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An Efficient Routing Algorithm for Optimizing Energy Conservation and Improved Scalability in WSN

R Amutha[1], Sivasankari G G[2], Venugopal K R[3]

[1]Research Scholar in VTU, Dept. of CSE, AMC Engineering College, Bengaluru, India,

[2]Professor, Dept. of CSE, AMC Engineering College, Bengaluru, India.

[3]Vice Chancellor, Bangalore University, Bengaluru, India.

E-mail:[1]amutha.shruthi@gmail.com,[2]shivashankarigg@gmail.com,[3] venugopalkr@gmail.com

ABSTRACT

Wireless Sensor Network (WSN) is a familiar technique to develop various real-world applications through sensor nodes on wireless networks. Energy efficiency and scalability are the important challenges in WSN, along withsome other parameters such as reliability, availability, and security. The nodes' path and communication network have been decided based on routing techniques among the network nodes. Classical routing algorithms have improved the efficiency and accuracy of WSN nodes, but it works only in the limited range. The number of nodes is increased in WSN, and security of data transmitted has a lot of limitations in routing. This problem has been considered for a long time, but the level of improvement is only within a short range, not for larger networks and high-volume nodes. This problem has been overcome by an efficient routing algorithm SEERA (Scalable Energy Efficient Routing Algorithm). Familiar routing protocol techniques such as LEACH (Low Energy Adaptive Clustering Hierarchy), Multi-LEACH, CELL-LEACH when compared with this algorithm shows that SEERA provides better security, energy efficiency and scalability. Also, the proposed algorithm uses hybrid MAC protocols along with the clusters communicated in Intra mode on the network. This research paper summarizes the results of SEERA withmore scalable nodes on WSN and also improved their energy efficiency among all nodes.

Keywords: Cluster hierarchy,LEACH,MAC protocol, Scalabilityand Routing algorithms

Introduction

WSN is made of combined,adaptive, low-power, multi-operational sensor nodes, which are collected and connected in a centralized place called a Base Station (BS). All the nodes are connected with the same operational entity known as size, functionality and the frequency range of sensors and are grouped to form clusters. A Cluster Head (CH) is assigned for all nodes in the network to control and monitor the sensors which are connected wirelessly. The nodes are connected to the CH and are then controlled continuously on the network clusters through CH. Routing is the technique used in WSN to maintain the distance between nodes and their cost-effectiveness through hops. To improve the scalability in WSN,a huge number of clusters are connected and their energy should be high at all times for efficient data transmission. When sensor nodes are connected continuously, routing them in a network is challenging for all researchers working on WSN. If nodes are connected in multi-hops, then the routing of sensor nodes gets confusingas the number of devices increases on the network path. To overcome this problem, several routing protocols are used to improve the routing in terms of distances. Most of the routing protocols have improved the energy efficiency of the sensor nodes in WSN but their scalability and security are still not consideredin the larger networks even though clusters are working perfectly. A major problem identified in WSN is scalability and energy efficiency over the networks. This routing algorithm improvesscalability on a huge number of nodes in a

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cluster. A cluster configuration doesn't change the energy efficiency throughout the lifetime of the sensors used in WSN.

Related Works

In recent days routing algorithms of WSN reveal the new innovative techniques based on energy efficiency improvement. Energy loss is reduced and routing chain strategy can be shortened for the improvement of WSN accuracy. Destination Oriented Routing Algorithm (DORA) solves this problem by implementing a multi-chip routing method for finding the optimal distance between the nodes that are connected on WSN. Base station or sink nodes have been configured at the top and remaining node distances have been calculated and made into amulti-chip strategy formation with accurate distance and direction [1].

Quality of Services (QoS) is an important concept considered in WSN, to improve the load balancing and routing techniques among the server nodes to develop energy efficiency. Prolonging the network lifetime can be achieved by implementing the tradeoff between the QoS, network lifetime and security due to limitation of energy in the nodes on the network. QoS aware energy balancing secure routing (QEBSR) has been developed by researchers to find the optimal routing path of end-to-end transmission delay [2]. A compromised resistance in the distributed balanced network has developed during data transmission.

