, LEACH-B (balanced leech), MOD-LEACH, I-LEACH, and Multi-hop LEACH are implemented by MATLAB to achieve simulation results. The performance evaluation is shown in more charts to prove the performance of these protocols.

Keywords - Modified LEACH protocols, Alive nodes, Packet to BS, Packet to CH, Energy of Network, WSN.

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1. INTRODUCTION

The Internet of Things (IOT) can be described as being able to connect anything you can monitor or control from the Internet anytime, anywhere. Even wireless is a very good way to achieve connectivity in this wide range [1].

'Wireless Sensor Network (WSN) as shown fig.1. has the ability to monitor environmental or physical conditions such as weather, pressure, sound, humidity, movement. etc. using a range of small low-cost, low-power, multifunctional sensor nodes that have limited connectivity and computing capabilities to collect and transfer different data from the environment to the base station, where measured parameters can be stored and made available to the end user.'

The main components of the sensor node are the sensor unit, processing unit, transceiver and power unit. There are some other application-based sub-units including location search and packaging [2, 3, 4].

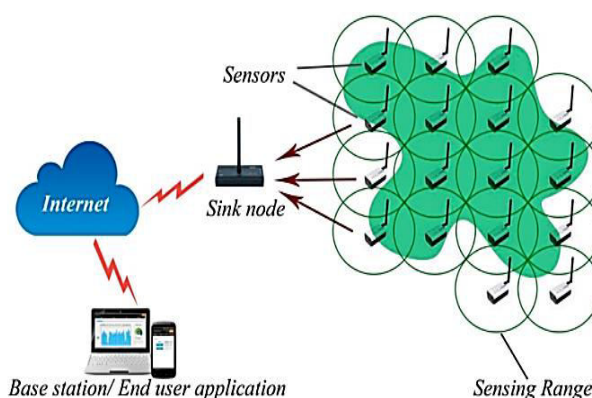


Figure.1.WSN structure

WSN acts as a virtual layer that acts like a bridge between the real world and the virtual world to pass real-world sensor values to the Internet so it is described as the ears and eyes of the Internet of Things (IOT) [1]. There are a lot of applications in WSN that include many areas, such as forest fire detection, military battlefield.etc. It is very difficult to replace dead nodes caused by energy consumption until depletion in such extreme environments with new ones to provide energy to the network. Even to make the sensor nodes live for as long as possible is the main method to maximize the lifetime of the network. The

long-distance steering path for data transfer is the main reason for energy consumption node sensor, to make the steering path efficient using the appropriate steering protocol will have a significant impact on energy consumption [6].

Strategies of routing are a big challenge in WSN. Hierarchical protocols are used to reduce the consumption of the energy that resulted by data collection and data transmission to the sink. In this paper we will focus on routing protocol called Low Energy Adaptive Clustering Hierarchy (LEACH), Which is one of the most popular routing protocols that are used to minimize the consumption of energy and uses the cluster based routing, and some modified versions of it. The idea of LEACH is to divide the sensor nodes of the network into clusters depending on the strength of the received signal and it uses the local cluster heads (CHs) as routers to the sink.

Routing strategies are a big challenge in WSN. Hierarchical protocols are used to reduce energy consumption from data collection and data transfer to the sink. In this paper we will focus on a routing protocol called low-energy adaptive cluster hierarchy (LEACH), one of the most popular routing protocols that are used to reduce energy consumption and uses cluster based routing, and some modified versions of it. LEACH's idea is to divide the network sensor nodes into clusters depending on the strength of the signal received and uses local mass heads (CHs) and routers to the sink. Studies in this paper present the best protocol through simulation [7,8].

The organization of the paper as follows: Section 2 shows the overview of LEACH and its modifications. Section 3 presents the related work. Section 4 proposed simulation and results. Section 5 the conclusion. Finally, section 6 the paper references.

2. OVERVIEW OF LEACH PROTOCOL AND ITS MODIFICATIONS

2.1. LEACH

LEACH assumes that the network consists of groups of sensor nodes called clusters. Each cluster has a cluster head and some other sensor nodes (normal). This sensor node is responsible for sensing the environmental conditions around them at a constant rate and collecting this data. After collecting this contract, the data sensor required to be sent to the base station (BS). Leach therefore considers that BS is static and away from sensors, sensors can communicate with each other and with BS. LEACH consists of several rounds each round consisting of two phases as follows:

Set-up phase.

