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Multihop Deterministic Energy Efficient Routing Protocol for Wireless Sensor Networks MDR

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Abstract

The inception of Wireless Sensor Networks (WSN) has brought convenience into many lives with uninterrupted wireless network. The nodes that transmit data consist of heterogeneous and battery equipped sensor nodes (SNs) that are deployed randomly for network surveillance. To manage the random deployment of nodes, clustering algorithms are used with efficient routing protocols. This results in aggregation and dropping of redundant data packets that enables flawless data transmission from cluster nodes to Base Station (BS) via Cluster Heads (CHs). In this paper, a dynamic and multi-hop clustering and routing protocol for thorough behavior analysis is proposed, taking distance and energy into consideration. This forms a smooth routing path from the cluster nodes, CHs, Sub-CHs to the BS. On comparing proposed process with the existing system, experimental analysis shows a significant enhancement in the performance of network lifetime, with improved data aggregation, throughput, as the protocol showing deterministic behavior while traversing the network for data transmission, we name this protocol as Multi-hop Deterministic energy efficient Routing protocol (MDR).

Keywords

Energy Efficiency, Multi-Hop Routing Protocol, Wireless Sensor Networks, Network Lifetime

1. Introduction

Wireless sensor networks (WSNs) are wireless networks that monitor physical or environmental conditions like sound, vibration, temperature, motion, pressure etc. WSNs generally consist of sensor nodes (SNs) that hold decent processing power but limited power source [1] [2] [3]. A sensor node consists of three basic units: a computing unit for data processing and storage, a wireless communication unit for data transmission and a sensing unit for data collection from surrounding environment. Nodes are usually deployed randomly where meteorological conditions cannot be monitored by humans [4].

Information is gathered and transmitted to the base station (BS) via nodes, which consumes battery. Continuous battery consumption leads to loss of battery power and failure in sensing. Replacement of SN batteries is nearly impossible when nodes are deployed in hazardous environments like volcanoes, battlefield etc. [5] [6]. So, a longer lifetime is required by the network to continue data transmission [7].

Figure 1 shows the basic architecture of WSN. The data flows from sensor node to sink node from where users can access it over internet [8]. There are some parameters like Fault Tolerance [9] [10], Power Consumption [11] [12], Data Aggregation [13] [14], Quality of Service [15] [16], Data Latency [17], Load Balancing [18] and Node Deployment [19] [20] that must be considered while implementing the clustering protocols.

In [21] with less than 100 nodes a very used routing protocol is AODV, increasing the number of nodes it is possible to find the best route for data transmission or message flow, However, isn't presents a higher performance, that is, a high energy cost, therefore, with a reduced life time.

To overcome the above mentioned problem, cluster-based routing protocols provide an efficient solution by dividing the sensor network into small and manageable clusters [22] [23]. The protocols form a dynamic multi-hop routing path which makes communication between clusters and BS more effective [24]. As a result, low-energy consumption is achieved by aggregating the collected data from same cluster [25]. Ultimately, network's lifespan also increases by cluster load balancing [26].

The purpose of this research work is to analyze the performance of the wireless sensor network under the proposed protocol called multi-hop deterministic energy efficient routing (MDR) protocol using MATLAB program to perform simulations in different scenarios. The rest of the research work is divided in the following way: section II details the previous research studies and determines the

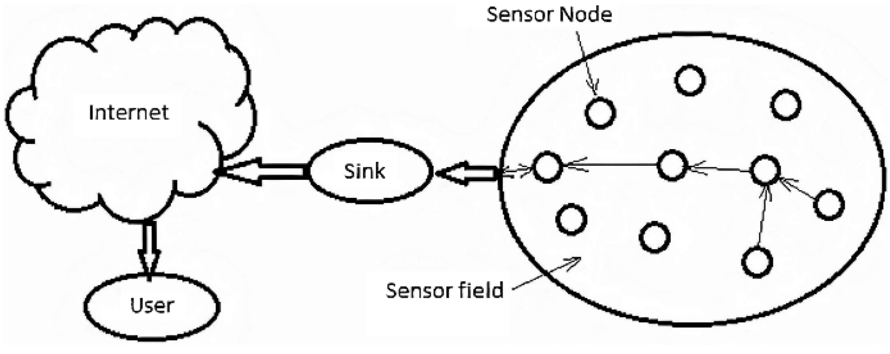

Figure 1. Basic Architecture of WSN.

existing problems in them, section III shows the proposed model, section IV shows the results and section V shows the conclusions.

