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Energy Efficient Routing Technique And Qos Provisioning For Heterogeneous Wireless Micro-Sensor Networks

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Abstract

In this research paper, an Energy Efficient QoS Routing Protocol for a WSN, i.e. QEERP has been proposed to reduce the energy consumption and increase the overall life-time of the networks. On evaluating the performance of the proposed algorithm QEERP, the participating normal node performs in terms of energy consumption 18%, 15% and 14% better with respect to LEACH and 12%, 9% and 7% better with respect to SEPE and further, on evaluating the performance of the advance nodes in terms of overall energy consumption, the energy consumption is reduced gradually and conserve 7% and 10% at 0.2 and 0.3 probabilities with respect to LEACH, however, adversely affected at 0.1 probabilities to be the CHs in a particular round. On evaluating the performance for all nodes, It shows that the average energy of all nodes conserve by 7% and 10% energy at 0.2 and 0.3 respectively but at the same time the proposed algorithm adversely affected by 0.7% with respect to LEACH because of less number of CHs are available to process the data that is received from the participating sensor nodes and to forward the same to the sink node.

The proposed algorithm gradually improves the average energy conservation of all participating sensor nodes on increasing the probability with respect to SEPE. It is also being observed that the proposed algorithm performing well when number of clusters and CHs are more in numbers.

1. Introduction

The wireless sensor network (WSN) is a collection of micro-sensors used to sense, collect, process, and transmit the data to the cluster heads (CHs). Further, the cluster heads are responsible to send the accumulated data to the sink node(s) to collect data from the different cluster nodes. The various challenging issues like the size of the sensors, memory size, processing speed, and data transmitting speed, energy efficiency, and computational power of the sensors always attract researchers and scientists towards the emerging area of WSN. The participating sensor nodes are generally based on the consumable power supply and prone to failure because of the size and available energy. In the recent past, the application of sensor technology has increased drastically in the environment, health care devices, surveillance, home appliances, vehicle tracking, detection, and IoT-based applications. Scientists and research scholars have shown their interest in sensor networks because the applications and demand for sensors-enabled devices have increased drastically. There are several challenges in WSN, and some are network lifespan, fault tolerance, reliability, security, data transmission, and QoS provisioning.

This paper proposes an algorithm for Optimized Energy Efficient Routing Technique and QoS Provisioning for Heterogeneous Wireless Micro-Sensor Networks.

The rest of the paper is structured in different sections. Section 1 discusses the introduction and related work, Section 2 is about the proposed technique, and Section 3 is described the performance evaluation of the proposed algorithm and compared it with LEACH and SEPE to validate the result. In the final section, the conclusion and future direction are presented.

1.1 Related work

In this paper [1], the authors discussed the resource management schemes in great detail for proposing a technique to improve the life span of the wireless sensor networks (WSN). The author has presented an optimized bio-inspired jumper firefly algorithm by increasing the transmission range of the participating sensor nodes towards the void region in the networks. The simulation based evaluation of the proposed algorithm gives better performance in terms of energy consumption than other conventional techniques in WSN. The proposed algorithm given in the paper provides superior results for energy consumption aspects. The setup cost has not been taken into consideration at the time of clustering by the author. The frequency of clustering always increases the overheads and setup cost.

In this paper [2], authors have proposed an algorithm based on a genetic algorithm to decide the optimum number of cluster heads (CHs) and the location of these CHs in a particular round. The performance analysis shows that the proposed algorithm outperforms the LEACH protocol in terms of average energy consumption. An agent CH was introduced in the proposed algorithm to manage the distance between CHs and Base station (BS). However, overheads are generated because the agent CH has not been taken into consideration during performance analysis.

In this paper [3], various techniques have been discussed to find the shortest path from source to destination by using Ant Colony Optimization (ACO) method. It was concluded that the pheromone value strengthens the quality of path for data transmission from the source to the destination node. However, validation and comparative study have not been given that could have supported justifications given in the cited work.

In this paper [4], the author has considered Bacterial Foraging Optimization Algorithm (BFOA), which inspired global optimization algorithms. A new fitness function was proposed for CHs selection based on residual energy and distance in this algorithm. A comparative study with EADC, DHCR, and Hybrid Routing was given, and the result shows that the proposed technique is performing better than conventional techniques. The performance of the proposed approach was analyzed on densely populated WSN.
In this paper [5] a comparative study was given, and particle swarm optimization technique, V-LEACH protocol, was compared with LEACH. The performance analysis shows that the proposed methods provide better results than LEACH in terms of energy dissipation in the transmission and increase the life span of the WSN. These techniques are not analyzed on a large network, and only a homogeneous network was taken into consideration to assess the performance of the networks.
In this paper [6], a trust-weighted secure data aggregation (TESDA) algorithm was presented to reduce the data aggregation deviation. The proposed mechanism to reduce redundant data transmission, detect the compromised behavior of the nodes, minimize the impact of the compromised nodes in aggregating results, and select CHs based on residual energy. The performance of TESDA was compared with secure data aggregation framework (SDAF) and shows that TESDA performs better. It has also been observed that the number of genuine nodes was increased, and these genuine nodes reduce the aggregation deviation. However, loss of energy in the computational process has not been considered, and no new technique for collaboration attack scenario was proposed.
In this paper [7], various aspects such as optimal deployment of nodes, node placements, node location coverage & linking, data grouping & routing, cross-layer design, clustering, routing, data aggregation, and fault tolerance, have been considered to resolve through a technique based on Meta-heuristic optimization algorithms. Comparative performance analysis was given in this paper. Further, many scopes design new strategies by using the best feature of the meta-heuristic techniques.
The proposed technique in this paper [8] utilizes combination of conventional gradient based clustering (using distance and remnant energy) with an evolutionary optimization method utilizing gravitational search algorithm (GSA) for improving the performance of WSN (large scale). At initial stage clustering, energy-balanced multi-hop clusters are formed, and participating sensor nodes' energy has been increased progressively as getting to the CHs.

At the second stage, the GSA-based algorithm is to run to attach CHs to specific gateway sensors for transmission of data to BS. Further, a fitness function was chosen and distance amongst CHs, BSs, and remnant gateways energy. In this way, a sufficient amount of energy was preserved at the participating nodes and at the gateways. The given algorithm provides superior results for network life & consumption of energy. However, the performance of the proposed technique should be analyzed for more than two sink nodes in the WSN.
In this paper [9], the author has suggested the CHs selection process by using neural networks. In addition to this, ACO particle swarm optimization (PSO) is used to improve energy efficiency and increase the networks' life span. The performance of the suggested algorithm and a comparative study with RZ LEACH, ACO RZ LEACH shows that the suggested technique given better performance in terms of energy efficiency. However, the performance of the suggested technique is analyzed by increasing the size of the

networks and as well as the density of the network and it is found that the suggested algorithm given better performance. But, affect of overheads because of scaling of network has not been considered by the author.

In the proposed technique [10], a searching mechanism is developed to sense the sensing coverage. This suggested technique contributed to solve the problem of searching network connectivity. Further, an optimization technique ACO was applied to improve the networks' energy efficiency and overall lifetime. In addition to that, an optimum path selection mechanism was developed for data transmission by considering the energy constraints of the participating sensor nodes of the WSN. A comparative study is given, and the study shows that the suggested technique performs better in terms of energy efficiency.