Steady state phase.

In the setup stage the clusters will be determined, each sensor node will know the cluster to which it belongs, and will be able to determine each cluster of its own cluster

head. In the case of steady stage sensor nodes transfer the data collected to the sink by cluster heads.

LEACH improves network lifetime and reduces energy dissipation better than other non-hierarchical routing protocols. But there are some limitations facing LEACH, they are not suitable for wide area networks because as we mentioned before the connection between the sensor node and the cluster heads occurs through a single hop transmission. Regardless of the distance each cluster head must communicate directly with the sink. the remaining energy of the node is not taken into account by LEACH when this is the time to choose the cluster head, so it is possible that the low-energy node will be head of the node before the other high-energy node that may lead to the rapid collapse of the cluster due to the rapid death of the cluster head and therefore, it will not be possible to reach that cluster [9].

Although leach use has many advantages, it does not provide any guarantee about the position or number of cluster heads. Overall performance will not be affected by getting a weak cluster setting during the round created, because the clusters are adapting. However, forming clusters by a central control algorithm may create better clusters by scattering cluster heads across the network. This is the central basis of LEACH-C [10].

2.2. LEACH-C

LEACH-C is a modified version of LEACH, which uses a central clustering algorithm. LEACH-C resembles LEACH in the steady state stage, but LEACH-C is different from LEACH in the two steps in the setup stage. In LEACH-C, specifically in the setup phase each node tells the sink about its position. It's the remaining energy level right now. After that, the base station calculates the average energy level for all nodes. That makes the base station (BS) capable of calculating the optimal CHs in the network and dividing the network into clusters for the current round. The base station then broadcasts an ad message to all the nodes over the network telling them the new configuration and new CHs with its members [11].

In LEACH-C the steady state phase is performed similarly as in LEACH. LEACH-C has its own modifications that distinguish it from Leach, and aims to extend the lifetime of the wireless sensor network (WSN) and reduce energy dissipation. At LEACH, each node has the opportunity to be CH in different rounds. Conversely, in LEACH-C, not all nodes will have the same opportunity [7]. LEACH-C is overall performance is better than LEACH because cluster heads are scattered across the network. However, LEACH-C is sensitive to BS position. Once the energy cost of communicating with BS is higher than the energy cost to create the cluster, LEACH-C no longer delivers good performance. Therefore, relying on the BS site is one of LEACH-C's main disadvantage [12].

2.3. MODLEACH

MODLEACH is promoting more than the LEACH protocol, MODLEACH introduced a new technique called CH efficient replacement system. There is a threshold for each next round in the process of forming a cluster head. If the existing of the current cluster did not consume much energy for the current round and it still has more energy than the predefined threshold it will remain CH for the next round as well in this way, wasteful energy can be saved in the process of forming cluster packages and steering for the cluster head of the new cluster. If the cluster head of the clusters has less power than the predefined threshold level, it will be replaced by another one according to LEACH [13].

2.4. LEACH-B (BALANCED LEACH)

Minghao and Mu Tong proposed LEACH-B algorithm to balance the number of CHs depending on the remaining energy of nodes. The initial choice of cluster heads depends on LEACH's basic algorithm and from the second round LEACH-B is used. LEACH-B is a near optimal routing method. LEACH-B's decentralized approach is used in the process of forming a cluster in which each node knows its location and the location of the final destination regardless of where the network rest node is located. LEACH-B works in three stages:

Cluster head selection.

Cluster formation.

Data transmission with multiple accesses.

Every node chooses its cluster head depending on the dissipated energy in the path between the node and the final receiver. LEACH-B is more energy efficient than LEACH protocol [14,15].

2.5. MULTI HOP LEACH

MultiHop-LEACH is very similar to LEACH, it makes contact mode from one hop to multi-hop between cluster heads and base station [16,14].

MultiHop-LEACH [15] uses two methods of communication, communication between multi-hop clusters and communication within the multi-hop intra cluster. In communications between multi hop clusters, data from the node is sent to the opposite cluster head from where it is sent to the base station through a series of cluster heads. The intracluster multi-hop connection is applied when the node sends a cut request to a connected node to have a temporary cluster head. This method makes multi-hop LEACH more efficient according to the energy of LEACH. However, the problem of the size of the unbalanced mass is still present because of the random selection of cluster heads. [17].

