

A Cross-Layer Enhanced Efficient LEACH Protocol for Data Forwarding in Wireless Sensor Networks

Mr.C.Prakash

Research Scholar, Department of Computer Science, Nandha Arts and Science College(Autonomous), Erode.
E-Mail:prof.cprakash@gmail.com

Dr. K. R. Ananth

Associate Professor & Head, Department of Computer Science, Nandha Arts and Science College(Autonomous), Erode.
E-mail:sapujaa@gmail.com

ABSTRACT

Wireless Sensor Networks is one of the leading and broadening research area by all the researchers since it has got its unique importance in day today's life. This research paper proposed a novel protocol for efficient data forwarding namely Enhanced Efficient Leach Protocol with Novel Cross Layer Technique (EELP-NCLT) to forward the data in the WSN. In the proposed structure, the role of cluster head (CH) is shared by the nodes in network so the utilization of energy is balanced among the nodes for energy harvesting. A node continues with data transmission to keep up the neutral operation to enhance network lifetime if it does not act as CH. To minimize the networks energy consumption, optimal number of clusters in network is analyzed. Simulations carried on NS2 Simulator tool exhibit noticeable performance improvements in embracing with proposed EELP-NCLT protocol unlike the conventional scheme in terms of lifetime and network throughput specifically in constrained conditions. To optimize the performance of relaying, a novel cross layer TDMA method is additionally exhibited. The network protocol is investigated by considering the performance metrics such as data arrival rate, packet drop ratio, packet delivery ratio, energy consumption, network traffic, delay and network lifetime. The proposed protocol is compared with the baseline techniques. The result shows that the proposed protocol works better than the existing in terms of all performance metrics.

KEYWORDS: Clustering, Energy, LEACH, TDMA, PDR, Latency, Network, WSNs.

How to cite this article: Prakash C, Ananth KR. A Cross-Layer Enhanced Efficient LEACH Protocol for Data Forwarding in Wireless Sensor Networks. *Int J Drug Deliv Technol.* 2026;16(18s): 505-514. DOI: 10.25258/ijddt.16.18s.54

INTRODUCTION

The Sensor Network is an infrastructure based network consisting of elements linked to the connectivity of sensor nodes and battery. It allows the user the ability to take just-in-time steps to reduce risks. There can be different fields where the WSNs usage is very high such as military, government, hospitals, industries etc. The sensor network ecosystems are linked to the real-time world linked to the IT architecture. Network-based sensors are identified as a technology that will be significantly enhanced in the next few years with many advanced techniques. WSNs are collection of sensor nodes that are grouped together in a broad range that is known as Internet of Things which is a dominating area in research. One of the primary difficulties faced in the implementation is because of its wide deployment in unattended area and huge consumption of energy. Since sensor nodes are dependent with its small battery, many number of sensors required to deploy in a wide area. So to fix this issue, expanding the network's lifetime is a remarkable solution in WSN conventions and data

transmissions. Among the other protocols, LEACH is one of the famous hierarchal technique algorithms that partitions network as clusters in which the nodes transmit their packets to CHs in a Time Division Multiple Access (TDMA) manner. After every TDMA, cluster head gets aggregated and forward the packets in a dynamic way from source to sink in the network space. The energy is distributed consistently among every node, which keeps the network balanced every time. But still the WSN depends upon the successful packet delivery from source to destination; there is a need for dedicated data forwarding method to make the network more reliable.

This paper proposes a novel protocol with duty cycle based clustering method named EELP-NCLT that is perfect for sensor networks. In particular, two duty cycles are proposed to keep up an Energy Neutral Operation. Initially, the node embraces a CH duty cycle for undertaking the role of CH that is designed by considering nodes capability in harvesting energy. Then for transmitting data, duty cycle that is dependent on nodes energy and data generating range is pursued during non CH (NCH)

rounds. Further, optimal percentage of CH (OCHP) is inferred in network terms of latency, energy and data transmission requirements. But the OCHP does not always limit the utilization of energy as in EELP-NCLT protocol. EELP-NCLT has numerous dominance over other techniques that are used in previous systems. To begin with, the selection of CH in EELP-NCLT is deterministic instead of being founded on a probabilistic methodology that requires various rounds equivalent to number of nodes before the required level of CHs is maintained.