Improved Energy Efficient Clustering Protocol (IEECP) has been developed to increase networklifetime. CH is used to rotate and select the optimal locations of the clusters and their functions are used to finding the rotations mechanism [3]. The content-Based Adaptive and Dynamic Scheduling (CADS) scheme is used to increase the lifetime of the clusters connected in WSN. Also, it is used to avoid traffic and forward the redundant message to the nodes for developing energy efficiency and lifetime [4]. The states of the nodes have been updated and will be adapted to all the changes in their states over the network. Data packets and their functions are analyzed using this concept and the lifetime of the network, availability can be improved.

An Energy Gaud Node (EGN) based infrastructure has been developed to improve the lifetime of the network with the help of SPR (Strength of Packet Reply) and their RTT (Round Trip Time) [5]. It is used in the homogenous network to perform load balancing uniformly. The residual energy consumption and the count of hop values have been balanced with the help of this system for the improvement of the routing tables. To find the neighboring node's energy and load balancing factors for effective communication,EGN is used to calculate the throughput, latency, and packet loss. Secure and Energy-Aware Heuristic-based Routing (SEHR) protocol was established with AI-based analysis for intellectual learning. It improves the throughput in the network and reduces the packet loss ratio to increase the energy efficiency in the WSN [6].

Light-weight Structure-based Data Aggregation Routing (LSDAR) protocol is used to perform encryption schemes using One Time Pad (OTP) for energy consumption. It also reduces the packet loss ratio on the networks [7] and decomposes the cluster into several portions, identifies the energy holes therefore preventing it from malicious attacks. The base station is used to

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maintain the locality of the cluster nodes and find the routing path on the network to maintain a loop-free efficient routing algorithm. This protocol is specially designed to improve data security and avoid malicious threats.

Mobile Edge Computing (MEG) is used to find node failures among the network nodes which are connected in larger networks. It provides secure communication between the nodes on every data transmission.If any node has failed, itwill immediately inform the base station to take further actions [8].

Co-operative communication protocol provides jamming to the packet drooping and identifies the wormholes on the network. It avoidscyber-attacks that happen in WSN [9]. Clustering Algorithm with Fuzzy Logic (CAFL) is used for improving network operations with fuzzy set values of the cluster head nodes [10]. Heuristic Dissemination Protocol (HDP) is used to find the structure between the sink nodes and intermediate nodes to maintain the energy consumption and latency on the network. To avoid the frequent updates in the packet delivery and location of the nodes, it uses the double ring virtual structure technique. African Buffalo Based Two-Tier Data Dissemination (ABTTDD) and Temporary Energy Mapping Algorithm (TEMA) [11] are the two techniques which are used to monitor the data transmission and information gathering along with the nodes for creating reference nodes in the network structure. Energy-drained nodes always create packet loss and consume a lot of energy.

INTER-HARE protocol is used to maintain scalability and traffic load on the networks to improve the concurrent multi-band nodes [12]. It is mainly used in the IoT framework for developing the network structure effectively. Energy Efficient Clustering and Hierarchical Routing Algorithm (EESRA) is used for the communication of intra-cluster and multi-hop transmission [13]. A WSN MAC protocol LEACH and their sub-protocols are working to improve theload balancing and lifetime of the network effectively. The selection of cluster heads israndomly chosen to develophigh scalability and network size [14]. Transmissions with Multiple Load Balancing schemes (TMLBS) are used to create a multi-path tree structure of nodes connected in the network and with the help of an ant colony algorithm. It is also used to avoid excess load on the nodes assigned by the cluster heads and provides the solution for imbalanced network depletion of energy [15].

Vehicle Ad-hoc Networks and Quality of experiences are used to find the solutions for tradeoff and to provide the solutions for energy optimization techniques [16]. For secure routing, key management has been developed with Zero-Knowledge Key Exchange (ZKKE) with computational hash functions to provide security for the nodes and packets. Cluster Head index has developed with fuzzy based energy-efficient clustering method to provide secured data transmission on the networks for reducing the energy consumption [17-19]. Sec-Trust RPL and Particle Swarm Optimization (PSO) routing protocols are used to provide security between the BS and gateway to maintain the nodes in the structure. It also provides data transmission and gathering over network nodes [20-24]. To maximize the lifetime of the network, Enhanced Clustering Hierarchy (ECH) is used and it also provides overlapping of the nodes located nearby. Data redundancy is also minimized and power consumption is reduced with the keys in ECH.

