

RESEARCH ARTICLE



An Optimal Energy Utilization of Cluster Routing Protocol for Wireless Sensor Network in Restricted Area

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Abstract

Objectives: To efficiently monitor the highly confined area by using security measurement methods to enhance the lifetime of a large area coverage network. **Methods :** the modified nodes are included in the normal execution process of the network to calculate the efficiency and lifetime of the WSN. With the help of the simulation and analysis process, the proposed protocol is found to be more powerful to impact the sustainability of the network by prolonging the lifetime of the nodes. To perform this operation, the following parameters are considered: Area of the monitoring area, Number nodes, Sink portion, Energies of radio amplifier systems, Data aggregation, node electronics, and data packet length. **Findings:** The proposed optimal energy cluster routing protocol finds the best topological structural protocol to select the cluster head with optimal connectivity path with other nodes in a group. The data of energy utilization, data communication rate between nodes and cluster head, and analysis of the number of alive nodes concerning time are obtained. **Novelty:** the proposed Optimal efficient cluster routing protocol (OECRP) selects the cluster head by considering energy consumption, cluster sustainability, and its proper communication with other nodes. OECRP is used to develop the optimal topological structural protocol to connectivity path with other nodes in a group.

Keywords: Heterogeneous network; Lowenergy adaptive clustering hierarchy (LEACH); optimal efficient cluster routing protocol (OECRP); Network lifetime; Cluster head selection

1 Introduction

In recent times, Wireless Sensor Networks (WSN) is in many sectors like military, environmental monitoring, medical surveillance, underwater, etc., where human activities are minimal. [Figure 1](#) shows recent applications in wireless sensor network communication process in the particular qualities of the underground climate. A group of micro sensor nodes constitute a wireless sensor network and are deployed in a particular area with at least one sink or base station.

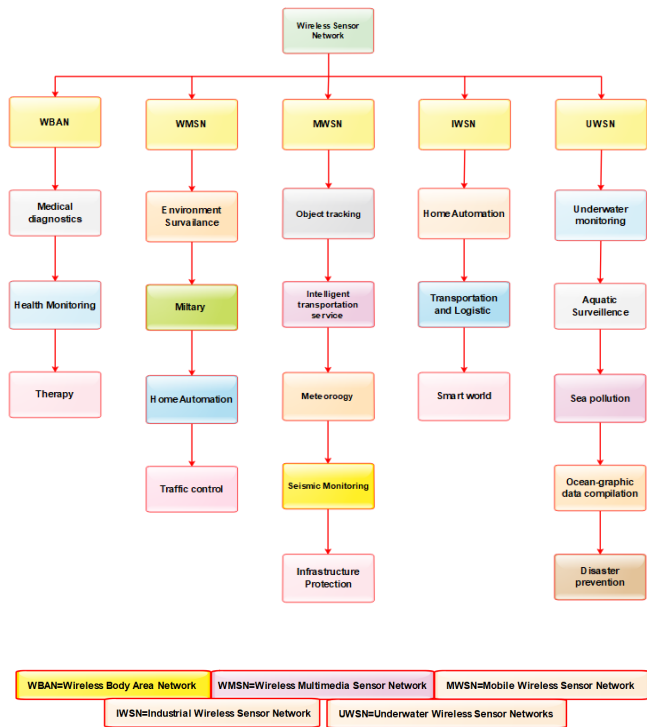


Fig 1. Wireless sensor network application

In the wireless sensor network, there are different kinds of sensor nodes which include source sensor node (normal node), intermediate sensor nodes (cluster head), and base station⁽¹⁻³⁾ as shown in Figure 2.

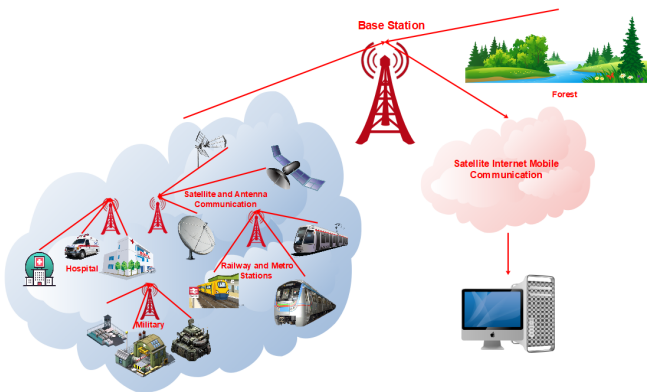


Fig 2. Fundamental communication process in wireless sensor network

1.1 Research Gaps

This micro sensor nodes monitor the environmental and physical parameters like heartbeat, temperature, pollution and so on. The sink gets the data from the sensor node devices and then sends it to the user through cluster heads. The energy consumption is due to data collection, processing, transmitting, or receiving of the packets. From the observations, energy consumption is the major constraint in a wireless sensor network. In addition to this, the redundancy of data also contributes to a decrease in energy efficiency. Increasing the network lifetime with an economical energy supply is a challenge for the wireless sensor network. Many studies on wireless sensor network in this aspect is gaining importance and establishes the importance of routing protocols. A

remote communication system technology in a restricted underground zone is fundamentally impacted on unconventional channel distribution features. Karpagam introduces a methodology of a model radio wave distribution or propagation in 3.2 GHz and 6.0 GHz of frequency groups appears in form of narrow curve shape decoration in multiple aspects⁽⁴⁾. Gomathi et al. introduced a model of consists a signal to noise ratio it is called Propagation Path Loss (PL) that portrays the loss of power against distance among transmitter and beneficiary for a passage climate⁽⁵⁾. T. Priya et al. introduced a Structure Aware Self Adaptive (SASA) wireless framework in the observation of underground coal mineshaft⁽⁶⁾. On controlling lattice sensor network sending and planning a collective system dependent on a customary guide procedure. SASA had the option of quickly identifying primary varieties brought out by underground breakdowns⁽⁵⁻⁷⁾. A model has been sent with 29 mica-2 motes in genuine coal mineshaft. It made a huge scope follow-driven recreation given genuine data gathered from the trials. A new taxonomy of leach descendant protocols has been proposed in this research work. The work concentrates on CH Selection and techniques to transfer data to classify LEACH variant protocols. Figure 3 depicts the taxonomy of leach-based routing protocols.