In the Wireless Sensor Networks, routing of the data packets from sender to receiver must be well-organized to sustain the performance of the protocol and to boost the lifetime of network. Generally the data packets are transferred from one end to other end through CH by forming clusters. Here clustering is achieved by using the optimized clustering algorithm. Formulated the problem of optimal CH range for clustering energy harvesting based networks that ensures Energy Neutral Operation, while fulfilling the requirement of latency and bandwidth. The issue is then resolved by utilizing an iterative strategy for which complexity is limited by quantity of nodes in network.

To keep up the energy harvesting ratio in a better way, CH selection scheme is proposed that are completely based on duty cycling. This helps to select the CH efficiently even when the energy sources varies frequently time to time in the network space. In LEACH, the number of rounds and nodes must be equal before maintaining the CH percentage that is required for data transmission. Only the harvesting rates of average nodes are required in the proposed system unlike previous systems. Besides, the proposed convention is appropriate in non-homogeneous systems, in which nodes have distinctive abilities and QoS prerequisites. In proposed, two duty cycles for CH determination and transmission of data that is dependent on Energy Neutral Operation is designed.

1.1 LEACH PROTOCOL

LEACH protocol alludes to Low Energy Adaptive Clustering Hierarchy [6], which is structured as routing protocol for WSN. Generally, there are three stages in cluster routing, cluster heads generation, cluster formation and communication between clusters. Likewise

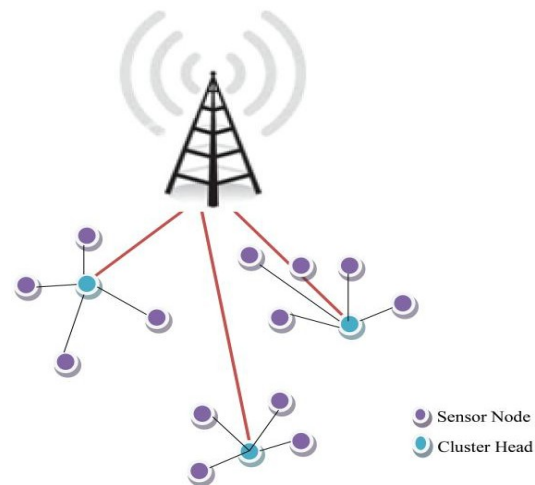
LEACH incorporates these three stages, simply blending the initial two stages into one that is creation of clusters and cluster communication. Thus, LEACH algorithm contains the cluster setup and stable transmission of data. With respect to the determination of CHs, LEACH follows equal probability strategy, choosing cluster heads randomly and distributes the energy equally among every node in network. Thus LEACH decreases the utilization of energy, maximizes network lifetime. The LEACH procedure is periodical, and every period incorporates formation of clusters and transmission of data, and here a period is a round is shown in as Figure 1.

1.2 OPTIMIZED CLUSTERING

Optimized technique for clustering depends primarily on Euclidian distances and selection of CH that relies upon residual energies of nodes[7]. So here central node

Figure1:LEACH Protocol

gathers the data about node id, position and remaining energy of all nodes and stores this data as list in central node. After receiving the required information from all nodes it begins the process of clustering using proposed clustering algorithm (k-mean) [8].



1.2.1 Algorithm

1. To form the nodes as “k” clusters, initially “k” number of centroid is taken randomly.
 2. Euclidian distance from every node is calculated and assigns it to the nearest centroid.
- The initial clusters are framed. Assume there are n nodes such that every single one node belongs to R_d . The issue of finding minimal variance of this nodes is that of finding k centroids $\{m_b\}_{b=1}^k$ as follows,

$$\min \sum_{i=1}^n (\min d^2(X_i, m_b)) , \text{ for } i = 1 \text{ to } n,$$

where $d(X_i, m_b)$ indicates Euclidean distance among X_i and m_b . $\{m_b\}_{b=1}^k$ refers to cluster means or cluster centroids.