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The LEACH protocol is used to minimize the load balancing and energy consumption. The MAC protocol addresses on the network nodes by the cluster heads [25-27].

Optimal Data Routing algorithm is used to find narrow lanes in the network for launching the data nodes. Maximum resource allocation concepts will decide the power consumption and energy-efficiency on the networks. The cost of the network is high and wiring is complicated in the clusters [28]. Chicken Swarm Optimization based Clustering Algorithm (CSOCA) with Genetic Algorithm provides the sigmoid functions with crossover and mutation for the achieving high scalability and resource allocation. [29].

Proposed Algorithm and System Model

The proposed system model consists of a number of nodes present in the network, grouped into clusters along with the corresponding initial energy of each cluster. The energy consumed by each node will be calculated and sent to the CH for monitoring. Every node will deliver packets to different nodes and also receive packets from various nodes connected in the cluster. The cluster has one CH and some nodes are connected in structure. For all clusters, there is one base station to monitor and control data transmission every second.

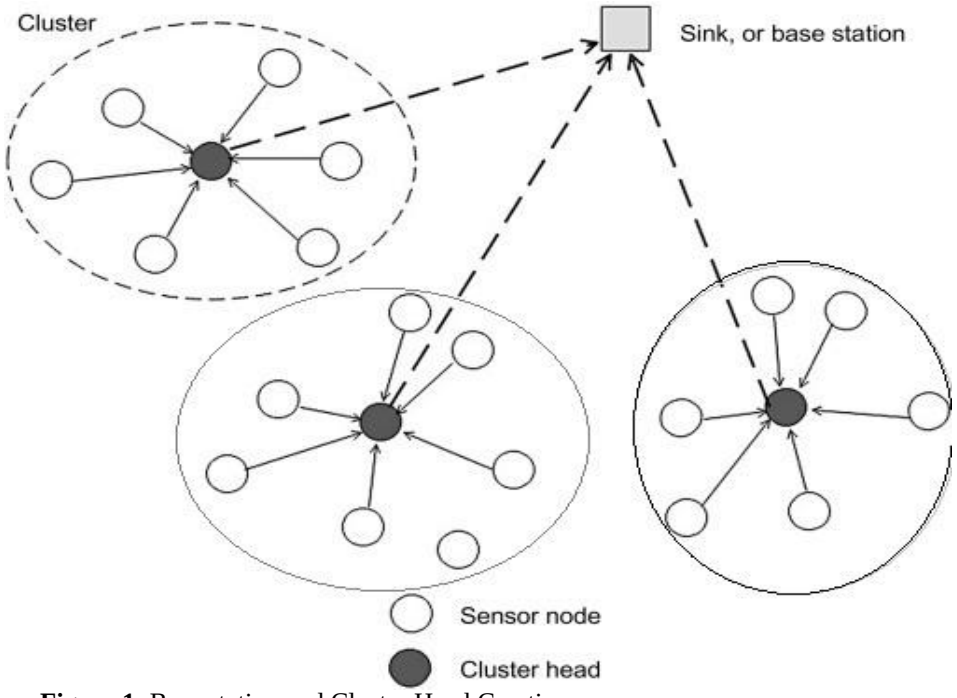

Figure 1: Base station and Cluster Head Creation

The number of packets sent and received is calculated and maintained in data frames as a protocol format. All nodes in a cluster have maintained energy consumption, packet loss, packet delivery ratio, number of clusters and nodes and size of the packets for every round of data transmission. Figure 1 shows the base station which is connected to the nodes and cluster is set up for implementation. Figure 2 indicates the nodes which are connected to BS and the clusters have created under one base station with the Topology set up