This paper [11], several optimization techniques have been discussed applied to decide the optimum number of CHs. Distance between the participating nodes is considered to reduce the utilization of energy consumption and increase the overall lifetime of the networks. However, several other aspects may also be considered in the study for the energy-efficient mechanism to prolong the lifespan of the WSN.

In this paper [12], a clustering mechanism based on k-mean with PSO was proposed, and Glowworm Swarm Optimization (GSO) is used to establish the routes. The proposed algorithms are named PSO-GSO-WSN. The simulation was performed to evaluate the node's energy consumption, Network lifetime, routing convergence, and path optimization. The results shows that the suggested technique is outperformed compared with LEACH.

Further, the performance of the proposed technique may also be analyzed for heterogeneous, densely populated, and large area networks.

Paper [13], a mechanism to choose CHs was proposed, and the CHs have been selected based on their respective ranks. The rank of a node is decided based on their residual energy and the distance from the participating nodes. In contrast, the rank of each CH is piggybacked along with the data sent during the inter-cluster communications. This mechanism significantly contributed to reducing the control messages and overheads in the WSN. The simulation study shows that it significantly reduces energy consumption and thus increases the networks' life span. The simulation results validate ECCR protocol performed better for the selected metrics as compared to the existing protocols.

In this paper [14], clustering by fast search and finding density peaks (CFSFDP) is combined with hierarchy protocol in WSNs. The author has suggested CFSFDP-E (here E-Energy) by taking residual energy into consideration of the participating sensor nodes in the process of CHs selection. The performance of the suggested algorithm analyzed, and it observed that the proposed technique increases the stability period by 50% of networks and outperformed energy efficiency when it was with LEACH-C PEGASIS and SEP. However, during the selection process of CHs in every round the proposed technique set a dynamic threshold value.

In this paper [15], the author has considered the Agglomerative NESting (AGNES) algorithm for further improvement in the life span of the WSN by applying energy-efficient techniques. AGNES was optimized by including (1) the introduction of distance variance, (2) the division of dual-cluster heads (D-CHs) into the energy balance strategy, and (3) the node dormancy mechanism. Further, a priority function was developed, that takes into account the residual energy and the position of the sensor nodes. The proposed technique shows appreciable enhancement in life time and energy drainage rate.

The suggested technique was analyzed for homogeneous and heterogeneous WSN by changing the initial energy i.e., 0.4 J, 0.6 J, and 0.8 J, of participating sensor nodes. Further, the simulation result shows a significant improvement in lifetime, throughput, and rate of energy drainage.

In this paper [16], Double Cost based Routing (DCFR) protocol was taken into consideration to prolong the lifespan of the WSN. The proposed routing technique gives information about the dead nodes and their energy consumptions. The dead nodes and energy consumed by the dead nodes play an important role in choosing routes to the destination node. The performance analysis and comparison with the conventional protocols show that the suggested routing techniques give better performance in energy consumption and counts of dead nodes.

In this paper [17], SEP (Stable Election Protocol) has been studied along with its variants. The fuzzy logic approach has been implemented to get real-time decisions, even with incomplete information. However, the method can further be extended by taking system complexity and real-time information processing into considerations.

This paper [18] suggested a new clustering approach that forms unequal size clusters of participating sensor nodes to deliver the data to the base stations. This distributed technique has taken few parameters such as residual energy, distance from the base station, and number of nodes into consideration to improve the life span of the WSN. The simulation study of the suggested technique shows that the proposed technique performs better in terms of energy consumption and increases the life span of the overall networks.

In this paper [19], average energy (Av E) prediction algorithm was proposed by utilizing the exponential decaying function (y=Ae-ax+B). Further, this was combined with the LEACH (probabilistic distributed) to find out the suitable CHs to form various clusters in WSNs. The performance of the proposed algorithm was analyzed, and the results show that the proposed technique has successfully achieved higher stability of 39%, Lifespan of 40%, and average energy dissipation at 11% per round, that is better than LEACH-Homo. However, the simulation was performed for homogeneous WSN, and further, the performance of the same technique may also be analyzed for heterogeneous networks.

This paper [20] suggested an algorithm based on distance-based clustering and routing algorithm utilizing multi-hop transmission. In the suggested technique, heterogeneous cognitive radio-based wireless methods are categorized into different regions and each having unique spectrum. The proposed algorithm was simulated and shows that the networks' stability period was increased significantly. In addition to this, it also shows that there is improvement in the overall life span of the networks. However, channel availability and 3D terrain have not been considered in the study to get more realistic results.

In this paper [21], the proposed technique was designed by taking data transmission, CH selection mechanism, and a technique for the formation of clusters into consideration. A threshold-based CHs selection process was adopted to avoid the unnecessary rotation of CHs. The concept of forwarding nodes was introduced that minimizes the routing distance between participating sensor nodes, CHs, and BS. The proposed technique is analyzed, and it shows that the overall lifetime of the WSN was increased significantly. However, the proposed work may further be extended to provide QoS provisioning.

In this paper [4], the author has taken nature-inspired Bacterial Foraging Optimization Algorithm (BFOA) algorithm to take care of CHs selection, and routing to transmit the data packets from a source to a destination node in WSN. Fitness functions are introduced to implement the CHs selection and routing mechanism and these fitness functions has taken residual energy and distance into consideration. The simulation study of the proposed technique has been performed, and it shows that it performs better when compared with conventional methods such as EADC, DHCR, and Hybrid Routing. Further, the performance of the same technique may also be tested by scaling the number of participating sensor nodes and terrain of the WSN.

This paper [5], CHs, vice CSs selection, and energy-efficient routing mechanism was introduced by taking swarm optimization technique and V-LEACH routing protocol into consideration. The performance analysis of the proposed algorithm shows better results in terms of energy dissipation and overall energy consumption of the entire WSN. Further, the same technique may be tested for high density and heterogeneous networks to propose a new energy-efficient technique.

In this paper [8], the author has proposed a new technique by combining the gradient-based clustering technique and an optimizing technique based on the Gravitational Search Algorithm (GSA) to improve the performance in large-scale WSN. The authors have also introduced additional gateway sensors for data forwarding to the base station. At the first stage, multi-hop clusters are formed based on the distances between the sensor nodes and CHs. In the second phase, a group of CHs is assigned to a specific gateway using a GSA-based algorithm to forward the data packets to the BS. Further, an appropriate fitness function was chosen, taking into account both distance from the CHs to the gateways and the BS and the residual energy of the gateways.

1.2 Contribution of the paper

The contribution of the papers is summarized as given below

i. In this paper an optimized energy efficient routing technique and QoS provisioning for heterogeneous wireless micro-sensor networks was proposed.
ii. A comparative analysis of the proposed algorithm “QEERP” is performed with LEACH and SEPE to compare the energy consumption of the normal, advance, all participating nodes and also compared the dead nodes on varying the probability to be the cluster head in a particular round.
iii. A simulation study is performed to evaluate the performance of the proposed algorithm “QEERP” and found that the proposed algorithm gradually improves the average energy consumption of all participating sensor nodes on increasing the probability with respect to SEPE. It is also being observed that the proposed algorithm performing well when number of clusters and CHs are more in numbers in the network.