4. Position of centroid is recalculated in every cluster and the change in centroid position is verified from the previous one.
5. If the change is encountered in centroid position, then step 2 must be followed, else clusters are decided and process of clustering ends.

2. LITERATURE SURVEY

A new way reconfigurable smart interface sensors introduced for successful delivery of packets in IoT environment [1]. Though it has running in a parallel real time environment, the life time of network is less due to large capture of data. Classification of energy efficient protocols study has been examined and compared all the protocols and it is noted that the throughput and packet delivery ratio is less in real time environment [2]. With the availability of limited sensor nodes efficient energy protocols are identified and discussed the challenges of cluster based protocols [3]. To reduce the energy the energy efficient communication protocol is proposed to maximize the network lifetime, but due to its long range the protocol fails to with stand in real time environment [4]. Energy harvesting techniques is been implemented and the same is discussed by the author to reduce energy [5]. The author proposed a novel LEACH protocol for power efficient to make the communication more reliable, but due to direct transmissions the protocol fails to work in large size of networks[6].

Parallel version of k-means clustering technique has been proposed to provide faster cluster solutions. But it has disadvantage in enhancing the lifetime of network [7]. For network operability the cluster techniques has been proposed and fuzzy logic system has been imposed to balance the energy consumption, but still the protocol creates an imbalance during the transmission while loading large coverage data [8]. K means cluster algorithm is proposed [9] for enhanced selection of CH via the value of Received Signal Strength (RSS). For continuous flow of packet delivery alternate choice of CH is made. Finding shortest path reduces the consumption of power. Additionally to reduce the data cost, compression technique is followed. But the protocol faced increase in latency time and overhead. In this method list routing with the assistance of table from where every node gets most limited path to destination from source is followed [10] but results in increase in traffic and energy consumption. Energy effective routing is divided into four primary plans such as Communication Model, Network Structure, Reliable Routing and Topology Based routing [11]. The routing conventions that belongs to second classification can be additionally named Query-based or Coherent and non-lucid based or Negotiation-based. The routing conventions with the third classification can be additionally named Mobile Agent-based or Location-based. The routing conventions having a place with the fourth classification can be additionally divided into Multipath based or QoS-based. An investigative study on energy effective routing conventions for

given WSNs is done. In this paper, initially the characterization is proposed, and is extended, to make more energy consumption. New conventions are being used in recent times to perform various tasks and effective conveyance in huge traffic. Thus, attention is given to delay and throughput [12]. This article shows the advancement of WSN MAC conventions in four classes: synchronous, multi channel, asynchronous and frame slotted. These structures are assessed by vitality productivity, data conveyance execution, and overhead expected to keep up a convention's systems. In [13] three routing conventions and their issues and difficulties are discussed and compared. RVSRRP is proposed to enhance the lifetime of the network and not discussed about the traffic issues in WSNs [14]. EH-WSN [15] is proposed for energy harvesting to increase the energy and decrease the latency, but the protocol fails to deliver data successfully on time due to traffic. ECO-LEACH is proposed for duty cycling energy harvesting but fails to dominate the dead node. The broadcast of network by node increases the error in delivering the data and it maximize the delay [16-18]. The protocols works with large arrange of networks but results indicates that the protocol took more time in capturing the data between nodes and WSN face delay than expected. Multihop energy clustering proposed to enhance the energy consumption but due to continuous overload the protocol fails to work in unattended area. The new protocol is proposed to find the alternative route to maximize energy but the overhead is increased [19].

PROPOSED METHODOLOGY

Efficient routing must be done for fast communication of data packets in wireless sensor network, to keep the better performance of network and to avoid latency. In our proposed system, Energy Efficient LEACH protocol is implemented for achieving the better routing in network for to achieve best data transmission. Once the routing is achieved, the data packets are sent as clusters through cluster head (CH). Sink node in network is responsible for sending the data packets to destination. If the sink node sends the packets directly to the nodes, chance of data failures is high and this in turn increases latency in network. So the data's are sent to the CH by the sink node and the CH directs the packets to destination via communication nodes. In network, anynode can act as CH, the role of cluster head changes frequently based in the energy level and capacity of node. CH also monitors each node whether it carries the data packets that are forwarded or if there is any data loss during transmission, this helps to rectify the packet loss, failures and traffic in network. Additionally TDMA scheme is been implemented to optimize the network

performance and it is bifurcated into slots to check the prospective relays active node transmission and best transmission relays. This helps in analyzing the clusters bandwidth usage, consumption of energy and latency. Our proposed protocol stands unique than the previous schemes in parameters of data arrival rate, packet drop ratio, packet delivery ratio, energy consumption, network traffic, delay and network lifetime.