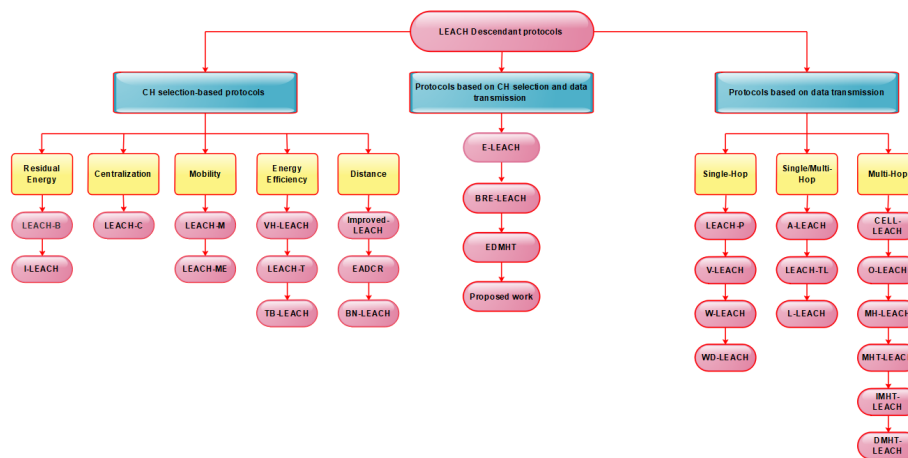


Fig 3. Taxonomy of various LEACH protocols in a wireless sensor network.

2 Energy Model

Let us consider the N distributed nodes in an A*A zone and utilized a mathematical model of fundamental WSN energy dissipation of hardware that appeared in⁽⁸⁾. The communication between source and destination through wireless sensor network in a free space and the multiple way blurring (fading attenuation of signals) models framework as per the distance among transmitter and beneficiary (receiver), it means r^2 (power loss in free space) and r^4 (multiple ways fading)⁽⁹⁾. The amount of energy utilized in the transmission of l bit data over a distance of a d is equivalent to Equation.1, considering energy distributed from a transmitter to operate the radio-based devices and power amplifiers, etc. Furthermore, to get this data, the receiver distributed a specific quantity of energy equivalent to Equation.2.

$$E_T(i, r) = \begin{cases} iE_e + i\epsilon_{fs}r^2 & r < r_0 \\ iE_e + i\epsilon_{mp}r^4 & r \geq r_0 \end{cases} \tag{1}$$

$$E_R(i) = iE_e \tag{2}$$

Where E_e = electronics energy. ϵ_{fs} and ϵ_{mp} are the energies of radio amplifiers in various systems. Moreover, the nodes of the sensor consume E_{Dagg} (nJ/bit/signal) quantity of energy in case of information aggregation⁽¹⁰⁾.

3 OECRP Protocol

Usually, the cluster head utilizes the amount of energy that is greater than the member nodes. To stay away from the prior death of the node, the overall node in a network revolves to act as a cluster head. Along these lines, calculation incorporates a setup

stage with a consistent stage in every circle⁽¹¹⁾. Choice of routing tree and also cluster head development between the clusters head are operated in the setup stage. At a steady stage, the information is transferred from member nodes to a relating cluster head, at that point the cluster head will going to aggregate the necessary information and forward it to the parent node and up to the root nodes. Here, at that point, the root node will communicate with the base station straight forwardly.

3.1 Selection of Cluster Head

This part gives some brief details regarding our OECRP convention methods. An OECRP utilizes the overall left-over energy of node and normal energy levels of a network to choose a cluster head. Here $p_{optimal}$ is the cluster head optimal proportionality variable⁽¹²⁻¹⁴⁾. Here, we have utilized n_k to represent the quantity of the circles that are required for the cluster head in a node A_s and we also refer to this as a revolving epoch. To ensure the average of $p_{optimal}$ cluster heads each round, let every node A_s ($k = 1,2,3,\dots,N$) turn into a cluster head once for each $n_k = \frac{1}{p_{optimal}}$ adjusts. By our OECRP convention, we consider various estimations of n_k depending on the remaining energy $E(C_r)$ of a node A_s at around C_r' . Let the $p_k = \frac{1}{n_k}$, it can also be additionally viewed as an average probability in case of cluster head during n_k rounds. Here we utilized $E(C_r)$ for the indication of required energy at round C_r' for a network, that can be processed by Equation 3.

$$\bar{E}(C_r) = \frac{1}{N} \sum_{k=1}^N E_k(C_r) \tag{3}$$

We have given an estimation of $E(C_r)$ here to minimize the financial expenditure of calculation. In an event that absolute rounds of a lifetime of the network are known, here it is possible from our side to estimate the normal energy of every round in a network⁽¹⁵⁻¹⁷⁾. Most importantly, it is necessary to analyze the network lifetime L_t that is the complete iterations. E_{Sum} is the network energy at the initial energy state. Under the ideal condition, every node passes on simultaneously. $E_{iteration}$ will remains the same in every round in case of energy cost equivalent. L_t is known from the estimated Equation 4.