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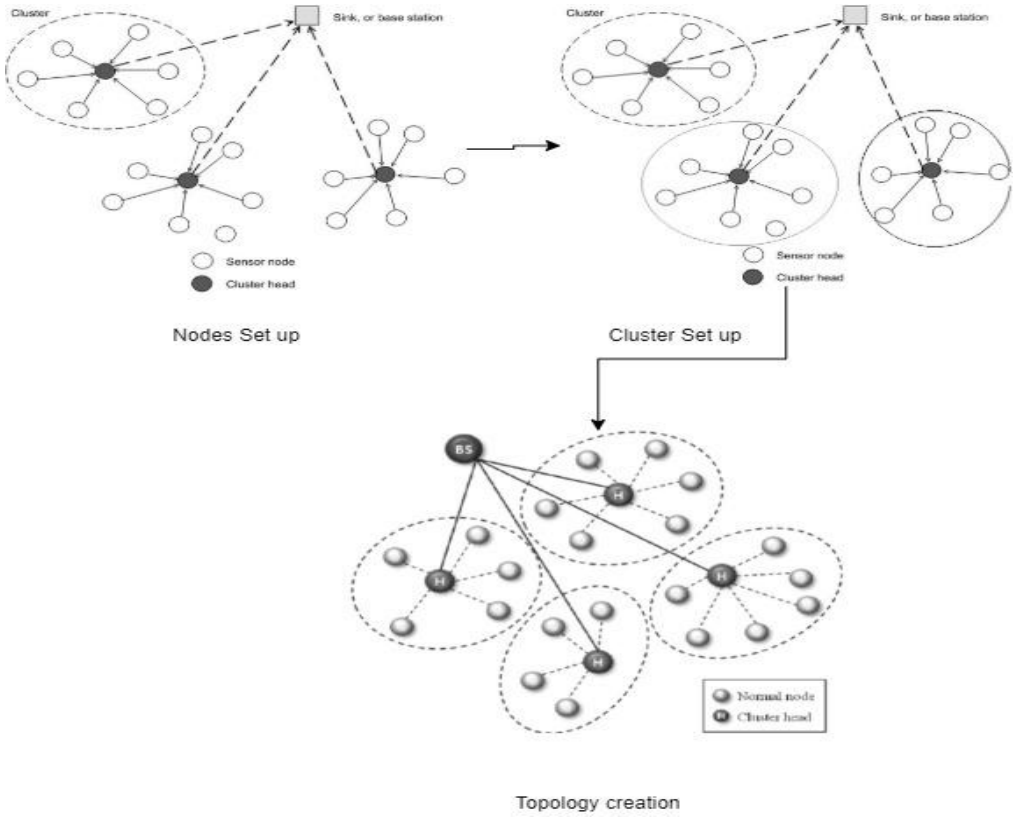

Figure 2: Topology Creation

The cluster head is created for controlling and monitoring the nodes in the network. Cluster members are controlledby the cluster heads. The topology has developed with this cluster andthe nodes in a setup phase. This model has been created for finding the total energy used by every node, cluster, cluster member, and cluster head. Several nodes are connected in a cluster and their energy consumption is taken at every round.

Table 1 explains the terms used in a network cluster.

Table 1: Terms Used in Network Structure

Network Notations	Descriptions
ECH	Energy used by theCluster Head
ECHS	Consumed energy at selection level
N	Number of nodes connected in network
SP	Packet size used for sending and receiving
d	Distances between the nodes
N C	Number of clusters
NCM	Cluster members used

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ECM	Energy used by cluster members

This is the SEERA algorithm for improving energy efficiency and scalability.

SEERA Algorithm

```
1   Start the node selection
2   Initialize the size of node
3   Create base station (BS)
4   Get the number of nodes and their packet size
5   Initialize clusters and cluster heads (CH)
6   Calculate the distance between the nodes (space vector)
7   Measure the packet control size
8   Calculate the energy (J) of the node initially
9   Initialize first round or trail
10  For each trail
11      CH optimal number selection
12      Connect the clusters
13      For each Cluster Head
14          CH selected for next round based on energy
15          For each Cluster Member selection
16          Started send and receive data
17      End for
18  CH to BS data transmission
19  End for
20  End for
21  Stop the trail
```

The cluster nodes' total energy can be calculated using the following equations.