2. Proposed Technique

2.1 Analysis & Simulations

To create the heterogeneous network, we slightly changed the initial energy levels of the participating sensor nodes into three different categories. However, all other limitations of Micro-Sensors were considered before setting to a higher energy level. Three different routing protocols, i.e., LEACH [4, 10], SEP [5, 11], and SEPE [6, 12] were taken into account to evaluate the performance in heterogeneous networks and comparative analysis were performed on different parameters. A network of 100 nodes has been considered, and different energy levels are set to make the network heterogeneous. An area of 100 x 100 m is reserved to perform the simulation. The position of the sink node is in the mid of the terrain. In order to evaluate network performance, we took different probability for the sensor nodes to become the cluster head, and 5% nodes of the total were decided as advanced nodes.

The performances of the networks were analyzed on scaling of CHs and heterogeneity of the networks.

Parameter	**Values**
Number of Nodes (n)	100
Initial Energy of Sensor Nodes (E_o)	0.5 J
Terrain (X * Y)	100 m x 100 m
Location of Sink node	0.5X m x 0.5Y m
Probability to be cluster Head (p)	0.1,0.2, and 0.3
Transmission Energy (E_{Tx})	50e-009J/bit
Receiver Energy (E_{Rx})	50e-009J/bit
Energy Loss Free Space (E_{fs})	1e-11 Joule
Energy Loss Multipath Space (E_{mf}) (Joule)	0.0013e-012 pJ/bit/m^4
Data Aggregation Energy (EDA)	5e-009 J/bit/signal
Percentage of the Advance node (m)	5%

Table 1: Parameters Used in the Simulation

2.2 Proposed Algorithm

All the participating nodes are categorized into three categories in the proposed algorithm: Normal Nodes, Intermediate Nodes, and Advanced Nodes. Additionally, a sink node is also placed and is responsible for collecting the different CHs' data in their respective clusters.

Different energy levels have been set to the participating nodes in the proposed algorithm to make a heterogeneous network. The Normal Nodes possess a 0.5 joule, Intermediate Nodes 1.0 joule, and the Advance Nodes possess 1.5 joules of energy at the initial stage. However, the initial energy of all the participating nodes of a particular group has the same energy level.

Further, a separate random number (between 0 and 1) is generated for selected nodes of a specific group, i.e., the random number for Normal Nodes, Intermediate Nodes and Advance

Nodes. After generating a random number, the cluster head (CH) selection procedure is initiated to decide the CHs randomly. The cluster heads (CHs) selection is based on random numbers generated for a particular group of nodes. Further, if a generated random number for a normal node is less than the threshold values of normal nodes (random number < T(nor)) then the node among the normal nodes becomes the CH for a particular round.

Similarly, if (random number < T(int)), then a node among the intermediate nodes becomes a CH, and if (random number < T(adv)), then a node among the advance nodes becomes a CH for a particular round.

There are two different phases in the proposed algorithm, Setup Phase and Steady-State Phase.

In the **setup phase**, cluster heads are decided among the participating nodes. However, the choice of the CHs depends on the wishes of a particular node, whether that node wants to become CH or not. Now, the cluster heads advertise the message to all the nodes to join the cluster. After receiving a message from a CH, a node can join the cluster only if the node is closest to the CH.

In the **steady-state phase**, the participating nodes of a particular cluster begin to transmit data to their respective clusters. The CHs are responsible for collecting the data captured, collected, and sent by the normal participating sensor nodes of respective clusters.

The Cluster distribution is based on logical decisions, and therefore cluster distribution is not uniform. If the CH of a particular cluster dies at some point, then the cluster will be ineffective, and the data collected by the CH will never be delivered to the sink node of the entire network. CHs are responsible for aggregating, process and transmitting the data to the sink node of the networks. A large amount of energy is consumed by a CH through the collection, processing, and transmitting of data. The CHs consume enormous amounts of energy due to aggregation, processing, and transfer speed and energy, resulting to reduced traffic throughout the network.

In the proposed algorithm, 10% nodes from the total participating nodes are selected as advance nodes in WSN. In the initial phase, all these advanced nodes have energy of 1.5 joule, which is the highest from the other participating nodes of the same networks. According to the proposed algorithm, the setup phase took into account these advance nodes, intermediate nodes, and normal nodes during clustering process. The CHs are selected according to the above criteria to form different network clusters.

In SEPE, the cluster heads (CHs) are changed in every round, and in conventional technique, all the participating advance nodes are available to be CHs for the next round. However, it is previously discussed that a large amount of energy is consumed in order to receive data from the participating nodes and subsequently collect process, and transmit the same data to the designated sink node of the networks.

Therefore, there must be an energy-efficient technique that can decide CHs efficiently and intelligently in a particular round in order to reduce the energy consumption of participating advance nodes, intermediate nodes, and normal nodes, to improve the overall lifetime of the entire networks.

In the proposed technique, energy-efficient technique was developed in order to reduce energy consumption of the participating nodes' and ensure the Quality of Services in the networks. In the proposed technique, the average remaining energy of all the advanced sensor nodes is calculated for the networks. In the next phase, these advanced nodes are identified; those are having more remaining than the calculated average energy of all the advanced sensor nodes.

Now, such advanced nodes, those are having more remaining energy than the average remaining energy will be available to be the CHs for the next setup phase. This process will be repeated repeatedly in every round until any of the advanced nodes are live and have a sufficient amount of remaining energy to collect, accumulate, process the data received from the sensor nodes, and transmit the same to the sink node.

After completing the setup phase, the participating sensor nodes sense, collect and transmit the data to the CHs in the steady-state phase (Phase 2). Further, the CHs of the various clusters are responsible for collecting, accumulate and transmit the gathered data to the sink node of the networks.

The performance of the proposed algorithm is analyzed, and a comparative study is also to verify the result of the proposed technique. The energy-efficient techniques, i.e., LEACH, and SEPE, have been considered to compare with the proposed algorithm.

The proposed technique has taken the given below parameters into consideration to evaluate and analyze the performance of the existing and proposed protocol. The metrics initial energy of the sensor, and advance nodes, residual energy of the sensor nodes, and advance nodes, overall energy consumption of the entire networks and overall average energy consumption of the entire networks, dead normal nodes, dead intermediate nodes, and dead advance nodes are considered to evaluate the performance. Comparative analysis of the proposed technique with SEPE and LEACH is also done by considering the above said protocols.