- The five major techniques used such as,
- Clusters Selection
- Path Selection
- Fitness Proportionate Selection
- EELP-NCLT - Forwarding Data
- TDMA method

Initially the node which captured the data will select the nearest node for forwarding the data to reach the clusters and then the end node will select the nearest cluster and sends the captured data. Once the captured data is received by the CHs it will select the finest path for forwarding to reach the destination. It uses non linear constrained optimization technique to make the packets to forward. Then the node fitness is calculated in the search space by using fitness proportionate method. The task of the EELP-NCLT convention is partitioned into numerous iterations, with each comprising of a short setup stage pursued by a long data transmission stage. In setup stage of round t, node z turns into a CH only if the randomly obtained number is higher than threshold in internal [0,1]. It is given by the below equation:

Where $\pi > 0$ is the needed percentage of CHs and S is the nodes that is not progressed toward becoming CHs in last $1/\pi$ rounds. This function guarantees that CH node will never turn into CH again, until other nodes have fulfilled their turns. Chosen CHs welcome the non-CH (NCH) nodes to the clusters through beacons. NCHs will pick the CHs with the value of best received signal strength indicator (RSSI) from invitation beacon and choose their transmit powers

$$P_z(t) = \begin{cases} \frac{\pi}{1 - (t \bmod \pi)}, & \text{if } z \in S \\ 0, & \text{otherwise} \end{cases} \quad (1)$$

transmission is comprised of different TDMA outlines where in for every time slot T_s , P_{CH} CM transmits its packets to CH, while rest of C_{tx} changes to sleep mode. Toward the finish of TDMA frame, CH sends total packets that are received from CM to sink node at

most extreme power . Every cluster chooses its unique frequency/code channel from available resources to eliminate collision with its neighboring clusters.

In spite of the additions of LEACH, uniform dispersion of CHs does not give consideration to residual energy of nodes. Thus, the nodes that move toward becoming CHs first will drain their energies, thus decreasing the system availability that will eventually minimizes network lifetime. In this convention, selection of CH joins energy harvesting status of every nodes in network to such an extent that the nodes with higher relative rates for harvesting will progress in becoming CHs more regularly and with and with no confinement to node in becoming CH. It is expected that every node knows the correct energy status of the considerable number of nodes in sensor network. Subsequently, the threshold of CH determination in equation (1) is replaced by:

$$P_z(t) = \frac{N\pi(E_z^{bat} + E_z^{har})}{\sum_{i=1}^N E_i^{bat} + E_i^{har}} \quad (2)$$

Where E_i^{bat} - residual energy

E_i^{har} - harvesting rates of node i

N – Total nodes in the network.

Where *fitness* is calculated

$$(x) = (f)/\text{Number of Nodes} \quad (3)$$

$$\text{CH Selection} = (x) \text{ Best fit Node} \quad (4)$$

2.1 Flow of EELP-NCLT Protocol

EELP-NCLT protocol carries the following flow process depicted in fig 2. Initially the formations of network are done, and then formation of cluster and CH selection is made. Energy utilized by every node is analyzed. If the lifetime of the CH that is chosen initially ends, the output result is achieved if not the next round starts. Then the process of energy efficiency started in each node by calculating the fitness value. Finally the TDMA scheme is implemented where the single node or active node sends the data to the CHs since the fitness is calculated, while other node is in the mute state or sleep state. In the other end CHs transfer the data to the destination and eliminate the accident or crash between the clusters.