2. Literature Survey

Heinzelman *et al.* [27] proposed the Energy efficient Multi-hops Routing protocol based on Clusters Reorganization (EMRCR) with three phase structural design *i.e.* cluster formation, divides the zones into sub-zones and transmission of data through multi-hop inter cluster routing. Proposed model does not consider the distance of sensor nodes from BS.

Younis and Fahmy [28] proposed the optimal number of cluster-heads that is based on changing the number of cluster-heads and associated consumed energy. On using the number of relay packets in intra-cluster and inter-cluster transmission, the energy change in total network consumption is calculated. Proposed model find that the change ratio of cluster-head's energy, the change ratio of inter-cluster energy and change ratio of intra-cluster energy is based on sensor energy model and relay packets by experiments.

Parmar and Thakkar [29] proposed the Energy-efficient data transmission that is required by WSN because of battery constraint. Energy consumption is independent of the number of clusters used; the number of clusters that work in local cluster made by CH influences the energy consumption of sensor nodes.

Heinzelman *et al.* [30] proposed the hierarchical clustering that is applied to manage the sensor nodes *i.e.* HCNM. To disperse the equal number of nodes, the network computes the distance of each node. By performing subsequent clustering, proposed model avoids the problem of over-fitting and under-fitting of CHs in a network.

Bharti *et al.* [31] proposed the CH selection that considered the impact of its distance from base station to cluster head and WSN's routing protocol based on improved LEACH algorithm. On performing experimental analysis and comparing it with the LEACH algorithm, delay in node's death time, and improvement in its survival rate and disperse nature in location of dead node is noticed. Also, its average power is increased and life cycle is extended.

Anjali *et al.* [32] proposed the distance-based routing algorithm that divides the whole network into smaller and manageable clusters with cluster heads to handle the data transmission. Proposed system enhances the lifetime of wireless networks by saving the energy of sensor nodes. After collecting the sensed data, it will transmit to the base station.

Singh *et al.* [33] proposed Energy Efficient Clustering Scheme (EECS) protocol by electing cluster heads with more remaining energy through local radio communication. The competition method is localized without iteration and brings uniformity among distributed cluster heads. In the cluster formation phase to balance the load among cluster heads will increase that will be handled by CHs by routing the packets to the base station.

Sivakumar and Radhika [34] introduced an energy-efficient LEACH (EE-

LEACH) protocol for data gathering. It offers an energy-efficient routing in WSN based on the effective data ensemble and optimal clustering.

3. Proposed Model

Various energy efficient routing protocols have been proposed since the inception of WSN. The first most successful algorithm for energy efficiency was LEACH. That was the time WSN had limited functionality and was usually deployed in smaller field size that was less dependent on AI (artificial intelligence), Cloud etc. With the advancement of technology and IoT (Internet of things), the demand of sensors increased significantly, but the base of algorithm remained same. Most of the authors still consider the standard parameters used in LEACH and investigate performance of protocols on these basis.

Our investigation shows that slightest change in the parameter will make significant impact in the performance. Table 1 represents the overview of features and technical specifications in terms of deliverables that includes the topography, number of nodes, energy distribution of each node, number of packets and number of rounds. Apart from number of nodes and topography *i.e.* 100, 300 and 1000 nodes and 100 * 100, 300 * 300 and 500 * 500 topography respectively, everything is common.

The proposed routing protocol named as MDR and is aimed at improving energy efficiency in WSN by ensuring distributed load balancing across the network. The protocol functionality can be described in two phases. Phase one comprises the selection of optimal CHs and phase two comprises how transmission is being done through node to CHs via automated selected SCHs and how the transmissions is done between the CHs to base station via cluster routing.

For the research purpose, the methodology is distributed into three phases.

Phase 1 The MDR protocol is structured to select cluster heads using three (3) parameters, *i.e.*, Average Communication Distance (ACD), Residual energy of

Table 1. Initial parameters of proposed model.