$$E_{CM} = \sum N*S_p*d \quad (1)$$

$$E_{CH} = \sum N_c*S_p*d \quad (2)$$

$$E_{CHS} = E_{CM} + E_{CH} \quad (3)$$

The distance between the base station and nodes is denoted byd and thesize of the delivery packets is also found in S_p. The energy consumed in cluster members is calculated using the first equation by multiplying the number of nodes, distances, and packet sizes in the nodes. In the same way, all the cluster head's energy consumption is calculated and stored in an index method. The energy consumed in all the individual nodes differs when it is connected with the clusters and cluster heads. The rounds or trails of data transmission is increased to prolong the network time. When the number of rounds is increased, the average energy consumed by the nodes in a cluster varies according to the distance. In other words, if the distance between thenodes and BS is high, then the energy consumed becomesmore whereas when the distance is less,then the energy consumed is low. The total energy utilized is calculated and the mean value has been identified to get the average energy used in the clusters. All the cluster heads' energy

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consumptions are measured and selective cluster head values are taken into consideration.

Experimental Setup

To evaluate the SEERA performance, this algorithm is compared with benchmarks like LEACH, CELL_LEACH, MULTI_LEACH, EERA and SEHR. The test experiments were conducted on different parameter requirements. The minimum size of 150m has been taken for initial level set up and then 3 base stations were created. This setup worked with a minimum of 100 nodes to a maximum of 1500 for analyzing the energy efficiency and latency. The size of the packets had been fixed in the frames for sending them from source to destination along with the security headers. A minimum of 35 bits with control structure and 2500 bits for data packet had been synchronized for transmission.

The following table 2 summarizes the parameters used for simulations. The energy level of all the nodes, clusters, cluster heads, and selected clusters was calculated to note the changes during transmission.

Table 2: Parameters Used for Simulation

Network Criteria	**Initial Measurements(approx.)**
Size of the Network	150 m x 150 m
Base stations count	3
Nodes used	100-1500
Packet size of data transferred	2500 bits, 35 bits(control)
Starting energy level of node	3J
Rounds	1-15(multiples of 100's)
Cluster head energy level	55nJ/bit
Free space vector (distance)	15pJ/bit/m^2
Average Energy of cluster selection	5 nJ/bit/signal

The energy consumption value got changed drastically due to the number of nodes present. The data was transmitted to different network path locations and was delivered at different times and locations. While sending packets, drops occurred due to the size of the clusters. That will be handled by this algorithm for the optimization of energy consumed in the clusters

Simulation Results

The simulation experiment was conducted with the parameters used in table 2 and their results were taken from simulation tools such as NS3 simulator. This simulator is used to analyze the results based on various options such as the number nodes changed and packet size change etc. The energy used in each node differed in every round and the percentage of variations have been measured. The initial number of nodes and rounds of trail has been selected for analysis in NS3. The benchmark protocolsworked effectively and the energy used was calculated for analysis. EERA, SEHR protocol values were also considered to give better accuracy among the nodes used in WSN. The following figure 3aand sub figures describes