2.6. I-LEACH

In [18] The authors proposed an E-HORM model that contains three main stages: the initializing phase, the threshold calculation phase, cluster formation and the sleep/awake scheduling stage. The probability of sleep nodes to hold the sensor is calculated using Eth from the distant nodes of each round, and increases the likelihood

of sleeping with a node that is far from the base station. Therefore, energy consumption will almost be balanced by the decade, enhancing network life. In wireless sensor networks due to the limited energy of the sleep scheduling sensor nodes is very important. If the node is set in awake (active) mode for a long time, it consumes a lot of energy. On the other hand, for a long period of sleep time transmission make further delays. The authors designed optimal sleep control technology to avoid both problems. They applied their scheme on four categories of cluster based protocols including LEACH and that produced an improved leach which we will call it ILEACH in this paper too.

3. RELATED WORK

In [8], Ala'a, hebatualah & saleh ft used MATLAB to try to compare LEACH and LEACH-C protocols. They used as many metrics as the number of data packets sent to BS, the total number of data packets delivered to BS, the total number of dead nodes in each round, and another measure they looked at in their results was the first dead node. The first node death occurred earlier in LEACH than in LEACH-C. This is an important factor that supports the purpose of LEACH-C, which is designed to increase network life. Another measure they used was energy dissipation and according to its results LEACH-C showed less energy dissipation than LEACH.

In [19] Nayak & Shree used the NetSim simulator to compare LEACH and LEACH-C in order to understand their properties. Use some performance metrics, such as Total no. of data signals delivered in BS over time, average energy dissipation over time, no. Live contract over time, No. of packets sent and packet delivery ratio, BS v/s site average power dissipation and BS v/s network lifetime. According to their discussion and results, they concluded that LEACH-C is better than LEACH.

In [20], the author used MATLAB to simulate and compare the LEACH and MODLEACH protocols using some different parameters. Such as different network areas, different number of nodes, different number of rounds, different probability of cluster head and different data aggregation energy. The comparison is run using different tested values and by leaving the other parameters fixed. The author concluded that MODLEACH is less time-consuming than the LEACH Protocol. He noted that the number of parameters used to compare performance decreased as the network area increased, and there has been a small decrease in the number of nodes. Increase these parameters in MODLEACH more than LEACH if the number of rounds increases to a fixed stage after 700 rounds.

In [21] the authors made a comparison between various hierarchical WSN routing protocols. They used MATLAB to simulate TEEN, SEP, and DEEC protocols to test the performance of these protocols and in [22] the author compared between various homogeneous protocols such

as DEEC, DDEEC, EDEEC and TDEEC and MODLEAC, that are modified from leach protocols.

In [18] The authors discussed energy consumption and the problem of energy hole. They implemented their technology on LEACH, DEEC, TEEN, and SEP protocols. They suggested an awake and sleep mechanism that removes energy holes in wireless sensor networks. Achieve better energy consumption than applying this mechanism. Balance energy is consumed by the sensor nodes leading to an increased network life.

4. SIMULATION AND RESULTS

We simulate different hierarchical routing protocols for the main Low Energy Adaptive Clustering Hierarchy (LEAC) and its modification protocols in WSNs using MATLAB. For simulation, we use the parameters in table 1. The studied effects of changing parameters used for evaluation of clustering protocols for heterogeneous WSNs are energy and residual energy network, number of nodes alive during rounds and data packets sent to BS.

- 1- Dead nodes: it is the nodes which died until last round, so, good performance which obtain minimum dead nodes.
- 2- Alive nodes: it is the nodes which still until the last round. Better performance with the higher alive nodes.
- 3- Packets sent to the BS: indicate quantity of packets received by BS for each round.
4. CH packets: indicate the quantity of sent packets to BS for each round.