Parameter	Description	Value
Topography	Dimensions of Field	100 m * 100 m, 300 m * 300 m, 1000 m * 1000 m
No. of	No of Nodes	100, 300 and 1000
rounds	Max no of Rounds	10,000
Eo	Initial energy of each node	0.5 J
ETx	Transmission energy of node	50 * 0.000000001 J
ERx	Receiving energy of node	50 * 0.000000001 J
EDA	Data aggregation energy	5 * 0.000000001 J
Efs	Energy dissipation for free space	10 * 0.000000000001 J
Emp	Energy dissipation for multi-path delay	0.0013 * 0.000000000001 J
Packet	Packet size	4000

nodes and Distance between cluster heads.

3.1. Average Communication Distance (ACD)

This ensures that the node to be elected as the first cluster head must have the lowest ACD in terms of central location to neighboring nodes. This value will be obtained based on the formula below:

$$ACD_i = \frac{\sum_{i=1}^{n} D_i}{n} \tag{1}$$

where D_i is the distance to the *i*th node and n is the number of nodes in the cluster.

3.2. Residual Energy (RE)

The second parameter ensures that the nodes to be selected as subsequent CHs must have enough residual energy that is not less than 0.2. This is because it takes more energy to carry out data aggregation and forwarding than required for data sensing.

As such a CH must have enough energy to carry out its functionality. This is estimated using the equation below:

$$RE = \frac{TNT + TNR}{N} \tag{2}$$

where N is used to represent the initial energy of the node from beginning of node life, TNT is total number of packets transmitted while TNR is the total number of packets received.

3.3. Distance between Cluster Heads

After the selected node is chosen as a CH candidate, it is then checked to know how close it is to the previous cluster head(s) by ensuring that the distance is not lesser than two cluster radius range ($2CRR$) which is the distance of each cluster in the network. This is to ensure that CHs are evenly spread across the network thereby ensuring that the load is appropriately balanced across the network. Cluster Range Radius (CRR) is calculated using the equation below:

$$CRR = \sqrt{(L * W)/((N * p) * p_i)} \tag{3}$$

where L and W represent the length and width of the network, N is the number of sensor nodes in the network, p is the percentage of cluster heads and p_i is equal to 3.142.

Phase 2 In MDR whenever node sensed the data, it transmits information always to nearby node, forming a chain of transmission until the data is reached to cluster head. Same Cluster Head forms the chain of Cluster Head transmission to allow most energy efficient manner for transmitting the data to sink. This approach makes network more scalable and suitable to face the real-world challenges.

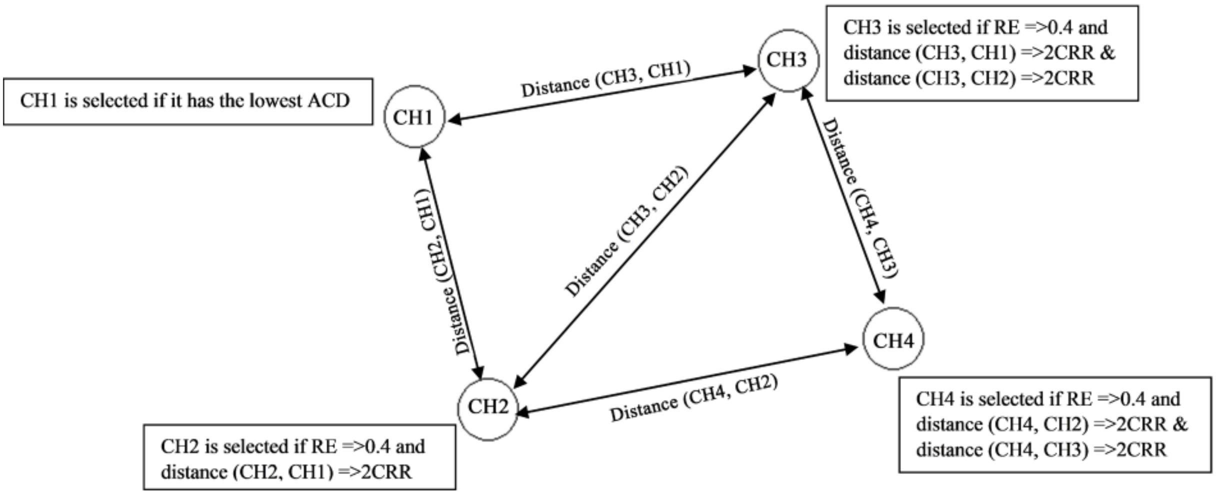

Figure 2. Shows the cluster head selection methodology.