$$L_t = \frac{E_{Sum}}{E_{iteration}} \tag{4}$$

With a model of energy given in part 2, overall energy which is distributed across the network in a single cycle is represented as follows

$$E_{iteration} = i(2NE_e + NE_{Dagg} + C_n \epsilon_{mp} r_{CHtoBS}^4 + C_n \epsilon_{fs} r_{MNtoCH}^2) \tag{5}$$

Where 'i' is quantity of cluster, E_{Dagg} data aggregation cost consumed in the cluster head, r_{CHtoBS} is the normal separation among cluster head and base station, r_{MNtoCH} will be normal separation among member node and cluster head^(18,19). With an assumption of uniformly distributed nodes, Equation .6 can be formed.

$$r_{MNtoCH} = \frac{A}{\sqrt{2\pi i}}, r_{CHtoBS} = 0.776 \frac{A}{2} \tag{6}$$

With a setting of a subsidiary of $E_{iteration}$ regarding when 'i' = 0, at that point we use an ideal number of cluster heads as Equation. 7.

$$i_{optimal} = \frac{\sqrt{N}}{\sqrt{2\pi}} \frac{\sqrt{\epsilon_{fs}}}{\sqrt{\epsilon_{mp}}} \frac{A}{r_{CHtoBS}^2} \tag{7}$$

Bringing both the equations (6) and (7) in (5), we have acquired an energy $E_{iteration}$ distributed in a single cycle. Along these lines, we can process the lifetime L_t with equation 4.

Accepting that every node utilizes energy in every round consistently, the average energy of the i^{th} iteration is stated as

$$\bar{E}(C_r) = \frac{1}{N} E_{sum} \left(1 - \frac{C_r}{L_T} \right) \tag{8}$$

Utilizing the reference energy $\bar{E}(C_r)$, we can get Equation. 9.

$$p_k = p_{optimal} \frac{\bar{E}_k(C_r)}{\bar{E}(C_r)} \tag{9}$$

In which $p_{optimal}$ is the number optimal proportional cluster head. We are utilizing p_k as a probability threshold rather than $p_{optimal}$ and afterward utilize every node SN_k to decide for the cluster head or not in every cycle^(20,21). Hence the value of the threshold level can be known from the Equation. 10.

$$T(SN_k) = \left\{ \begin{array}{ll} \frac{p_k}{1 - p_{k(c,mod)} \frac{1}{p_k}} & SN_k \in G \\ 0 & \text{Others} \end{array} \right\} \tag{10}$$

$$\delta_k = \frac{1}{p_k} = \frac{\bar{E}(C_r)}{p_{optimal} E_k(C_r)} = \delta_{optimal} \frac{\bar{E}(C_r)}{\bar{E}_k(C_r)} \tag{11}$$

Equation 11 describes nodes with a large amount of remaining energy along with its more probability to turn into a cluster head more than the lesser ones. With Equation 9, here we can observe that the $p_{optimal}$ is the reference value of a probability p_k , that decides the revolving epoch δ_k and edge $T(SN_k)$ of the node SN_k . From a homogenous network, every node is outfitted with a similar starting energy, along these lines, the nodes utilize the same $p_{optimal}$ values as a reference point of the p_k . At the point when the network is heterogeneous, the values of reference of every node must vary regarding starting energy. In the case of a heterogeneous network, we have replaced the value of reference $p_{optimal}$ with a mass probability stated in equation.12.in the case of the normal and extraordinary node as Standard election protocol (SEP) convention⁽²²⁻²⁶⁾.

$$p_{normal} = \frac{p_{optimal}}{1 + \alpha\beta}, p_{special} = \frac{p_{optimal}(1 + \alpha)}{(1 + \alpha\beta)} \tag{12}$$

In which β is a special node fraction and also that's energy can be considered as an α time greater than normal ones. Hence p_k in an equation 9 becomes

$$p_k = \left\{ \begin{array}{ll} \frac{p_{optimal} \bar{E}_k(C_r)}{(1 + \alpha\beta) \bar{E}(C_r)} & , \text{ Normal Node} \\ \frac{p_{optimal} (1 + \alpha) \bar{E}_k(C_r)}{(1 + \alpha\beta) \bar{E}(C_r)} & , \text{ Special Node} \end{array} \right\} \tag{13}$$

Putting Equation 13 in 10, the probability of the threshold value $T(SN_k)$ can be known that can be utilized to choose a cluster head. At that point, the value of the threshold is straightforwardly associated with an initial and leftover energy of every node.

The selection of threshold edge $T(SN_k)$ has been utilized to choose that the node SN_k will be cluster head. Furthermore, the $D_{threshold}$ is the threshold distance in Equation 14 that has been included. Hence, in the case of distance among the existing cluster head and node was not as much as $D_{threshold}$, at that point the node couldn't be chosen as a cluster head. This behavior optimizes the cluster strategy effectively.

$$D_{threshold} = \frac{\sqrt{A_s}}{N * p_k} \tag{14}$$

Where N is the number of sensor nodes, p_k is the small portion of cluster head A_s is the area size to be observed,

3.2 Routing Tree

During information transmission, once after cluster arrangement, it broadcasts the message of mass in a coverage zone of a $2D_{threshold}$. An ID of nodes and also weight W was remembered for a message. At that point each cluster head has been contrasted to its weight and gained one in a weighted message, afterwards, the nodes with the greatest weight have been chosen as a parent node. A node of more modest weight at that point will be going to send a child message to a parent node and afterward, the node of maximum weight has been chosen as a root node in a routing tree. In an event that the node didn't get any messages about the child message or weight, it demonstrates as there will be none of the cluster heads across it. Hence it must speak along with those kinds of base station straightforwardly. Figure 4 represents the cluster plan of the OECRP convention. Here V-Z signifies both the cluster head and weight in a section. The Node Z receives the Weight message of the nodes V, W, X, Y, and it going to pick node W as its parent node. Similarly, node V and Y pick node Z as their parent

node⁽²⁷⁻²⁹⁾. Node X will pick node W as its parent node. Moreover, the heaviness messages of X and Z are obtained from W are comparatively lower than the own one, hence W speaks along with a base station straightforwardly. Convention of OECP develops directing tree which is appeared in Figure 4.