Table 1: List of simulation parameters

S. No.	Parameters	Values
1	Network Area	200*200
2	Number of nodes	500
3	Cluster head probability	0.1
4	Transmitter energy	50*0.000000001
5	Receiver energy	50*0.000000001
6	Aggregation energy	5*0.000000001
7	Amplification energy	0.0013*0.000000000001
8	Number of rounds	2500
9	Hard threshold	100
10	Soft threshold	2
11	Initial energy	0.5

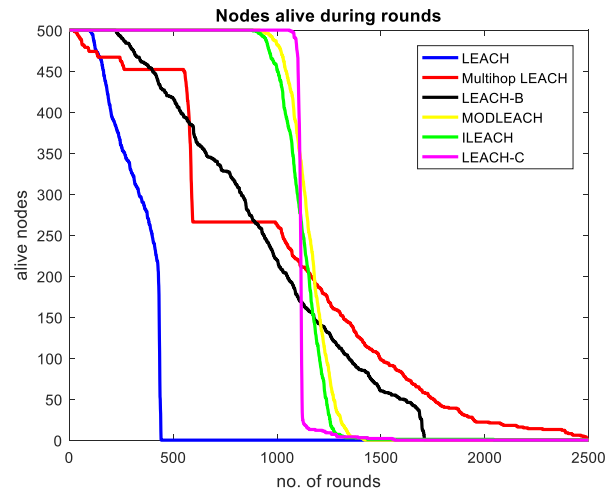


Figure.2. Shows the alive nodes number

Figure 2 shows that the number of live nodes for all protocols is reduced as the number of rounds increases. LEACH-C protocol performs well but multi-hop LEACH is the best lifetime protocol for all rounds that have extended the lifetime of the protocols network for our comparisons.

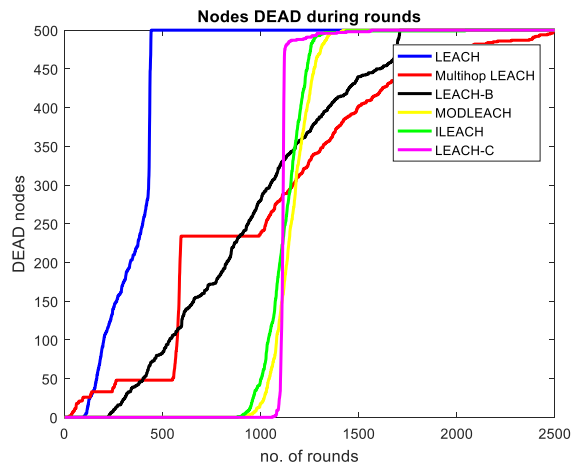


Figure.3. Shows the dead nodes number

Figure 3 shows that all dead nodes exceed as the number of rounds increases. The number of dead nodes of Multihop-LEACH is lower than other protocols. Multihop-LEACH protocol number of dead nodes up to the maximum at that time 2500 rounds is final rounds and other protocols number dead nodes up to the maximum in 2500 rounds faster and before Multihop-LEACH.

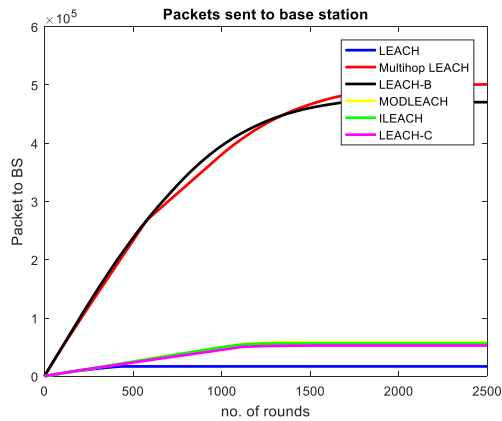


Figure.4. Depicts the packet to BS

Figure 4 shows that the package reaches with BLEACH and Multihop-LEACH protocols to base station performing better than LEACH, iLEACH, MODLEACH and LEACH-C protocols but BLEACH and Multihop-LEACH performance is very good other than protocols but the package arrives with excellent performance protocol and reaches the maximum with increased number of rounds.