Our proposed MDR will be based on dynamic selection of CHs and sub-CH, multi-hop routing protocol. Sub routing path formation between the cluster nodes, sub-CHs to CHs and Base Station makes protocol more energy efficient in real world applications. The overall setup and transmission architecture is show in Figure 2.

4. Results and Discussion

In this section we make comparison between the proposed protocol and the existing protocols with simulations. All simulations have been done in MATLAB. We start investigating the performance of protocol with considering the same scenario as being proposed by authors. With field size 100 * 100 and number of nodes 100 and all nodes are randomly placed in the field.

Extending the research, the investigation will be done to test the scalability and real world challenge we extend the work for scenario with field size 300 * 300 and 1000 * 1000 with number of node 300 and 1000 respectively considering the rest of parameter standard and distribution of node in the network is random, with mobility of node either very low or stationary further ignore any energy dissipation because of signal interference of dynamic channel condition.

To justify that the performance of the MDR is better than that of the existing protocols, the performance of protocol is compared with in term of network lifetime, packet to base station and network energy dissipation is compared with that of LEACH, O-LEACH EEE-LEACH and ZSEP, taking all simulation conditions same.

Figure 3 is the representation of the communication-based with respect to the network lifetime of the node. Figure 4 shows the performance of protocol in field size 100 × 100 with 100 nodes. As shown in figure the proposed MDR protocol is outperform the rest of protocol in network lifetime.

Figure 5 is the representation of the energy dissipations of network and in Figure 6, shown the packet to base station with number of rounds over the field