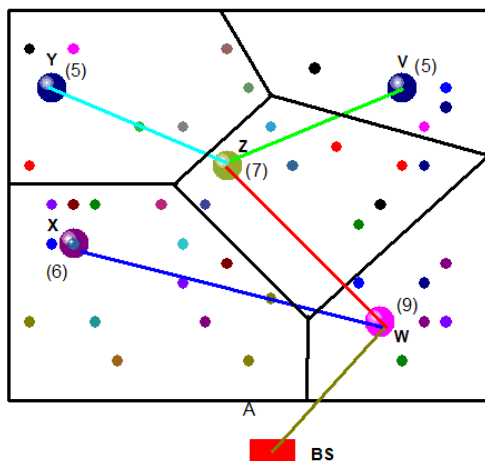


Fig 4. Fundamental structure of OECP cluster

Left-over energy across the node and also separation among the node and base station have been considered for the weight calculation.

$$W_k = \frac{E_k(C_r)}{E_{pri} * RSII}$$

In which E_{pri} is primary energy and $RSII$ is a received signal intensity identifier. Towards the starting of the complete network, values of RSSI are gained from communicating the signal testing of a base station⁽³⁰⁻³³⁾. Consequently, cluster heads that are nearer to a base station and having a sufficient amount of energy will have a high need to turn into the root node. At the point when two nodes having a similar weight, the parental node must be chosen from the IDs of the node⁽³⁴⁾.

4 Results and Discussion

Here, we have implement the developed protocol of OECP using NS2. The overall simulation results have tabulated in Table 1. The network topology produced from LEACH and OECP conventions has appeared in Figures 5 and 6. Normally nodes of cluster head across OECP have been conveyed all consistently since they considered that the distance is constrained for the optimization of cluster strategy.

Table 1. Criteria's for performance analysis

Criteria	Range
Area of monitoring Range (m)	(0,0)-(100,100)
Number of nodes	150
Sink position	(60,180)
$\epsilon_{fs}(pj/bit/m^2)$	10
$\epsilon_{mp}(pj/bit/m^2)$	0.0016
$\epsilon_e(nj/bits)$	60
$E_{Dagg}(nj)$	10
$E_O(J)$	0.8
Data packet length (Bytes)	550

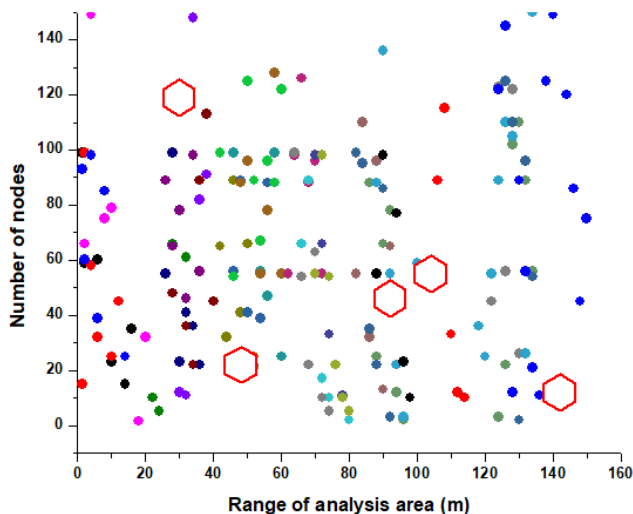


Fig 5. Conventional LEACH topology structure.

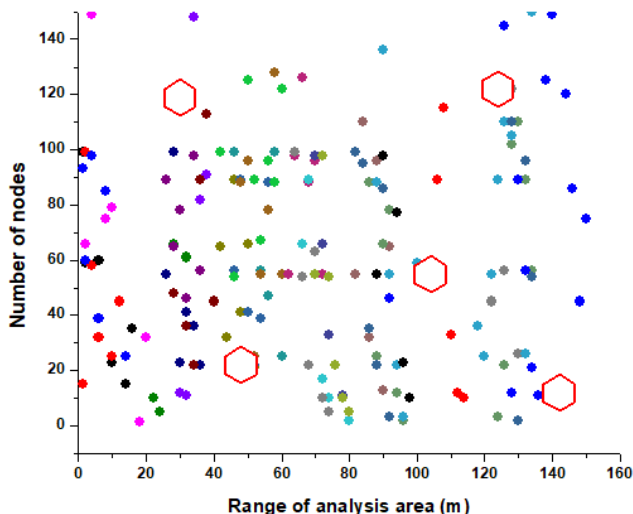


Fig 6. Proposed OECRP topology structure.

4.1 Comparison of OECRP and LEACH in the Heterogeneous Network

4.1.1 Variety of α and β

The primary energy of an ordinary node will be 0.6 J. Here we replaced the beginning essential energy of an extraordinary node and also the quantity of the unique node under changing the estimation of α and β . Later the protocol is simulated and also analyzed the variation of the network lifetime⁽³⁵⁻³⁸⁾.

With Figures 7 and 8, it is clear that it accurately shows the time interval for the survival of a network using a different kind of α and β . At a point when a negligible portion of the exceptional node is expanded in a range of 0.1 to 1, as demonstrated in Figures 6 and 7, we can notice that the filter doesn't take benefits of the expanding complete energy brought about by modification of α and λ . These manage every node similarly and don't consider the quality of the heterogeneous energy. Along with the Contraction of LEACH, the OECRP convention can completely consider the distinction of energy on the time of cluster head selection. The lifetime of the network expands too rapidly along with the node's energy. In this way, the presentation of an OECRP convention is superior to the LEACH.