The sink node plays a major role in transferring of data, but if the sink node directs the packets directly to selected nodes in network, there occurs huge latency and data failure. So clustering technique is been followed by optimized clustering algorithm. The sink node transfers data packets to CH and then the CH sends to destination

through nodes. CH also does the job of monitoring the nodes that carries the data packets to detect the packet drops. The nodes energy capacity and amount of data packets it carries are monitored and reported to sink node. The techniques proposed helps in reducing traffic and latency, increases PDR and avoids packet drops. The optimization of network is maintained by using TDMA scheme.

2.2 Novel Cross Layer Technique

To maximize the performance of the protocol smart routing is required for effective data transmission between the layers. The cross layer technique allows exchanging the information between the layers with minimal delay. In short it is also called the cross layer optimization. Here the CHs will give message to the application layer about the energy rating and other surrounding nodes in the WSN. Also other layers will inform about the channel status and resource allocations. During this NCLT the application layer will inform the PHL layer about the resource needed for the next hop information. So these types of direct communications will minimize the delay and enhance the timely data transmission in the networks.

Here the two neighboring layers are T_x and T_y and the delay is mentioned as $D^{DS_{TxTy}}$ and the direct communication is calculated as

$$D^{DS_{TxTy}} = \frac{DTxTy}{n-1} \quad (5)$$

4. IMPLEMENTATION OF NOVEL PROPOSED PROTOCOL

Implementation is done by analyzing the drawbacks of existing system in forming a network model are rectified and high performance is achieved. Here the major role plays the EELP-NCLT protocol in finding the routing path. To avoid data failure and latency, optimized clustering technique is followed. Our implementation of network model is done NS2 Simulator as it is considered one of the most trusted one in evaluating the performance of protocols. Here the protocols compared are EH-WSN, ECO-LEACH and EELP-NCLT. This research work uses TCL commands and C++ language for NS2 simulation.

5. PERFORMANCE EVALUATION

Table1:Experimental Simulation Settings

Parameter	Values
Nodes Count	500 -2000
Time Slot	100 ms
Data Packet Rate	0.5packets
Initial Transmission Range of Deployed Nodes	75m
Type of Traffic	Wireless
Initial Energy of Each Node	20 J
Sensing Range	10 m
Threshold Distance	75 m

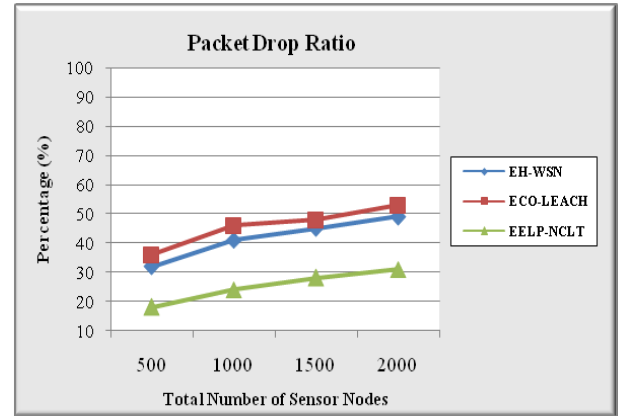


Figure 2: Packet Drop Ratio vs Nodes

6. PERFORMANCE METRICS

Performance metrics used to analyze the proposed EELP-NCLT protocol against EH- WSN and ECO-LEACH in terms of data arrival rate, packet drop ratio, packet delivery ratio, energy consumption, network traffic, delay and network lifetime.

7. RESULT AND DISCUSSIONS

7.1 Packet Drop Ratio Analysis

Packet drop ratio indicates how the packets travel from source to destination in WSNs. Here the packet drop ratio is minimized to 18% in newly introduced protocol EELP- NCLT when compared to EH-WSN and ECO-LEACH. It is noted that the proposed protocol works better than the existing and delivered the remarkable performance is shown in the Figure 2.

7.2 Packet Delivery Ratio Analysis

Packet delivery ratio shows that how much percentage of packets or datas has been delivered to the destination without any duplicate or noisy datas. It is noteworthy that EELP-NCLT protocol delivered packets in a successful manner compared to EH-WSN and ECO-LEACH protocols. EELP-NCLT protocol shows the delivery rate of 89% in the result during the simulator execution where other protocols marked only up to 75% of packet delivery ratio is shown in Figure 3.