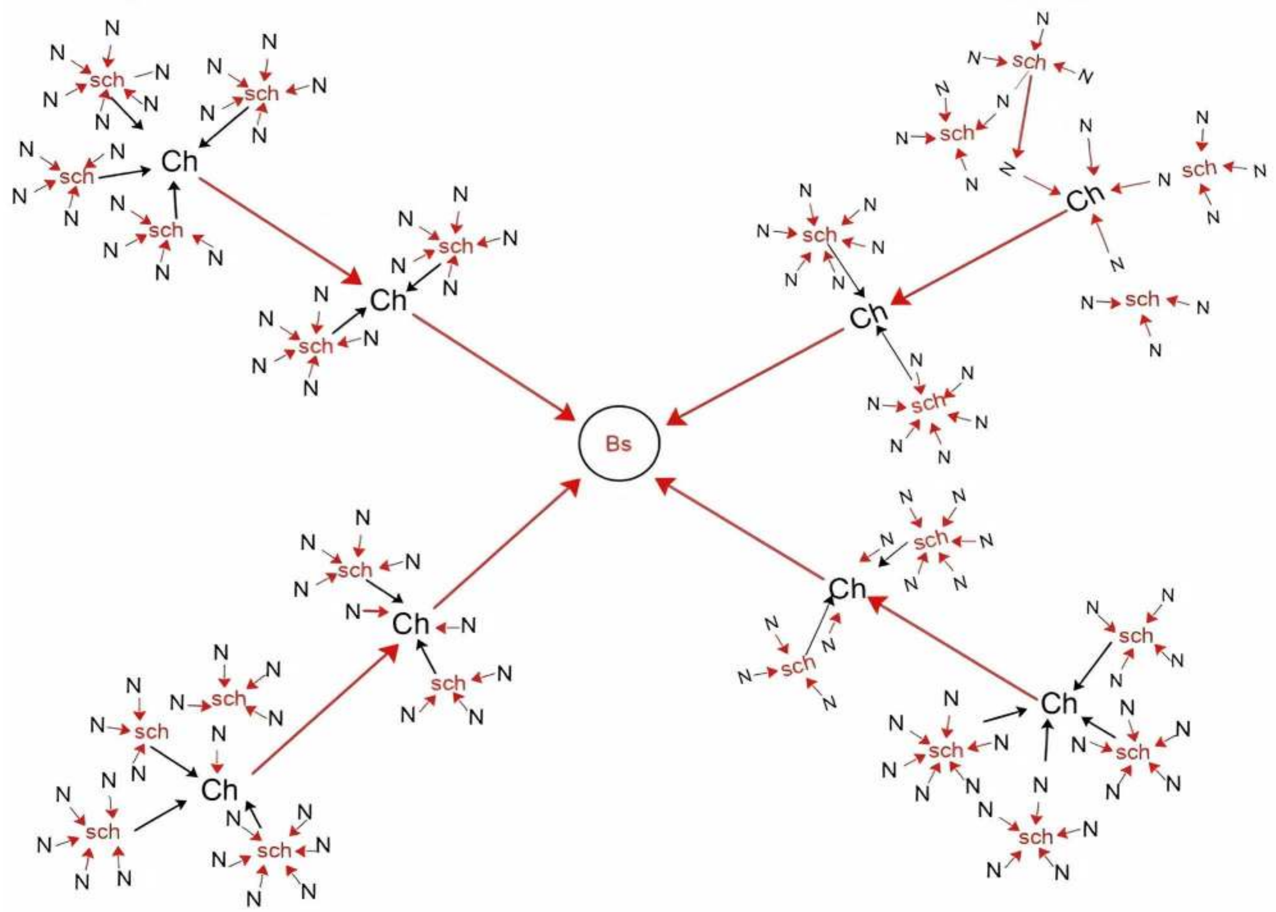

Figure 3. Network communication between node to Sub Cluster Head (SCH), SCH to CH (cluster head) and Cluster Head to base station.

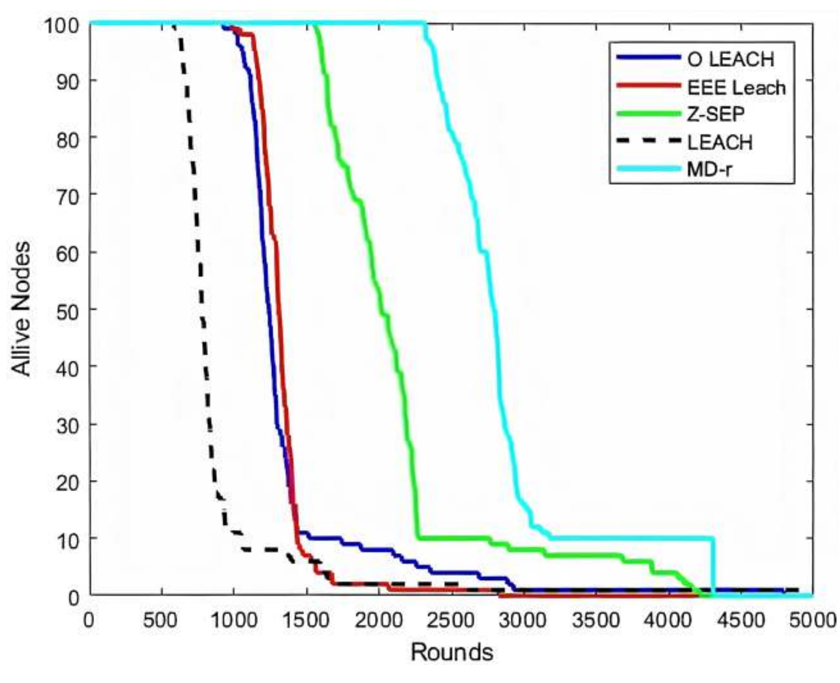

Figure 4. Alive nodes vs. round. For smaller field size 100*100 and no. of nodes are 100.