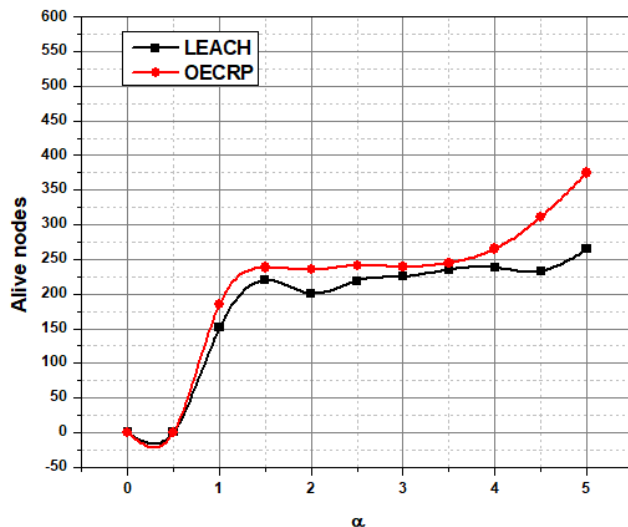


Fig 7. Network lifetime concerning α

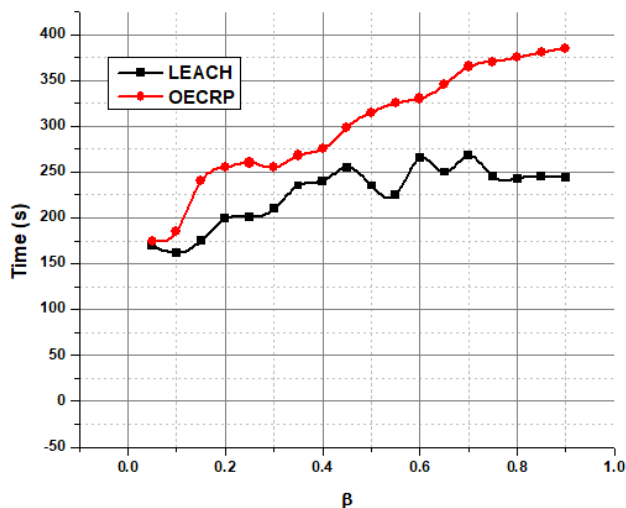


Fig 8. Network lifetime concerning β

4.1.2 Fixed α and β

Here we have completed some similar analysis using the exact values of the α and β to reach the differences in performance among LEACH and OECRP. From Figure 9, the connection has been introduced among the lifetime of the network and quantities of a live node at the values of $\alpha= 1.8, \beta= 0.3$. We have seen the time that the principal node which kicked the bucket and an hour of an ending node in OECRP convention happened after that in filter convention^(39,40).

The explanation will be that the OECRP convention is not just considered for choosing nodes that have more remaining energy to be cluster heads, yet additionally brings into thought the requirement of separation which improves the cluster scheme of the cluster.

Also, at the time of transmission of information, the development of a routing tree between every cluster head can adjust the energy utilization of the cluster head^(41,42).

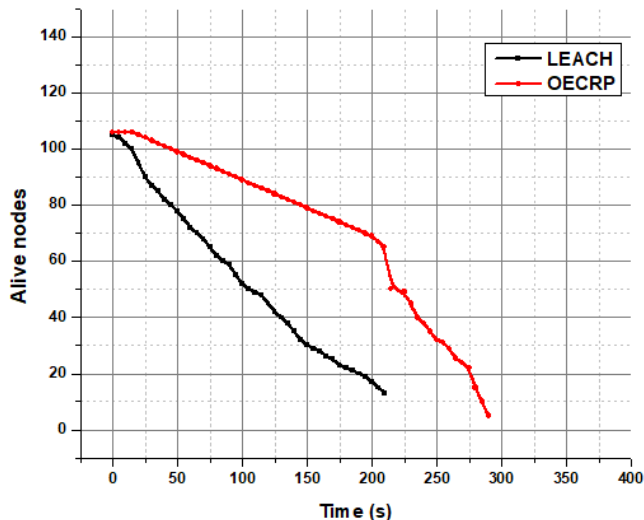


Fig 9. Synchronization between the number of alive nodes and network lifetime

4.2 Comparison of OECRP and LEACH in the Homogenous Network

4.2.1 In 150 m x150 m monitoring area

Here, the simulation has been done in these two kinds of protocols through the homogenous network and also made an examination of the network lifetime. The starting energy of every node will be 0.8 J. Figure 10 represents the lifetime of 150 nodes in a LEACH and OECRP convention while comparing the number for Figure 11 is 250. By this diagram, it is observed that the network lifetime of an OECRP is more than LEACH. Also, the difference between the lifetime curve of LEACH and OECRP is that the OECRP lifetime curve improves with the thickness of the node. This shows that OECRP thinks about the current remaining energy of nodes and the separation among cluster heads to upgrade the cluster strategy all the while, that not just adjusts just only load but also adjust energy utilization but additionally improves the network lifetime^(43,44).