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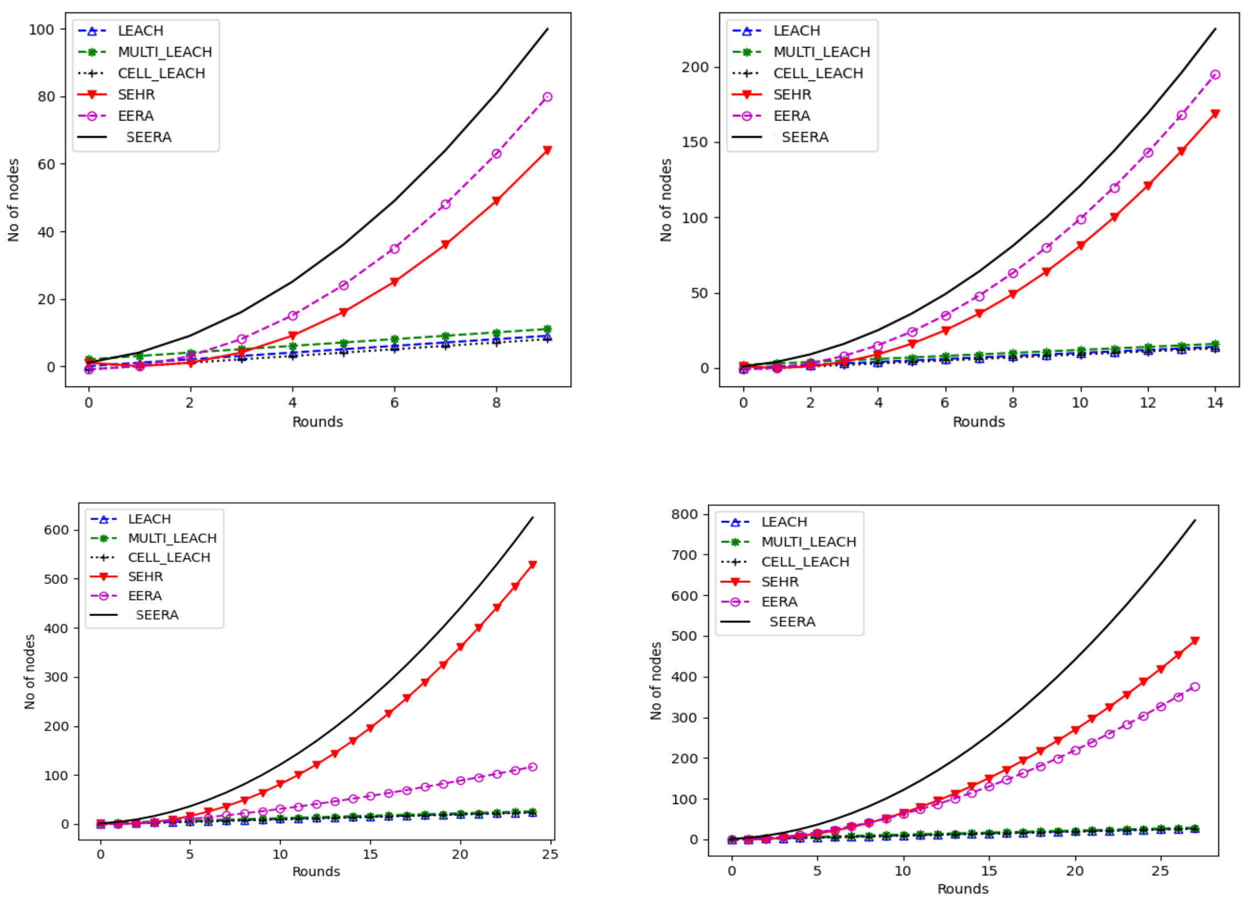
SEERA routing algorithm results separately.

The below diagramsdenote alive nodes used forthe experimental setup and thenumber of rounds taken for all considerations. Initially, all the energy consumed by the nodesare minimum in the BS but the distances increase between nodes and BS instantly. So, it needs a lot of energy to do the data transmission. Multiple rounds are started among the nodes and all are getting deviated according to the nodes present. In figure 3a, 100 nodes can be selected for analysis and the energy consumption varied from the 30th node which is slightly in the middle of the network nodes. When it reaches the 100th node, SEERA algorithm provides better results compared with all the other benchmark protocols. The same experiment will be conducted for 200, 600, 800, 1000, and 1500 respectively.

From all diagrams, the solution is that the scalability of the WSN has increased with the usage of the SEERA algorithm. It also provides better results in energy usage. The other figures 3b, c, d, g, and f describe the energy consumption variations in the network structure based on the cluster head selected during the experiment. Benchmark protocols are initially given the same values as used in this algorithm, but the levels of the node increased their performance and slightly improvedthe result by 35-48%.