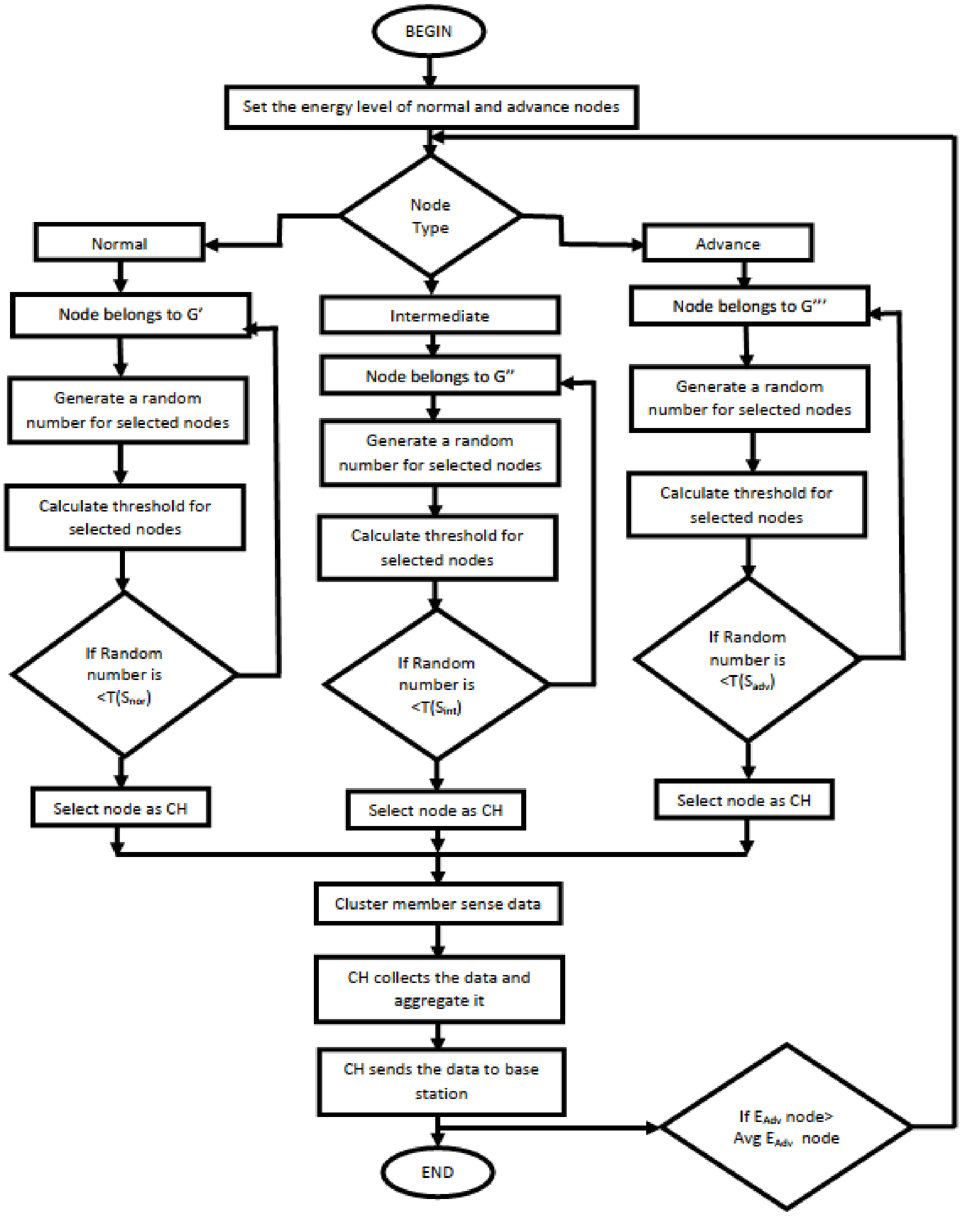

Figure 1: Proposed Algorithm QEERP Flowchart

Parameter	Values
Number of Nodes (n)	100
Initial Energy of Normal Nodes (Enor)	0.5 J
Initial Energy of Intermediate Nodes	1.0 J
Initial Energy of Advance Nodes (E Adv)	1.5 J
Terrain (Xm x Ym)	100 m x 100 m
Location of Sink node	0.5Xm x 0.5Ym
Probability to be cluster Head (p)	0.1,0.2, and 0.3
Transmission Energy (ETx)	50e-009J/bit
Receiver Energy (ERx)	50e-009J/bit
Energy Loss Free Space (E_{fs})	1e-11 Joule
Energy Loss Multipath Space (E_{mf})	0.0013e-012 J/bit/m4
Data Aggregation Energy (EDA)	5e-009 J/bit/signal
Percentage of the Advance node (m)	10%
Percentage of the Intermediate node (x)	20%

Table 2: Simulation Parameters

2.3 Performance Analysis Metrics

Various performance metrics have been decided to evaluate the performance of the existing routing protocols, i.e., LEACH and SEPE, and the proposed algorithm. As per performance metrics, 100 nodes have been taken into consideration. Out of these 100 nodes, 10% nodes have been taken as advance nodes, 20% nodes are intermediate nodes, and the rest are normal nodes to make a heterogeneous network.

100m x 100m terrains are used to place the sensor nodes and evaluate the performance. A sink node is centrally located off the terrain responsible for collecting the data from all the CHs to accumulate and process the same. In addition to that, the probability of becoming a cluster head (CHs) is 0.1, 0.2, and 0.3, Transmission (ET x) and Receiver Energy (ER x) is 50e-009J/bit, Energy Loss in Free Space (Efs) is 1e-11 Joule, and Energy Loss in Multipath Space (Emf) is 0.0013e-012 pJ/bit/m^4

3. Simulation and Analysis

As shown in Figure 2 to Figure 4, the performance of the networks as analyzed in terms of average Energy Consumption of Normal Nodes against the number of rounds by varying the probability 0.1, 0.2 and 0.3 of the participating sensor nodes to become the Cluster Heads (CHs) in the networks.

In Figure 5 to Figure 7, the performance of the networks was analyzed in terms of average Energy Consumption of Advance Nodes against the number of rounds by varying the probability

0.1, 0.2 and 0.3 of the participating sensor nodes to become the Cluster Heads (CHs) in the networks.

In Figure 8 to Figure 10, the performance of the networks is analyzed in terms of average Energy Consumption of Nodes against Number of Rounds by varying the probability 0.1, 0.2, and 0.3 of the participating sensor nodes to become the Cluster Heads (CHs) in the networks.

In Figure 11 to Figure 13, performance of the network is analyzed in terms of Dead Nodes at probability against Number of Rounds by varying the probability 0.1, 0.2, and 0.3 of the participating sensor nodes to become the Cluster Heads (CHs) in the networks.

3.1 Number of Rounds Vs. Energy Consumption of Normal Nodes at probability 0.1

In Figure 2, the proposed Energy Efficient Routing Protocol algorithm for QoS provisioning QEERP was compared with LEACH and SEPE at 0.1 probabilities; the comparative analysis shows that the LEACH is the worst performing algorithm compared to the previous SEPE and proposed algorithm QEERP. The participating sensor nodes consume a huge amount of energy in a few rounds; in comparison, SEPE works better than LEACH but not QEERP. In LEACH, all the participating nodes are available in each round to become the CHs. Suppose a particular node accepts to become CHs; in that case, a large amount of energy is consumed to collect and accumulate data from the normal sensor nodes of that cluster before sending it to the sink node of the networks. The LEACH did not set any specific criteria for accepting or rejecting a request to be CH for a specific round.

Whereas the proposed algorithm QEERP is performing better in terms of average energy consumption of the normal nodes with respect to LEACH and SEPE at probability 0.1 because of its design and implementations of the same.