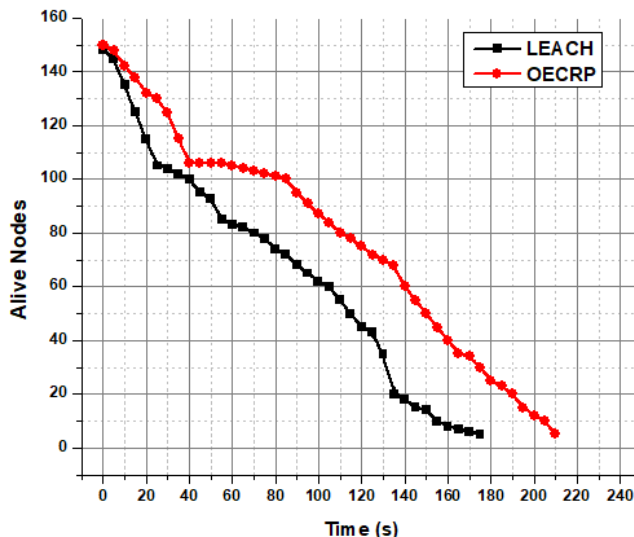


Fig 10. Network efficiency for 150 nodes concerning time

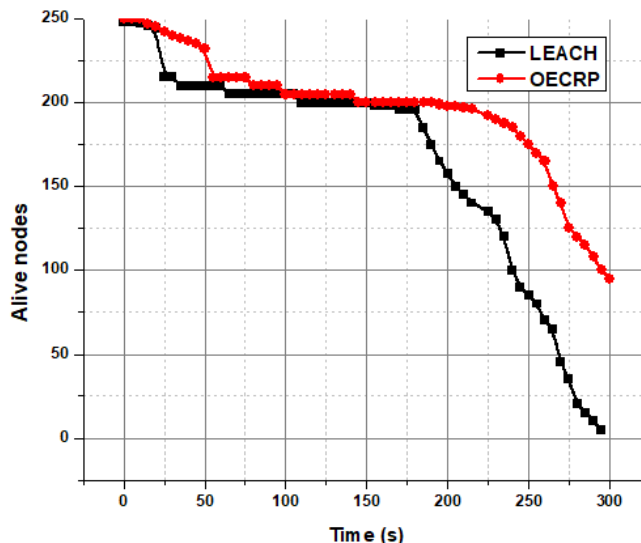


Fig 11. Network efficiency for 200 nodes concerning time.

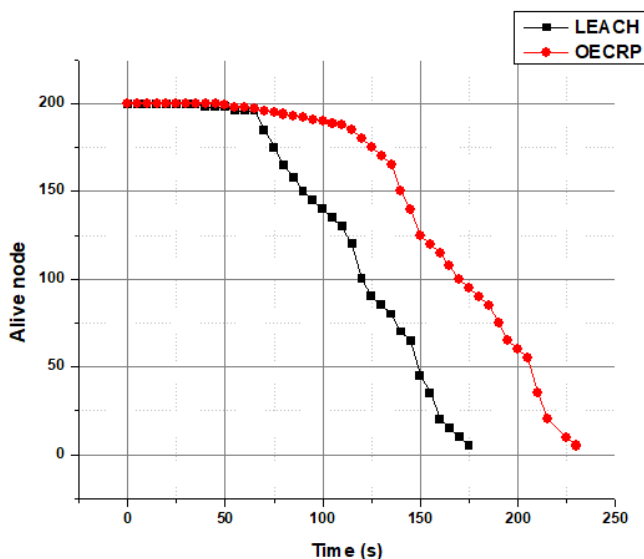


Fig 12. Network efficiency for 200 nodes concerning the time

4.2.2 In 200 m x 200 m monitoring area

Here, the simulation has been done in these two kinds of protocols through the homogenous network and also made an examination of the network lifetime. The starting energy of every node will be 0.8 J. Figure 12 represents the lifetime of 200 nodes in a LEACH and OECRP proposed method⁽⁴⁵⁾.

4.2.3 In 250m x 250m monitoring area

From the above, every node starts with the underlying energy of 2 J. We have simulated the conventions with various measures of nodes. The results of a simulation are shown in Figures 13 and 14 respectively. Those curves tend to 50, 150, 250, 350, 450, and 550 nodes. Individually, under the quantity of nodes 250, the behavior of conventions is superior to others that leads to one of the conclusions in which the thickness of nodes will move up in a region with an increment of several nodes. Moreover, it builds up an impedance between nodes, that impacts the transmission of information, utilization of huge energy, and tends to

the death eerier than the expectation.