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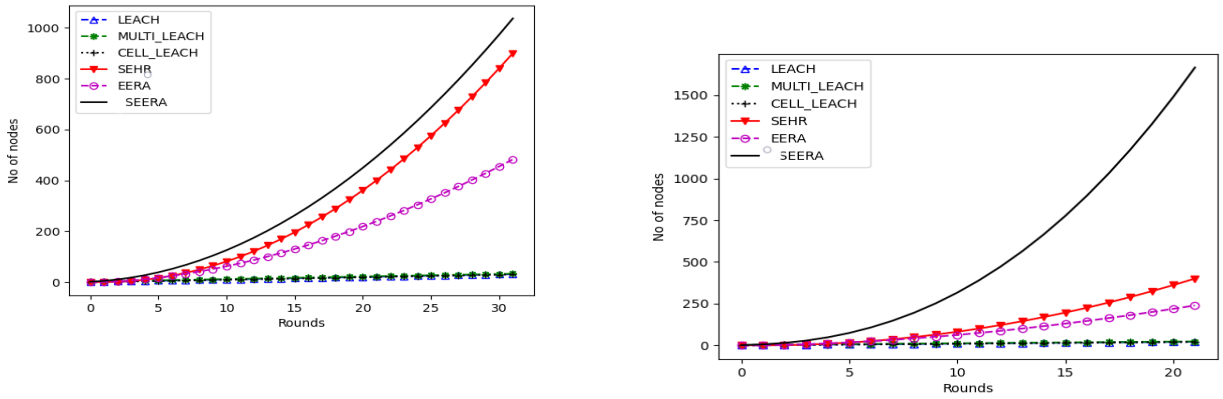
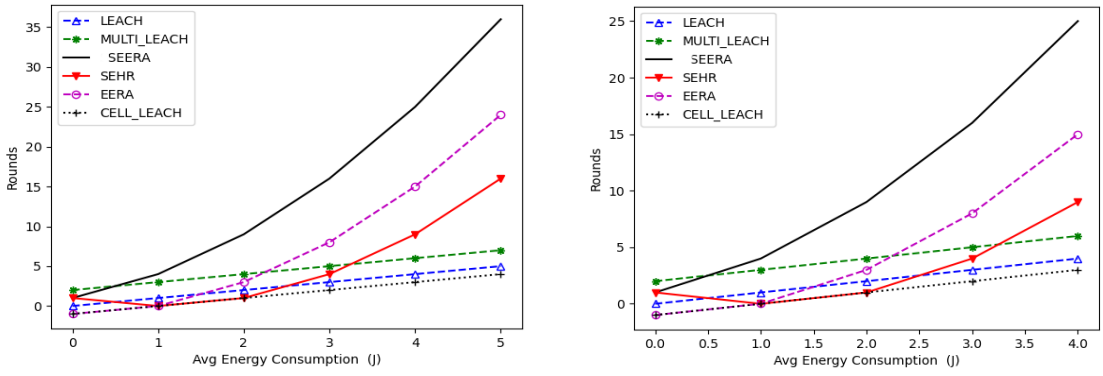


Figure 3: Nodes used at various sizes: a) 100 b) 200 c) 600 d) 800 e) 1000 f) 1500

The results are taken from all the clusters and were analyzed with parameters with the initial value set at the beginning of the experiment. The average residual energy level has been measured from the experimental setup and compared with the benchmark protocols in the NS3 simulator. The power source has distributed its strength to all the nodes in the clusters, but due to the variations of the distance between the nodes from the base station, the nodes' energy got drained in the process of data transferring. To overcome that problem, scalability is improved along with optimized energy in SEERA. The following figure 4a with sub figures are summarize the average energy consumption used in the experiment with SEERA algorithm.

The lifetime of the network has been prolongedwith a suitable routing algorithm present in the entire cluster classification. The results were accomplished with average residual energy utilized and then will be considered based on the number of nodes present in the system. It shows that all the predefined nodes have consumed minimum energy whereas the nodes willincrease to reach the maximum of 100 when deviation started.

The unit of energy consumption used in nodes is represented as J and will be varied in all the nodes which come under cluster heads. Moreover, all the diagrams that represent the level of energy consumption start from 0-7.5 as a maximum number of nodes used but it varied from 0.5 to 2.5 by default. The SEERA algorithm clearly states that the energy utilized can be reduced when the scalability of the nodes is increased in the WSN architecture. The performance level is improved using the SEERA algorithm and through this the energy-efficiency level is optimized.