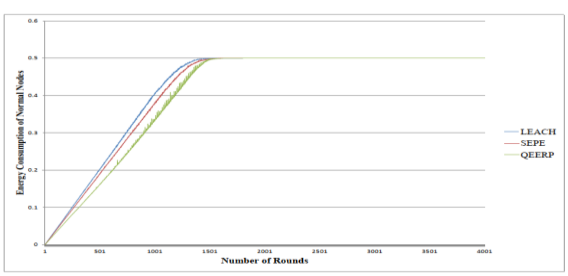

Figure 2: Number of Rounds Vs Energy Consumption of Normal Nodes at probability 0.1

3.2 Number of Rounds Vs Energy Consumption of Normal Nodes at probability 0.2

The performance of the proposed algorithm (QEERP) was analyzed and compared with LEACH and SEPE, at a probability 0.2. It shows in Figure 3 that when the probability was increased, the performance of the proposed algorithm deteriorated lightly but still much better than LEACH and SEPE. However, there are not many differences reflected in the performance of the LEACH and SEPE. The overheads have not been increased for these two algorithms, but the computational overheads are increased slightly because of increasing the probability. However, even after increasing the computational overheads, the proposed algorithm is still much better than the LEACH and SEPE.

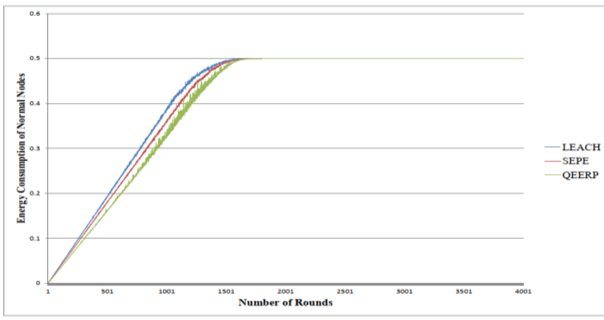

Figure 3: Number of Rounds Vs Energy Consumption of Normal Nodes at probability 0.2

3.3 Number of Rounds Vs Energy Consumption of Normal Nodes at probability 0.3

When the probability is set to 0.3 to be the CH for a particular round, it can be seen in Figure 4, that performance of LEACH and SEPE is degraded. Although the performance was deteriorated for LEACH and SEPE between 1000 – 1500 rounds, there are no changes or very slight changes reflected in the proposed algorithm at probability of 0.3.

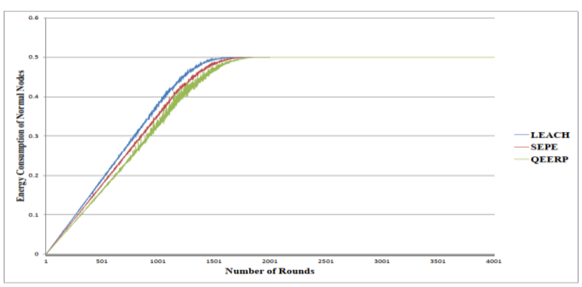

Figure 4: Number of Rounds Vs Energy Consumption of Normal Nodes at probability 0.3

Therefore, we may conclude that the proposed algorithm performs much better than LEACH and SEPE at probability 0.1, 02, and 0.3, even after increasing the computational overheads in the proposed algorithm.

Comparison	**Comparison at the Probabilities**		
	0.1	**0.2**	**0.3**
QEERP Vs LEACH	18%	15%	14%
QEERP Vs SEPE	12%	9%	7%

Table 3: Comparison of the proposed QEERP algorithm with LEACH and SEPE at Probability 0.1, 0.2 and 0.3

On evaluating the performance of the proposed algorithm QEERP, the participating normal node performs in terms of energy consumption 18%, 15%, and 14% better concerning LEACH and 12%, 9%, and 7% better with respect to SEPE at 0.1, 0.2 and 0.3 probabilities respectively. It shows that on implementation of the proposed algorithm, the overall life span of the normal sensor nodes is increased significantly.

Further, in Figure 5 to Figure 7, the performance of the proposed QEERP is compared with LEACH and SEPE at probability 0.1, 0.2, and 0.3, respectively.

3.4 Number of Rounds Vs Energy Consumption of Advance Nodes at probability 0.1

In Figure 5, the performance of the proposed algorithm was analysed to number of rounds and energy consumption of advance nodes at 0.1 probabilities.

At probability 0.1, it observed that the proposed technique QEERP performed better up to some extent. But, when the density of the participating nodes decreases then, the SEPE performed better in terms of energy consumption of the advanced nodes. The SEPE performed better on the lower density of the participating sensor nodes because the rate of consumption of computational energy is more petite in SEPE than QEERP and LEACH. But on decreasing the density of participating sensor nodes, the performance of the proposed algorithm was improved slightly. At the same time, the performance of the SEPE and LEACH is degraded significantly.

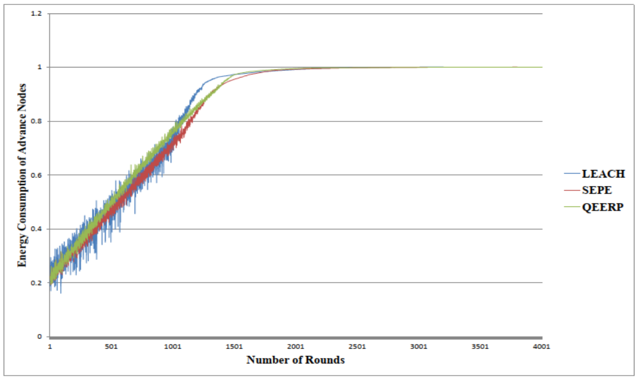

Figure 5: Number of Rounds Vs Energy Consumption of Advance Nodes at probability 0.1

It was observed that the performance of the proposed QEERP algorithm is affected by 0.7% and 4% in terms of overall energy consumption of advance nodes for LEACH and SEPE up to 1000 rounds. However, the proposed algorithm QEERP performs 4% better in terms of overall energy consumption of Advance nodes with respect to LEACH between 1000 to 1400 rounds. It turns out that as the density of participating nodes in the networks decreases, the performance of advanced nodes has improved significantly because the overheads are drastically reduced.

3.5 Number of Rounds Vs Energy Consumption of Advance Nodes at probability 0.2

In Figure 6, on increasing the probability from 0.1 to 0.2, it was observed that the proposed technique QEERP worked better to some extent. However, on increasing the probability from 0.1 to 0.2, more nodes will be available to become the CHs and computational energy consumption will be increased. Due to higher lose of energy the life span of participating sensor nodes is reduced.

However, the proposed technique is performed better than LEACH, but when it is compared with SEPE then its performance degrades slightly for few rounds, but once again, the proposed technique regains its performance in terms of energy consummation of the advance nodes at probability 0.2. Because of decreasing the density of the participating sensor nodes, the energy dissipation rate will be reduced, and the proposed technique's performance is improved gradually. Figure 5 shows that the proposed technique outperformed up to 500 rounds, and it regains its performance once again after 1300 rounds.