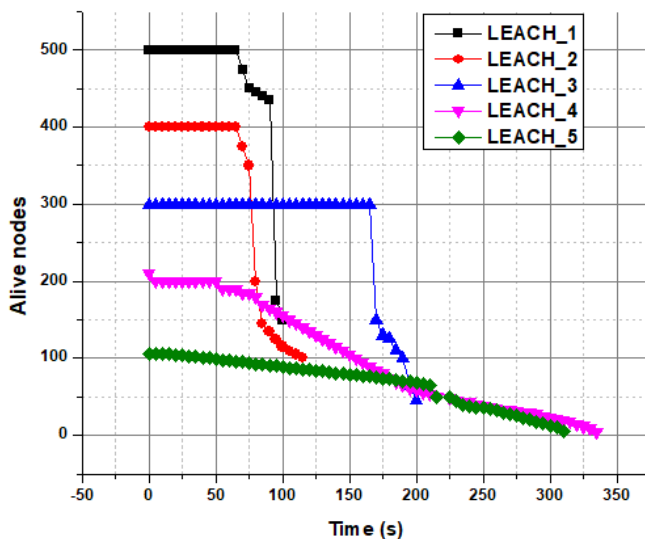


Fig 13. Various range of nodes lifetime using LEACH

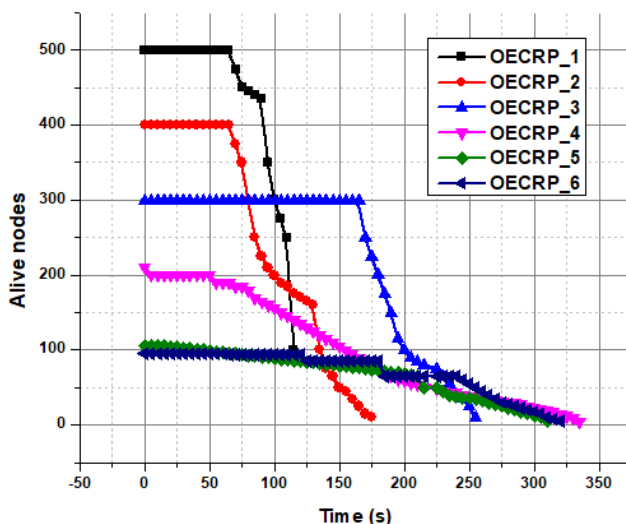


Fig 14. Various range of nodes lifetime using OECRP

Thus, it utilizes excess energy as transmission and reduces the lifetime of nodes. From Figures 13 and 14, it is clear that every curve represents the behavior of OECRP and also that will be superior to its LEACH counterpart. Through the instance of OECRP and nodes, death time is after that in LEACH, regardless of it is the starting node or the ending one. One of the reasons is OECRP thinks about the leftover energy of the nodes and the requirement of the distance between the cluster heads. This gives rise to the arrangement of nodes is more uniform, which makes the utilization of the energy all the more even also, minimizes the energy lost, and extends out the lifetime of the system⁽⁴⁶⁻⁴⁸⁾.

4.2.4 Comparison of LEACH, LEACH-C, and OECRP

Here we have simulated the overall behavior of LEACH, LEACH-C, and OECRP for the number of 60, 200, 300 nodes at the time of base station in the location of (60, 60) in this work. A LEACH-C selects the cluster head as per global guidelines. The creation of a cluster head carries with the topological placement of the node itself and separation by the base station. That will

enhance the rule of LEACH-C conveniently.

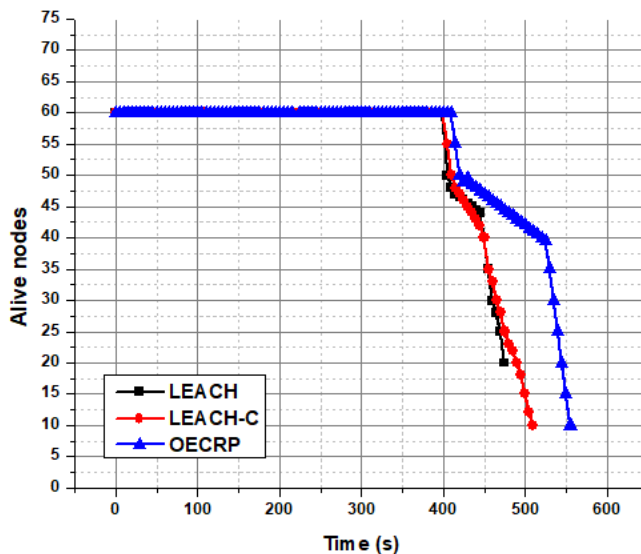


Fig 15. Network lifetime of three methods concerning 60 nodes.

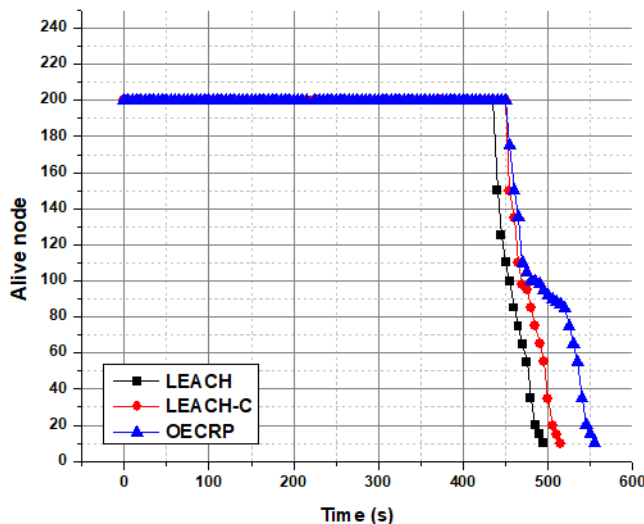


Fig 16. Network lifetime of three methods concerning 200 nodes.

From the Figures 15, 16 and 17, OECRP will have good characteristics with more lifetime of the nodes compared to the other two. The benefit is highly evident in pace along with an increment of node quantity. OECRP convention thinks about what has been specified here just as framing a routing tree depending on the weight of the node. In this situation, regardless of its cluster head or non-cluster head node, the utilization of the energy is more adjusted. It also avoids fewer energy nodes as a cluster head and improves the lifetime of the network.

Table 2 shows the performance analysis of network lifetime and energy consumption of various conventional methods with the proposed method. Figures 18 and 19 shows the analysis and comparison of energy consumption and network lifetime of various methods with the proposed method respectively⁽⁴⁹⁻⁵¹⁾.

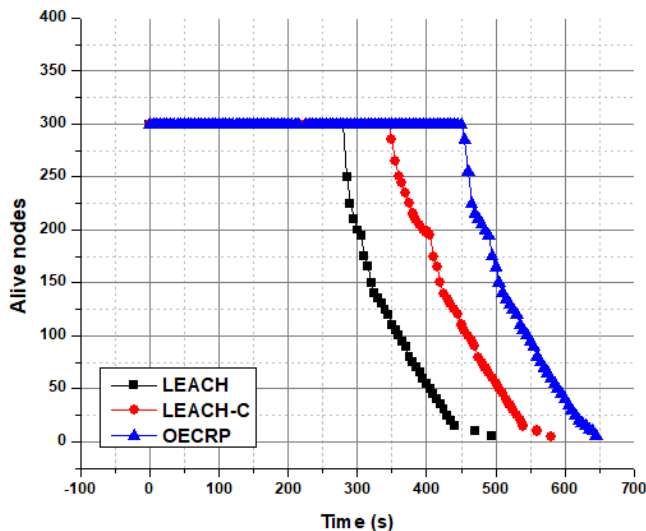


Fig 17. Network lifetime of three methods concerning 300 nodes.