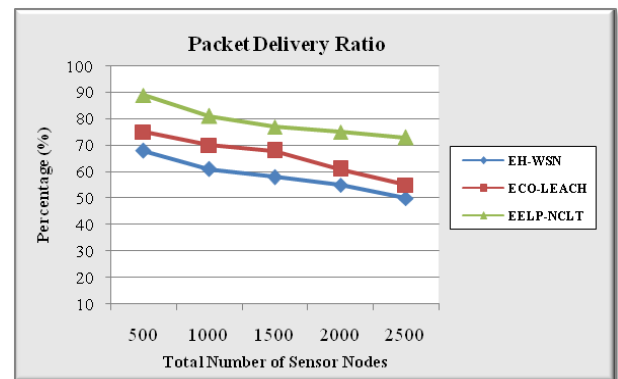


Figure 3: Packet Delivery Ratio vs Nodes

7.3 Delay Analysis

Delay is the latency time or time taken for data transmission from one end to another end. Here in this delay analysis it is clearly shown that the proposed protocol EELP- NCLT took minimum time to deliver

the packets compared to EH-WSN and ECO-LEACH protocols is shown in Figure 4.

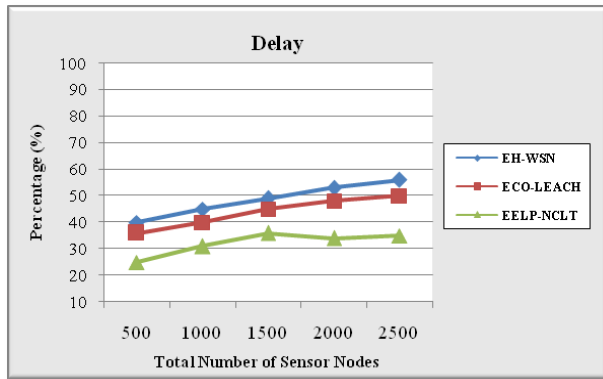


Figure 4: Delay vs Nodes

7.4 Energy Consumption

Energy consumption is how much energy is worn out during the data transmission in WSN from one end to other end. In this analysis it is clearly shown that the proposed protocol EELP-NCLT minimize the energy level compared to EH-WSN and ECO-LEACH protocols is shown in Figure 5.

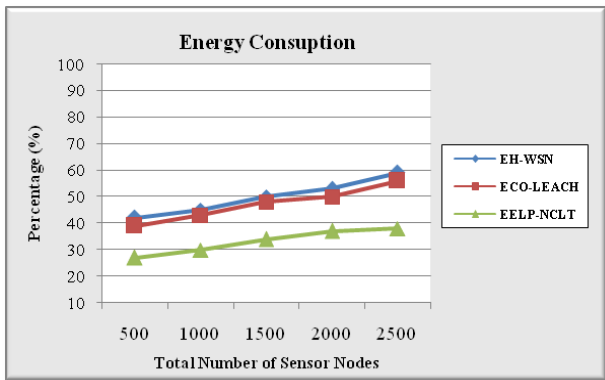


Figure 5: Energy vs Nodes

7.5 Data Arrival Rate

Data arrival rate is how much time taken to deliver the data without any duplicates in the wireless sensor networks, It also shows that how much noisy datas captured and eliminated. In this analysis the data delivery rate is high in EELP-NCLT protocol compared to EH-WSN and ECO-LEACH protocols as shown in the Figure 6.