It was observed that the proposed QEERP algorithm is performed 7% better compared to LEACH, but it affected by 2% in terms of overall energy consumption of advance nodes with respect to SEPE up to 1100 rounds. However, a significant improvement is observed in the performance of the proposed algorithm between 1100 to 1400 rounds. It shows that on decreasing the density of participating nodes in the networks, the performance of advanced nodes is improved significantly.

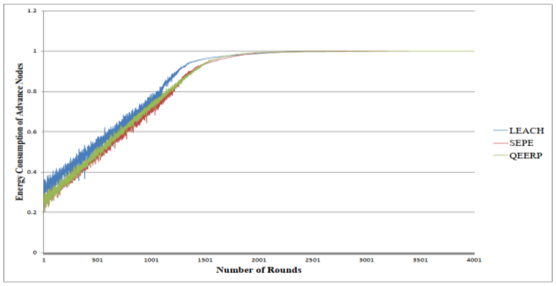

Figure 6: Number of Rounds Vs Energy Consumption of Advance Nodes at probability 0.2

3.6 Number of Rounds Vs Energy Consumption of Advance Nodes at probability 0.3

Further, Figure 7 shows the performance in terms of energy consumption of the advance nodes at probability 0.3. In figure 7, on increasing the probability from 0.2 to 0.3, the proposed technique performs better when compared with LEACH and SEPE in terms of energy consumption of the advance nodes. The performance of the LEACH is very unsatisfactory because huge amount of the energy is being consumed by the participating sensor nodes on increasing the probability of the nodes to be the CHs. However, the performance of the LEACH has been improved slightly after completing 1500 rounds, but at this point in time, most of the participating nodes are dead, and very few are left to be part of the networks.

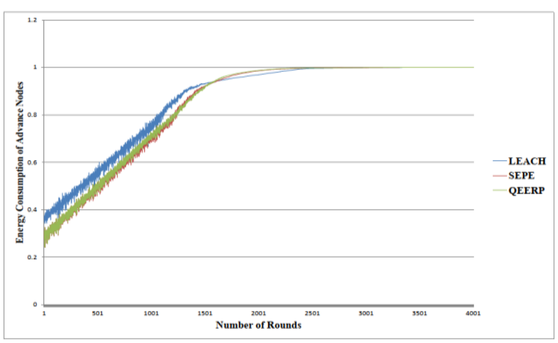

Figure 7: Number of Rounds Vs Energy Consumption of Advance Nodes at probability 0.3

It is also observed In Figure 7, that the SEPE and proposed QEERP work better when more nodes are available in the networks to be the CHs in a particular round. However, it has been previously discussed that when more number of participating sensor nodes are available in the network to be the CHs then obviously energy dissipation rate will be increased and adversely affect the network's overall performance.

However, it is observed that the proposed technique works better compared to SEPE in terms of energy consumption, but at the same time, the QEERP performance decreases slightly on increasing the number of round. The performance of the proposed algorithm is reduced by increasing the probability from 0.2 to 0.3, it consumes a lot of computing energy and this affects the performance of the entire network.

It is observed that the proposed QEERP algorithm is performing 10% better compared to LEACH. It affected the total energy consumption of Advance nodes with respect to SEPE by 0.7% up to 1500 rounds. However, the proposed algorithm works 5% and 0.6% better in terms of overall energy consumption of Advance nodes with respect to LEACH and SEPE, between 1200 and 1500 rounds. It shows that by reducing the density of participating normal nodes and increasing the advanced nodes in the network, the performance of the advanced nodes has been improved significantly.

Comparison	Comparison of the Probability		
	0.1	0.2	0.3
QEERP Vs LEACH	-0.7%	+7%	+10%
QEERP Vs SEPE	-4.0%	-2%	+0.7%

Table 4: Comparison of proposed QEERP algorithm with respect to LEACH and SEPE on overall energy consumption of advance nodes the at Probability 0.1, 0.2 and 0.3

Table 4 also shows that the proposed algorithm works better in terms of the overall energy consumption of the advance nodes with a probability 0.3. This indicates that on implementation of the proposed algorithm, the overall life span of the advanced sensor nodes was increased significantly on increasing the probability of becoming the cluster head.

The performance of the proposed algorithm is analyzed for advance nodes, and the observations show that energy consumption gradually decreases during evaluation with probabilities 0.1, 0.2, and 0.3. It shows that the average energy of all nodes conserves by 7% and 10% energy at 0.2 and 0.3 respectively, but at the same time the proposed algorithm adversely affected by 0.7% with respect to LEACH because less number of CHs are available to process the data that is received from the participating sensor nodes and to forward the same to the sink node. The proposed algorithm gradually improved the average energy conservation of all participating sensor nodes on increasing the probability with respect to SEPE. It is also being observed that the proposed algorithm works well when the number of clusters and CHs are more.

Further, the performance of the proposed algorithm was analyzed in terms of energy consumption of all participating nodes (Normal, Intermediate, and Advance) and compared with LEACH and SEPE with probability 0.1, 0.2, and 0.3, respectively.

3.7 Number of Rounds Vs Energy Consumption of All Nodes at probability 0.1

In Figure 8, the performance of LEACH, SEPE, and QEERP was analyzed and compared with each other at 0.1 probabilities. The LEACH performed better up to 1100 rounds, and SEPE is the worst performed algorithm in terms of energy consumption of all the participating sensor nodes in the networks.

However, the performance of the proposed techniques, i.e., QEERP is better than SEPE but not performing well when compared with LEACH with the same scenarios. It is observed that when the density of the participating nodes is higher, then LEACH is performing significantly well. When the participating nodes started to die and the density of the sensor nodes reduced, then the performance also decreased because on increasing the number of rounds, the chances to be the CHs has been increased. The overheads are also increased, and because of these overheads, the rate at which energy dissipated is also increased. On increasing the rate of energy dissipation, the performance of the network based on LEACH is degraded suddenly.

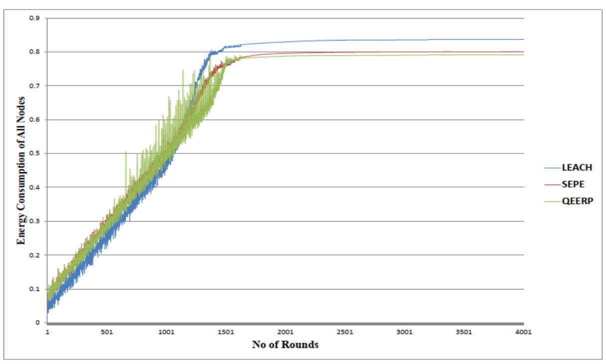

Figure 8: Number of Rounds Vs Energy Consumption of All Nodes at probability 0.1

3.8 Number of Rounds Vs Energy Consumption of All Nodes at probability 0.2

Figure 9 shows the performance of LEACH, SEPE, and QEERP while increasing the probability of the participating sensor nodes to be the CHs from 0.1 to 0.2. The comparative graphs in Figure 8 show that the performance of LEACH, SEPE, and QEERP techniques are performing almost similar up to some extent, but after completing 580 rounds, the proposed technique, i.e., QEERP is performing better on evaluating the performance with 0.2 probability.