Table 2. performance analysis of energy consumption and network lifetime between conventional methods and the proposed method

SI. No	Reference Methods Number	Protocol	Number Cluster nodes	Cluster head selection	Communication method	Scalability (%)	Network Lifetime (%)	Energy Consumption (%)	
1.	(8)	Residual energy	200	LEACH-B	Random, Residual energy	Single hop	50% (Good)	25	15
	(52)			I-LEACH	Residual energy	Single hop	75% (very Good)	59.04	62
2.	(16)	Distance	200	BN-LEACH	Residual energy	Single hop	55% (Good)	52.61	28
	(17)			Improved-LEACH	Distance Residual energy,	Single hop	56% (Good)	25	32
3.	(18)	Energy Efficiency	200	TB-LEACH	Random	Single hop	45% (Limited)	20	55
	(19)			LEACH-T	Residual energy	Single hop	58% (Good)	60	23
	(21)			VH-LEACH	Residual energy	Single hop	81% (Very Good)	59.04	41.178
4.	(23)	Single hop	200	V-LEACH	Random	Single hop	60% (Good)	49.37	42
	(53)			W-LEACH	Random	Single hop	52% (Good)	60	13
5.	(54)	Multi hop	200	MH-LEACH	Random	Multi hop	57% (Good)	4.57	9
	(38)			MHT-LEACH	Random	Multi hop	59% (Good)	77.70	69
	(39)			IMHT-LEACH	Random	Multi hop	61% (Good)	55.31	23
6.	(40)	Single/Multi hop	200	LEACH-TL	Random, Residual Energy	Multi hop	75% (Good)	52.76	65
	(41)			BRE-LEACH	Residual energy	Multi hop	86% (Very Good)	55.73	55.73
	(44)			E-LEACH	Residual energy	Multi hop	80% (Very Good)	49	55
	(53)			L-LEACH	Random	Multi hop	79% (Very Good)	51	22
	(16)			EDMHT-LEACH	Residual energy	Multi hop	83% (Very Good)	88.43	25
				Proposed	Proposed OECRP	Distance, Density, Residual energy	Multi hop	86% (Very Good)	90.25

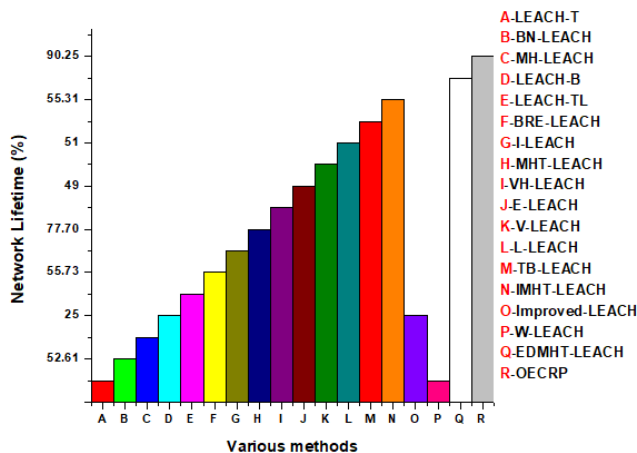


Fig 18. Energy consumption analysis between conventional methods with the proposed method.

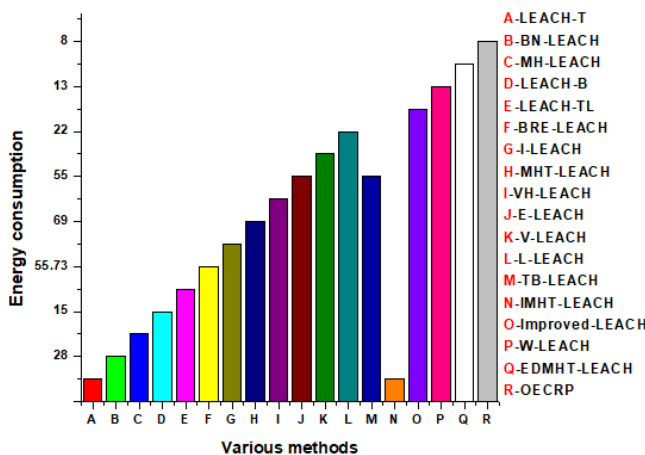


Fig 19. Energy consumption analysis between conventional methods with the proposed method.

5 Conclusions

The proposed method monitors more efficiently in a highly confined area such as 150M * 150 M, 200M *200M and 250M *250 M with 200 node density in each monitoring area with improved efficiency of 2.5%, 47.5 % and 55% respectively compared to conventional methods. It enhances 1.82 % network lifetime with respect to 300 nodes and 250 M * 250 M monitoring area compared to conventional methods. The result clearly shows that the proposed method selects the cluster head with highly optimal path integration between the nodes. Due to this approach, data communication between nodes efficiency increases to 3 % without creation of any overheads. The proposed OECP enhances the network lifetime of heterogeneous nodes by analyzing their characteristics in energy levels of 0.8J and 2 J. The proposed OECP resolves the constraint of distance consideration to the formation of cluster heads in the 100M * 100M monitoring area. The proposed topological structure avoids the 21.22 % of energy consumption due to packet loss during data transmission from node to node, node to cluster head, and cluster heads to the base station.

Limitation

In our proposed research work, there exists some limitations. When more nodes are communicated through the multi-path method in a highly restricted and remote area with high bandwidth in 5G technologies, there may be a loss of information due

to attenuation.

Future scope

The proposed research work helps in further enhancement of this approach in the future. The best-optimized results can be obtained using the optimization algorithm. The proposed work improves stability and wise selection of cluster heads. Image segmentation, artificial image intelligence, digital imaging, optimization can be implemented using this approach.

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