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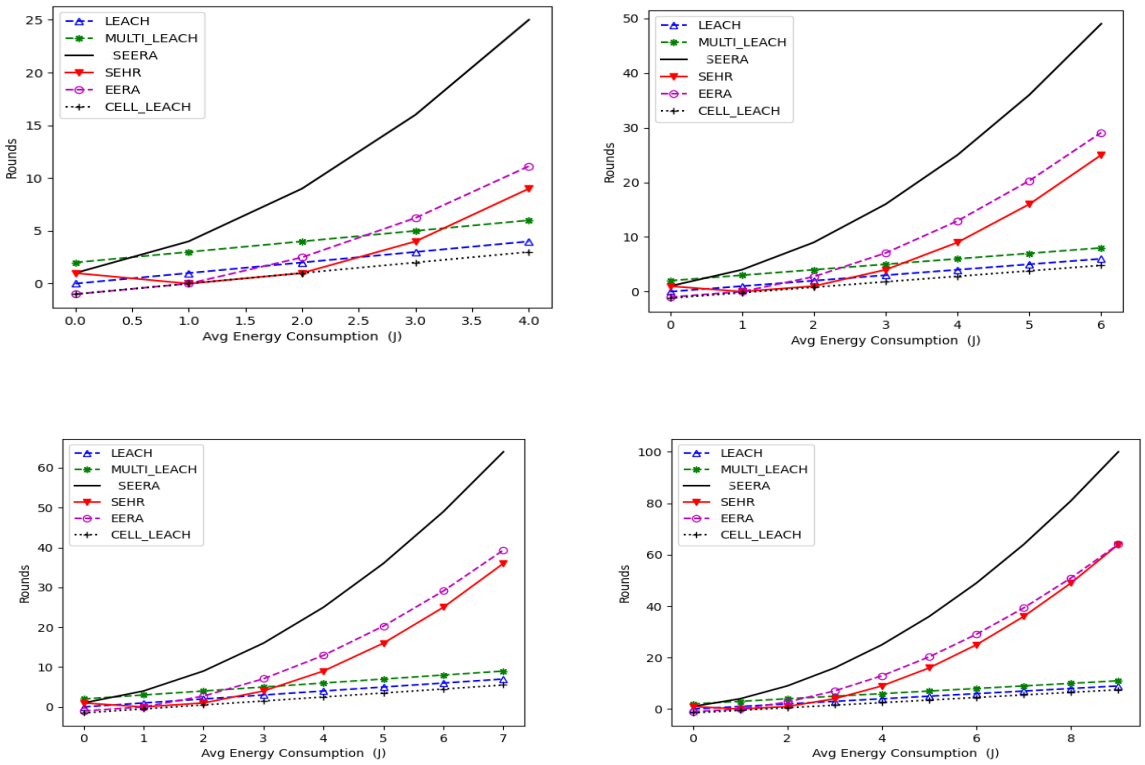

Figure 4: Performance levels energy efficient of various nodes: a) 100 b) 200 c) 600 d) 800 e) 1000 f) 1500

Conclusion

The CH packet size has been noticed in every transaction for security purposes to avoid any intruders which will enter into the system for unauthorized purposes. To manage the scalability criteria in this SEERA algorithm, a minimum of 100 nodes to 1500 nodes has been considered for experiments. The benchmark protocols provide better results in the initial level but when the number of nodes is increased, then they get distracted due to scalability issues. This was the challenge met in WSN normally, but SEERA provides better results.

SEERA demonstrated good results in increasing the network lifetime and extended it up to 72% from the minimum of 34 %. The other benchmark protocols did not extend the lifetime as high as this and their maximum levels was 67% from 34%. The number of nodes considered for the experiments were 100, 200, 600, 800, 1000, and 1500 respectively. For all the nodes the deviation starts at the 100th node selection. Initially, all the other protocols gave the same values in the energy and scalability parameters. But when the number of nodes were increased, then their values changed according to the distance between the nodes in the cluster. The SEERA algorithm provides better results when compared with benchmark protocols which were presented in the previous routing algorithm approaches.

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Future Enhancement

The experimental results have given the idea of WSN sensor nodes' energy consumption and their scalability levels. This algorithm would be further checked for prolonging network lifetime in WSN at various scenarios. This algorithm minimizes the time management on the WSN, by increasing the cluster member's availability in the network structure. The throughput will be improved inlarger network also be developed in future.

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