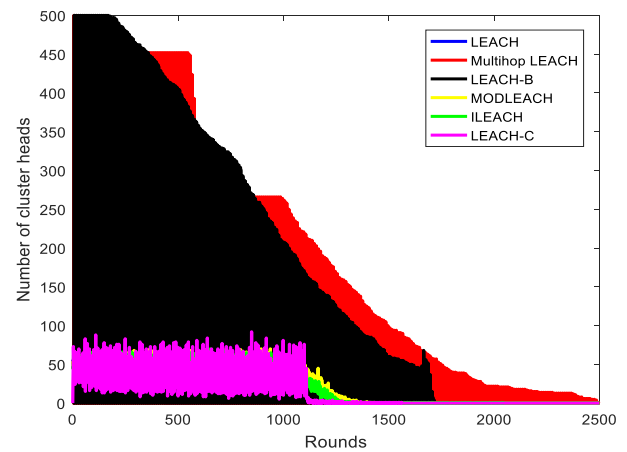


Figure.6. Shows cluster heads number

Figure 6 depicts that the cluster heads number of protocols. The all are decreased with increasing number of rounds. Multihop-LEACH and B-LEACH are the highest and are still for along rounds other than protocols. iLEACH, LEACH, MODLEACH and LEACH-C are perfect and the less clusters number in all number of rounds.

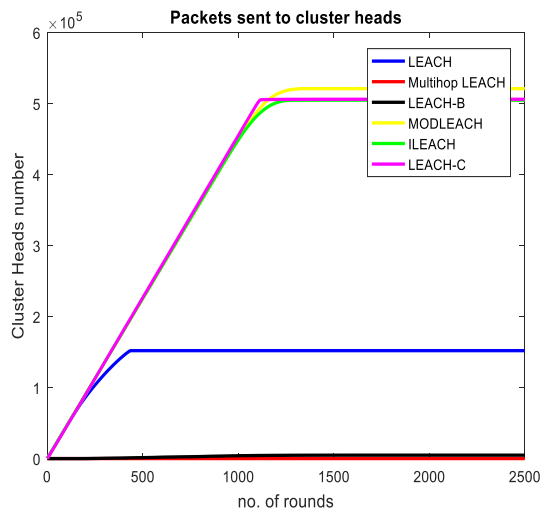


Figure.5. Depicts packet to CH

Figure 5 depicts that the packet sends to base station the energy hole protocol iLEACH, and MODLEACH are the perfect other than LEACH and BLEACH performance but LEACH-C better performing other than all protocols but the packet sends with Multihop-LEACH protocol is the worst performing in all number of rounds.

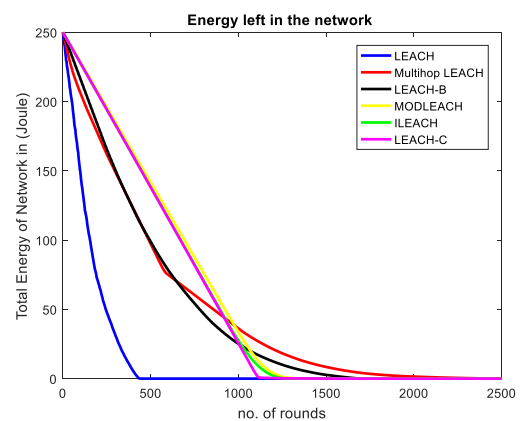


Figure.7. Shows the network energy

Figure 7 shows that the energy for all protocols are decreased with increasing number of rounds. We are observed that the LEACH-C protocol performs well but the Multi-hop LEACH is the best lifetime protocol for all rounds it extended the network energy for along time other than protocols for our comparisons.

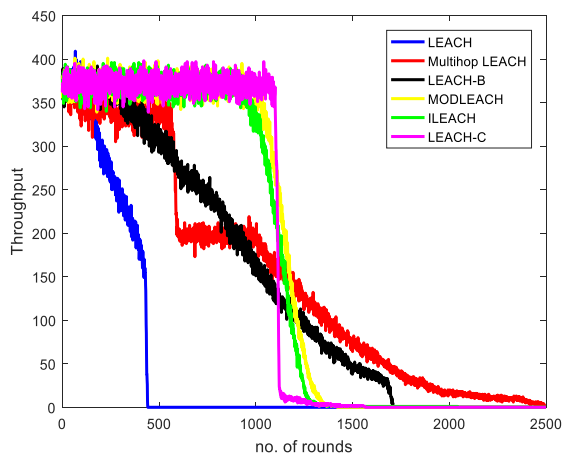


Figure.8. Depicts the throughput protocols

Figure 8 shows the throughput between LEACH, Multihop-LEACH, MODLEACH, iLEACH, B-LEACH and LEACH-C protocols. it depicts that the Multihop-LEACH throughput rate is more exceeds than protocols and best one other. Finally, we could say that the Multihop-LAECH protocol performing is better other than protocols.