The sudden change is observed after 1380 rounds. The performance of LEACH and SEPE has been degraded drastically while the performance of the proposed technique, i.e., QEERP is improved significantly.

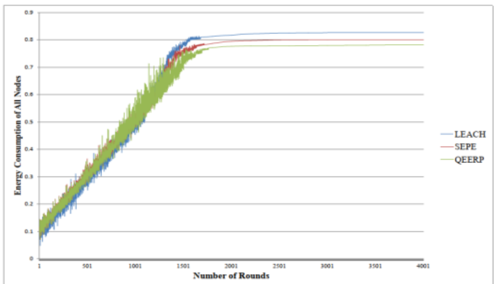

Figure 9: Number of Rounds Vs Energy Consumption of All Nodes at probability 0.2

Once a participating node becomes CH of a cluster, a sufficient amount of computational and processing energy is consumed. The energy consumption in in LEACH and SEPE is very high, a huge amount of energy is consumed, which has a negative effects on the overall performance of the networks. However, the proposed algorithm, i.e., QEERP, performs better on increasing the probability because more nodes will be available to be the CH in a particular round. It is evident if more sensor nodes are available to be the CHs for different rounds, then the rest of the nodes may remain alive and participate as a normal node to sense, collect, and send the desired information to the CHs for a more extended time and comparatively consume less energy as normal nodes than the nodes those who have decided to become a CH in a particular round.

3.9 Number of Rounds Vs Energy Consumption of All Nodes at probability 0.3

It has already been stated earlier that on increasing the probability to be the CH, we will observe that the performance of the proposed technique i.e. QEERP in terms of energy consumption, will be improved. Figure 10 shows that SEPE is the worst performing, and the proposed technique, i.e., QEERP is the best performing algorithm in terms of energy consumption of all nodes. The better performance of the proposed technique lies in the fact that the algorithm is designed to identify those advanced nodes that have more remaining energy than the average remaining energy of all the advanced nodes of the networks. Further, such advance nodes are preferred to be CH in the next round The rest of the nodes remain alive and work as normal nodes and are used to send the data to their respective CHs. The process of node identification repeats itself for every round. Due to this process, a significant amount of energy is saved, and the advance nodes may keep themselves alive for a long duration.

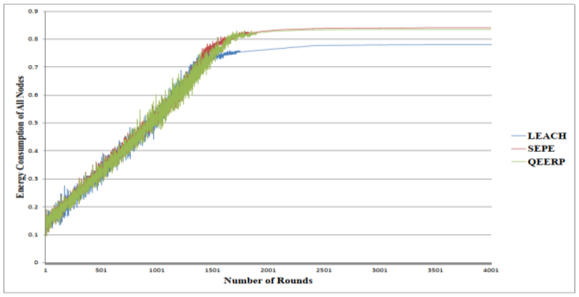

Figure 10: Number of Rounds Vs Energy Consumption of All Nodes at probability 0.3

It is also observed that the proposed technique works significantly well when the performance is analyzed in terms of energy consumption of normal nodes and all participating sensor nodes. However, if the same technique is used to evaluate the performance in terms of energy consumption of advanced nodes then the proposed technique, i.e., QEERP is performing moderately well.

Comparison	Comparison of the Probability		
	0.1	0.2	0.3
QEERP Vs LEACH	-3%	-3%	1%
QEERP Vs SEPE	1%	1%	1%

Table 5: Comparison of proposed QEERP algorithm with respect to LEACH and SEPE on overall energy consumption of advance nodes the at Probability 0.1, 0.2 and 0.3

It is observed that the proposed QEERP algorithm performs 2% better than SEPE, but it adversely affects 3% in terms of overall energy consumption of all participating nodes with respect to LEACH up to 1500 rounds. However, the proposed algorithm QEERP performs 8% and 4% better in terms of overall energy consumption of all participating nodes with respect to LEACH and SEPE, respectively between 1000 to 1500 rounds.

Further at probability 0.2, It is observed that the proposed QEERP algorithm is performing 1% better compared to SEPE, but it adversely affected by 3% in terms of overall energy consumption of all participating nodes with respect to LEACH up to 1500 rounds. However, the proposed algorithm QEERP performs 5% better in terms of overall energy consumption of all participating nodes with respect to LEACH and SEPE, respectively, between 1000 to 1500 rounds.

Further on increasing the probability and analyzed at 0.3 probability, It has been observed that the proposed algorithm QEERP is performing 1% and 1% better in terms of overall energy consumption of normal nodes with respect to LEACH and SEPE, respectively, up to 1500 rounds. However, all three algorithms, i.e., LEACH, SEPE, and QEERP are identical or negligible deflection after 1400 rounds. However, the proposed algorithm QEERP performs 3% and 2% better in terms of overall energy consumption of all participating nodes with respect to LEACH and SEPE, respectively, between 1000 to 1500 rounds. This shows that on decreasing the density of participating normal nodes and increasing the advance nodes in the network, the performance of the advance nodes has been improved significantly.

Therefore, it is concluded that the proposed algorithm is performing better on increasing the probability at which more number of the nodes are available to be the CHs because more clusters can be formed and the overall overheads can be distributed on more CHs that helps to improve the overall lifespan of the participating nodes and entire networks. However, it has also been observed that LEACH performs better up to some extends at less probability.

Further, in Figures 11, 12, and 13, the performance of the LEACH, SEPE, and QEERP was analyzed and compared with each other in terms of dead nodes with respect to the number of rounds at probability 0.1, 0.2, and 0.3.

3.10 Number of Rounds Vs Dead Nodes at probability 0.1

In Figure 11, the performance of LEACH, SEPE, and QEERP was analyzed, and the figure shows that the QEERP is outperforming the algorithm's stability period. The stability period of the sensor networks is the time before the first node is died and gets inactive. The reliability of the networks depends on the stability period of the network.

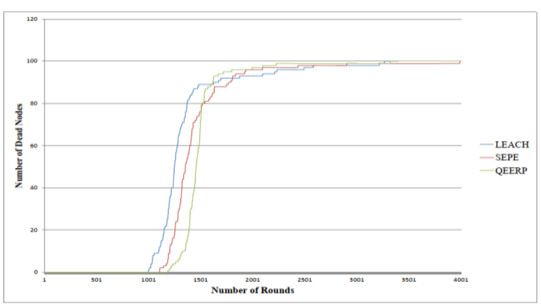

Figure 11: Number of Rounds Vs Dead Nodes at probability 0.1

Therefore, it can be concluded that the participating sensor nodes of a particular cluster may deliver more data packets to the CHs if the stability period is comparatively large. Therefore, the larger stability period shows the reliability of the network. The more reliable the network is, the more data can be transferred through the networks and delivered to the destination node. The graph in Figure 11 shows that the stability period of the proposed technique QEERP is more than that of LEACH and SEPE. However, it is also observed that the LEACH is the worst performing technique in terms of stability**.**

Further, the instability period of the participating sensor nodes has also been analyzed at different probabilities. The instability period of a network is defined as the time interval between the death of the first active sensor and the last sensor nodes.