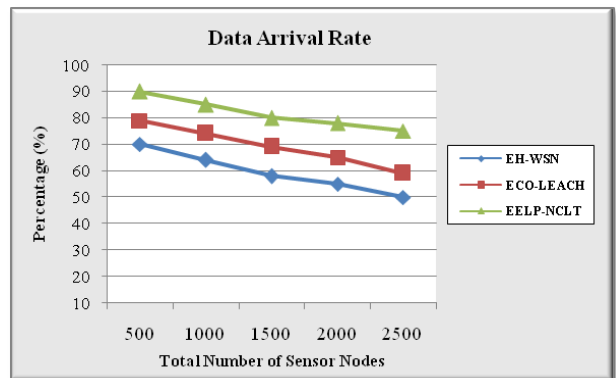
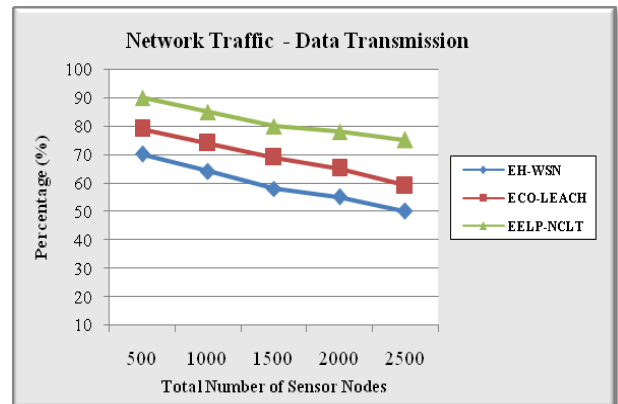


Figure 6: Data Arrival vs Nodes

7.6 Network Traffic Analysis

Network Traffic indicates the routing traffic during the data transmission or the amount of data transmitting at a given point of time. In this performance indicator the protocol EELP-NCLT shows high rate in data transmission even the load is high compared to EH-



WSN and ECO-LEACH protocols as shown in the Figure 7.

Figure 7: N/W Traffic vs Nodes

7.7 Network Lifetime Analysis

Network Lifetime signify that how long the network withstand successfully when the number of nodes get increased every time. The life span of the network is maximized in this proposed protocol EELP-NCLT up to 92% compared to EH-WSN and ECO-LEACH protocols as shown in the Figure 8.

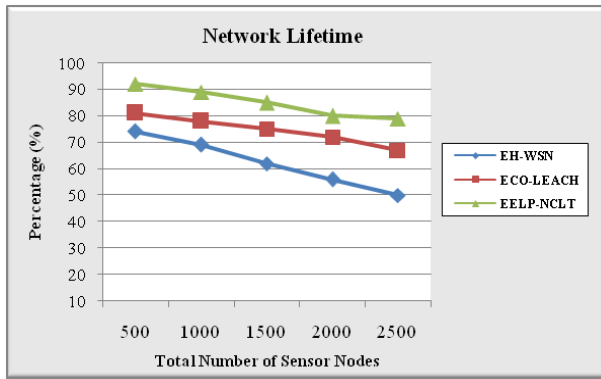


Figure 8: N/W Lifetime vs Nodes

8. CONCLUSION

Another energy harvesting method to LEACH convention is proposed called EELP-NCLT dependent on the strategy of duty cycling for assigning CH ensures with determined percentage and its optimal value was explored. Successful data forwarding is done with optimized routing and the ratio of delay is minimized in this protocol. An effective DC that guarantees consistent operation was developed for transmission of data based on nodes harvesting and arrival rates of data. The results acquired utilizing simulations showed improved system execution as far as energy, delay, lifetime and latency regarding benchmark conventions in both EH and battery controlled systems. Future advancements may consider position of nodes in cycle configuration and also various leveled and multi hop network.

9. REFERENCES

[1] Q.Chi, H.Yan, C.Zhang, Z.Pang and L. D. Xu, "A reconfigurable smart sensor interface for industrial WSN in IoT environment," IEEE Trans. Ind. Inf., Vol. 10, no. 2, pp. 1417–1425, 2014.

[2] N.A.Pantazis, S.A.Nikolidakis and D. Vergados, "Energy-efficient routing protocols in wireless sensor networks: A survey," Communication Surveys and Tutorials.,Vol.15,no.2,pp.551–591,

Second 2013.

[3] C. Wei, J. Yang, Y. Gao, and Z. Zhang, "Cluster-based routing protocols in wireless sensor networks: A survey," in International Conf. Comput. Sci. and Netw. Technol. (ICCSNT),2011, Vol.3, pp.1659–1663. 2011.