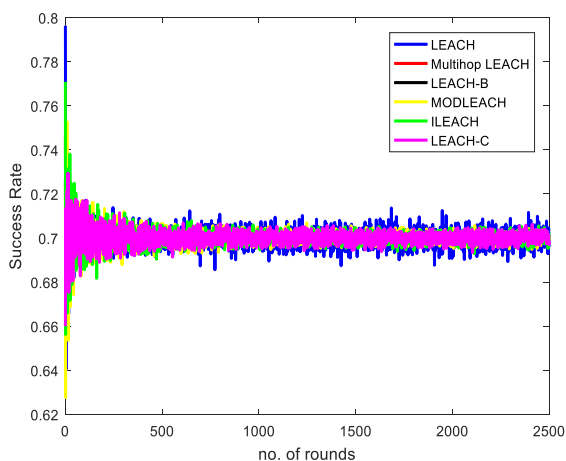


Figure.9. Packet delivery ratio

Figure 9 shows the ratio of number of packets delivered in total to the total number of packets sent from source node to destination node in the network. LEACH, ILEACH, MODLEACH and LEACH-C uses that maximum number of data packets has to be reached to the destination. All performing well than B-LEACH and Multihop-LEACH protocols.

5. CONCLUSION

It is observed according to the simulation and comparisons of previous studies of the protocols that have been compared in our article with different parameters of routing protocols the results showed that the alive nodes, dead nodes, packet to BS, cluster heads, total energy network, throughput and packet delivery ratio are effected

and differentiate with LEACH protocol and its modifications. As regards to the comparisons for hierarchical protocols we found different results of using deferent parameters to test the performanceof these protocols. Therefore, the network lifetime different as compared to these protocols.

We conclude that these parameters will increase the performance of the network quality. It will beaffected in all applications that use the WSNs. It is expected towork infields such as industry, rubout or battle tracking. The modeling of these protocols seems to suggest that in future of design and process of the classification of these protocol must take in consideration these parameters because these protocols will be efficient for applications that are time critical by nature.

FUTURE CONTRIBUTION

In future many other techniques should be developed which should focus on improving the network performance so that the lifetime as well as the performance of the wireless sensor networks can be improved. The LEACH routing protocol and its modifications have been affected in its performance as well as different parameters that have been used to test the performance and quality. The adaptability of the protocols can be checked out and they even can be made more flexible to all kinds of applications as well as environments from time to time. This work could be used as application of internet of things.

REFERENCES

- [1] Trupti Mayee Behera, Umesh Chandra Samaland Sushanta Kumar Mohapatra, "Energy-efficient modified LEACH protocolfor IoT application", *IET Wireless Sensor Systems*, p. 223 – 228, May 2018.
- [2] Sayed Ali FatemiAghada, Mahdi Mirfakhraei, "An Improved Cluster Routing Protocol to Increase the Lifetime of Wireless Sensor Network (WSN)", *Wireless Personal Communications* Vol.109, pp.2067–2075, August 2019.
- [3] Reshma I. Tandel, "Leach Protocol in Wireless Sensor Network: A Survey", (*IJCSIT*) *International Journal of Computer Science and Information Technologies*, Vol. 7 (4), pp.1894-1896,2017.
- [4] S. K. Singh, P. Kumar and J. P. Singh, "A Survey on Successors of LEACH Protocol," in *IEEE Access*, vol. 5, pp. 4298-4328, 2017.
- [5] Sujan J, Isaac Sajjan R, "AN ENHANCED CLUSTER (CH-LEACH) BASED ROUTING SCHEME FOR WIRELESS SENSOR NETWORK", *International Research Journal of Engineering and Technology (IRJET)*, e-ISSN: 2395-0056 Volume: 06 Issue: 02, pp.1456-1459, Feb 2019 .