3.11 Number of Rounds Vs Dead Nodes at probability 0.2

Further, the performance of LEACH, SEPE, and QEERP was analyzed after increasing the probability of the participating sensor nodes being the cluster head in a particular round. The performance is analyzed by increasing the probability from 0.1 to 0.2 for a specific round. On increasing the probability from 0.1 to 0.2, it has been observed in figure 12 that the proposed algorithm, i.e., QEERP, performs well in terms of dead nodes up to some extent. However, Figure 11 also shows that the overall instability period of the proposed algorithm is more than LEACH and SEPE, and LEACH is the worst performing algorithm for the given scenarios.

The instability period of the proposed algorithm is more because the energy dissipation rate of the participating sensor nodes is significantly low, and a significant amount of energy is saved in CH selection. In addition, the proposed mechanism for selecting CH for a given round is very energy efficient and based on logical decisions. The CH selection is based on the average residual energy of all nodes and residual energy of a particular node. A sensor node must have more residual energy than the average residual energy of all the participating sensor nodes in the networks; then, the node can participate in CHs selection. Otherwise, it will be treated as a normal participating sensor node of the network.

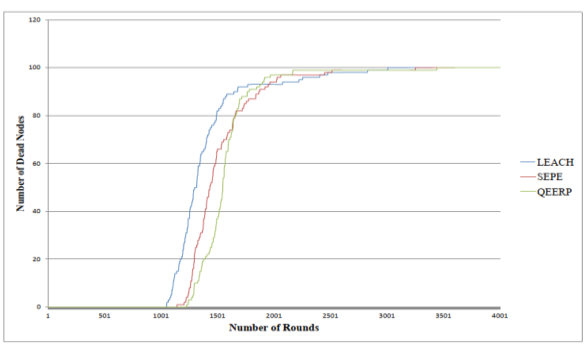

Figure 12: Number of Rounds Vs Dead Nodes at probability 0.2

3.12 Number of Rounds Vs Dead at probability 0.3

Figure 13, shows that the LEACH is the worst performing algorithm while the proposed technique performs comparatively well, when the probability has been increased from 0.2 to 0.3 for the participating sensor nodes to become the CH for a particular round. But, in figure 12, it is being observed that the stability period of both the algorithm, i.e., SEPE and proposed QEERP is almost the same. Still, the overall performance of the proposed technique is far better than LEACH and SEPE.

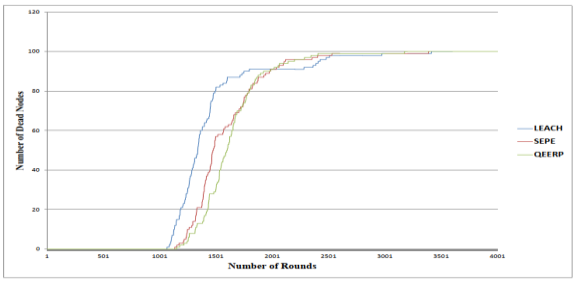

Figure 13: Number of Rounds Vs Dead Nodes at probability 0.3

However, the performance of the proposed algorithm is degraded after 1500 round and performs similar to the SEPE. When 1300 rounds complete, almost 50% of nodes have died, and probability of CH at a particular round increases to 0.3. On increasing the probability, more nodes are selected to be the CH from the available pool of the participating sensor nodes. Therefore, obvious overheads will be increased for the rest of the nodes, which will adversely affect the performance of the sensors with respect to their overall life span. In addition to that, the computation energy is also increased significantly. The rate of energy consumption has also been increased considerably. These are the main factors for the adverse performance of the proposed technique because on increasing the probability the significant amount of energy is consumed and that adversely affect the overall life span of the participating sensor nodes and overall networks.

4. Conclusion

The participating sensor nodes have limited and exhaustible energy to last longer time and deliver data to the destination node(s). Therefore, it is an essential and challenging task to design energy-efficient routing protocols that provide QoS for wireless sensor networks. In this paper, an energy-efficient technique was designed and implemented taking into account the provision of QoS. In the proposed algorithm, an energy-efficient CHs selection mechanism is introduced. The proposed QEERP technique took into account the residual energy of the sensor nodes when selecting the CH selection. In order to select CH for a given round, the residual energy of all the participating sensor nodes was calculated and an algorithm was developed to select the senor nodes as a CH that have more residual energy than the average energy of all the CH participating in WSN. This selection procedure repeated to select CH in each round.

Further, the performance of the proposed technique was analyzed and compared with the two most cited algorithms i.e. LEACH and SEPE, to validate the results. The performance was analyzed by increasing the probability to 0.1, 0.2, and 0.3 of sensor nodes to become CH in particular round. It has been observed that the proposed technique is works better on evaluating the performance on various parameters in spite of the high computation energy consumption.

In scenario 1, when the performance of the proposed algorithm was analyzed in terms of energy consumption of normal nodes with respect to the number of rounds, then it was observed that the number of participating sensor nodes in LEACH and SEP starts to dye earlier. Still, the overall lifetime of the networks is more or less the same for all three protocols.

A comparative analysis of proposed algorithm with LEACH and SEPE is performed by increasing the probability of the participating nodes to become the CHs in a particular round. If the probability is set to high, the nodes become cluster heads, and obviously, multiple clusters are created. As more clusters are formed than the density of the participating nodes in each decrease, the overheads will be reduced accordingly, but energy consumption of CHs increases. But, this will help reduce the energy consumption of the participating nodes and increase the overall life networks. On evaluating the performance of the normal nodes, it is observed that the proposed algorithm is achieves better results with 18%, 15%,and 14% better with respect to leach and at 0.1, 0.2, and 0.3 probabilities. On the other hand, when evaluating the performance of the proposed algorithm with respect to SEPE, the proposed algorithm has 12%, 9%, and 7% better results, with the same probabilities.

In scenario 2, when the performance of the proposed algorithm is analyzed in terms of Energy Consumption of Advance Nodes with respect to the number of round, then it is observed that the proposed technique is performs better in terms of energy consumption when it is compared with the SEPE, but at the same time, the performance of the QEERP has been deteriorated slightly as numbers of round increased. The performance of the proposed algorithm is slightly reduced because on increasing the probability from 0.2 to 0.3, the computational energy is significantly consumed, that affects the performance of the entire networks.

On increasing the probabilities, more number of nodes will become the CHs and at the same time rate at which energy is consumed must also be increased significantly. When the proposed algorithm is compared with the LEACH, the proposed algorithm is adversely affected at 0.1 probabilities. The advance nodes consume 0.7 % more energy but significantly improved and show that 7% and 10% less energy are consumed at 0.2 and 0.3 probabilities.

Similarly, when the proposed algorithm is compared with SEPE, the proposed algorithm's performance is affected by 4% and 2% at 0.1 and 0.2 probabilities but significantly performing well and consumes 1% less energy than at probability 0.3.

In scenario 3, when the performance of the proposed algorithm was analyzed in terms of Dead Nodes with respect to the number of round at different probability, then it is observed that the computation energy increased significantly, and energy consumption is also increased significantly, and these are the main factors for the adverse performance of the proposed technique. Because of increasing the probability the significant amount of energy is consumed and that adversely affect the overall life span of the participating sensor nodes and overall networks.

It has also been found that the proposed technique is energy efficient and capable of increasing the overall lifespan of the network.

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