[4] W. R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "Energy efficient communication protocol for wireless micro sensor networks," in Proceedings of the 33rd Annual Hawaii International Conf. on Syst. Sci., pp. 10 pp. Vol.2. 2000.

[5] D. Benedetti, C. Petrioli, and D. Spenza, "GreenCastalia: An energy harvesting-enabled framework for the Castalia simulator," Proceedings of ACM ENSSys 2013, pp. 7:1–7:6, 2013.

[6] S. Lindsey and C. S. Raghavendra, "PEGASIS: Power-efficient gathering in sensor information systems," Proceedings, IEEE Aerospace Conference, Big Sky, MT, USA, 2002, pp. 3-3.

[7] Manasi N. Joshi, "Parallel K - Means Algorithm on Distributed Memory Multiprocessors",2003.

[8] Pedro A. Forero, Alfonso Cano, and Georgios B. Giannakis, "Distributed Clustering Using Wireless Sensor Networks", IEEE Journal of Selected Topics In Signal Processing, Vol. 5, No. 4, 2011.

[9] B. Baranidharan Assistant Professor, School of computing, SASTRA University, Tamil Nadu, India "A Survey on Energy Efficient Protocols for Wireless Sensor Networks" International Journal of Computer Applications(0975-8887) Vol 11, No.10, 2010.

[10] B.P.S Sahoo, Satyajit Rath, Deepak Puthal "Energy Efficient Protocols for Wireless Sensor Networks: A Survey and Approach" International Journal of Computer Applications(0975-8887) Vol 44, No18,2012.

[11] Nikolaos A. Pantazis, Stefanos A. Nikolidakis and Dimitrios D. Vergados, Senior Member, IEEE "Energy Efficient Routing Protocols in Wireless Sensor Networks: A Survey IEEE Communications Surveys & Tutorials,Vol.15, No. 2, Second Quarter 2013.

[12] Pei Huang, Li Xiao, Senior Member, IEEE, Soroor Soltani, Student Member, IEEE, Matt W. Mutka, and Ning Xi,Fellow, IEEE, "The Evolution of MAC Protocols in Wireless Sensor Networks: A Survey" IEEE Communications Surveys & Tutorials, Vol. 15, No. 1, First Quarter 2013.

[13] Nithyanandh S, Jaiganesh V. Reconnaissance Artificial Bee Colony Routing Protocol To Detect Dynamic Link Failure in Wireless Sensor Network".

International Journal of Scientific
& Technology Research,10(10), 3244–3251.

2019.

[14] Ms. Parul Tyagi, Ms. Surbhi Jain
“Comparative Study of Routing Protocols in Wireless
Sensor Network” International Journal of Advanced
Research in Computer Science and Software
Engineering Research Paper Volume 2, Issue 9, 2012.

[15] Nithyanandh S, Jaiganesh V, Quality of
service enabled intelligent water drop algorithm based
routing protocol for dynamic link failure detection in
wireless sensor network. Indian Journal of Science
and Technology 13(16): 1641-1647, 2020.

[16] M. S. Bahbahani and E. Alsusa, "A
Cooperative Clustering Protocol With Duty Cycling
for Energy Harvesting Enabled Wireless Sensor
Networks," in IEEE Transactions on Wireless
Communications, Vol. 17, no. 1, pp. 101-111, 2018.

[17] S. Peng and C. P. Low, “Energy neutral
clustering for energy harvesting wireless sensors
networks,” IEEE International Conf. Netw. (ICON),
pp. 1–6, 2013.

[18] L.Yang, Y.Lu, Y.Zhong, X.Wu and
S.X.Yang, “A multi-hop energy neutral clustering
algorithm for maximizing network information
gathering in energy harvesting wireless sensor
networks,” Sensors, Vol. 16, no. 1, p. 26, 2016.

[19] Nithyanandh S, Jaiganesh V. “Dynamic
Link Failure Detection using Robust Virus Swarm
Routing Protocol in Wireless Sensor Network”.
International Journal of Recent Technology and
Engineering.8(2),1574-1579. 2019