- [6] Fuzhe Zhao, You Xu, and Ru Li, "Improved LEACH Routing Communication Protocol for aWireless Sensor Network", *Hindawi Publishing Corporation International Journal of Distributed Sensor Networks*, pp.1-6, November 2012.
- [7] Reenkamal Kaur Gill, Priya Chawla and Monika Sachdeva, "Study of LEACH Routing Protocol for Wireless Sensor Networks", *International Conference on Communication, Computing & Systems (ICCCS)*, pp.196-198, 2014.
- [8] Ala'a Al-Shaikh, Hebatallah Khattab & Saleh Al-Sharaeh, "Performance Comparison of LEACH and LEACH-C Protocols in Wireless Sensor Networks", *Journal of ICT Research and Applications* 12(3):219. Appl. Vol. 12, No. 3, 2018, pp.219-236.
- [9] Muhammad Kamran Khan, Muhammad Shiraz ,KayhanZrar Ghafoor Suleman Khan , Ali Safaa Sadiq, and Ghufran Ahmed, "EE-MRP: Energy-Efficient Multistage Routing Protocol for Wireless Sensor Networks", *Wireless Communications and Mobile Computing* ,pp.1-13, 8 January 2018.
- [10] Wendi B. Heinzelman, Member, IEEE, Anantha P. Chandrakasan, Senior Member, IEEE, and Hari Balakrishnan, Member, IEEE, "An Application-Specific Protocol Architecture for Wireless Microsensor Networks", *IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS*, VOL. 1, NO. 4, pp.660-670, OCTOBER 2002.
- [11] Youssef EL FATIMI, Fihri Mohammed, EZZATI Abedallah, "Improvement of Leach Routing Algorithm Based on the Use of Game Theory and Centralized Adjustment Mechanism", *International Journal of Applied Engineering Research* ISSN 0973-4562 Volume 13, pp. 8223-8231, Number 10 (2018).
- [12] Salim EL KHEDIRI, Nejah NASRI, Anne WEI, Abdennaceur KACHOURI,"A New Approach for Clustering in Wireless Sensors Networks Based on LEACH", *Procedia Computer Science* 32, pp.1180 – 1185, 2014.
- [13] D. Mahmood, N. Javaid, S. Mahmood, S. Qureshi, A. M. Memon and T. Zaman, "MODLEACH: A Variant of LEACH for WSNs," *2013 Eighth International Conference on Broadband and Wireless Computing, Communication and Applications*, pp. 158-163, 2013.
- [14] G. Rama Subba Reddy, Dr. S. Balaji, "A Review on Different Types of LEACH Protocol for Wireless Sensor Networks", *International Journal of Scientific Research in Computer Science, Engineering and Information Technology*, pp.840-844, July-August 2017.
- [15] M. Madheswaran and R. N. Shanmugasundaram, "ENHANCEMENTS OF LEACH ALGORITHM FOR WIRELESS NETWORKS: A REVIEW", *ICTACT JOURNAL ON COMMUNICATION TECHNOLOGY*, Vol.04, pp.821-827, DECEMBER 2013.
- [16] F. Xiangning and S. Yulin, "Improvement on LEACH Protocol of Wireless Sensor Network," *2007 International Conference on Sensor Technologies and Applications (SENSORCOMM 2007)*, pp. 260-264, 2007.
- [17] S. Rahim et al., "Circular Joint Sink Mobility Scheme for Wireless Sensor Networks," *2015 IEEE 29th International Conference on Advanced Information Networking and Applications Workshops*, pp. 311-319, 2015.
- [18] M. B. Rasheedl, N. Javaid, A. Javaid, M. A. Khan, S. H. Bouk, Z. A. Khan, 'Improving Network Efficiency by Removing Energy Holes in WSNs', *J. Basic. Appl. Sci. Res.*, 3(5)253-261, 2013.
- [19] Padmalaya Nayak, Ph.D, Pallavi Shree, 'Comparison of Routing Protocols in WSN using NetSim Simulator: LEACH Vs LEACH-C', *International Journal of Computer Applications* (0975 – 8887) Volume 106 – No.11, November 2014.
- [20] Hamdy H. Elsayed, 'Some WSN Characteristics Effects on the performance of LEACH and MODLEACH Protocols', *Appl.Math. Inf. Sci.* 13, No. 3, 361-368(2019).
- [21] Hamdy H. Elsayed, Hassan Shaban Hassan , 'Performance Comparison of Various Hierarchical WSN Routing Protocols', *Int. J. Advanced Networking and Applications*, Volume: 11 Issue: 02 pp. 4218-4223, ISSN: 0975-0290, 2019.
- [22] Hamdy H. Elsayed, 'Effects of Number of Nodes and Network AreaSize Parameters on WSN Protocols Performances', *Int. J. Advanced Networking and Applications*, Volume: 11 Issue: 02 pp. 4244-4251, ISSN: 0975-0290, 2019