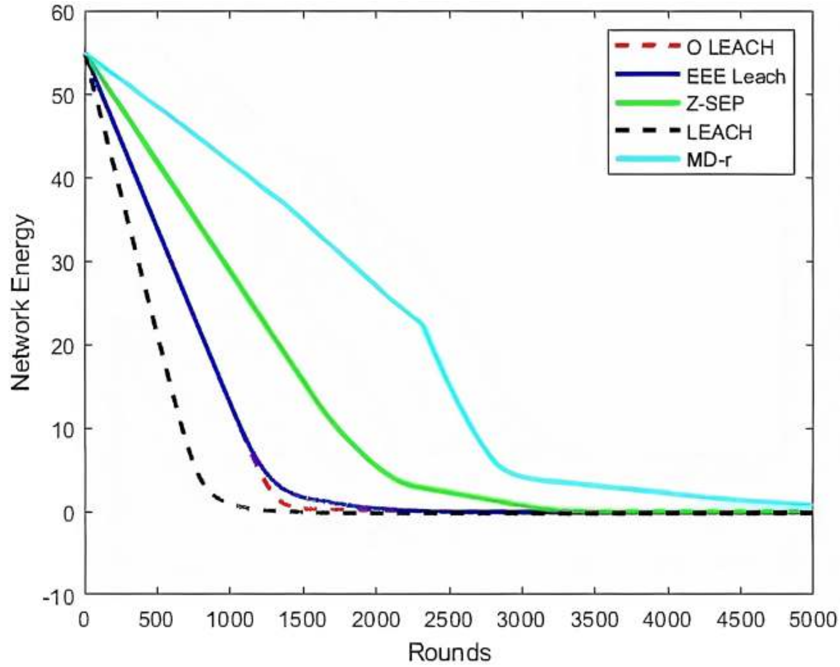

Figure 5. Energy dissipations of network in field size 100 * 100 and node no. 100.

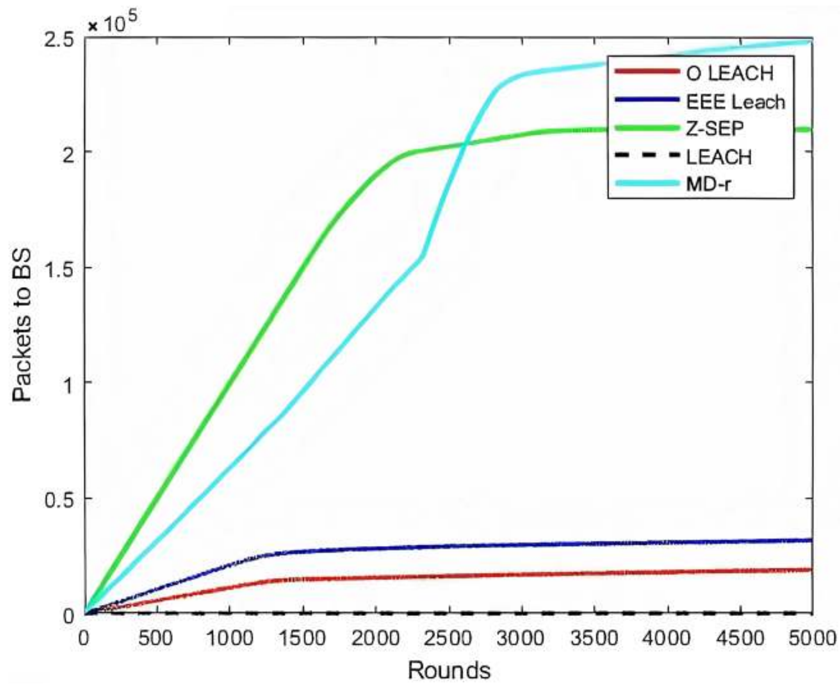

Figure 6. Packet to base station with number of rounds over the field size 100 * 100 and node no. 100.

size 100 * 100 with 100 nodes. As shown in figures, the analysis of the proposed MDR protocol unlike the others in a small scenario clearly shows that the proposed protocol shows the most stable performance of the network.

In the next section we move toward validating the performance of MDR for variable field size, we investigate the performance for larger network size and a greater number of nodes. We considered the scenario for 300 * 300 and 1000 * 1000.

Figure 7 shows the performance study based on the comparison with respect to the node network lifetime in a field of size 300 * 300 with 300 nodes.

Likewise the analysis in this field shows that the MDR protocol has a better performance in terms of network lifetime.

Figure 8 is the representation the packet to base station with number of

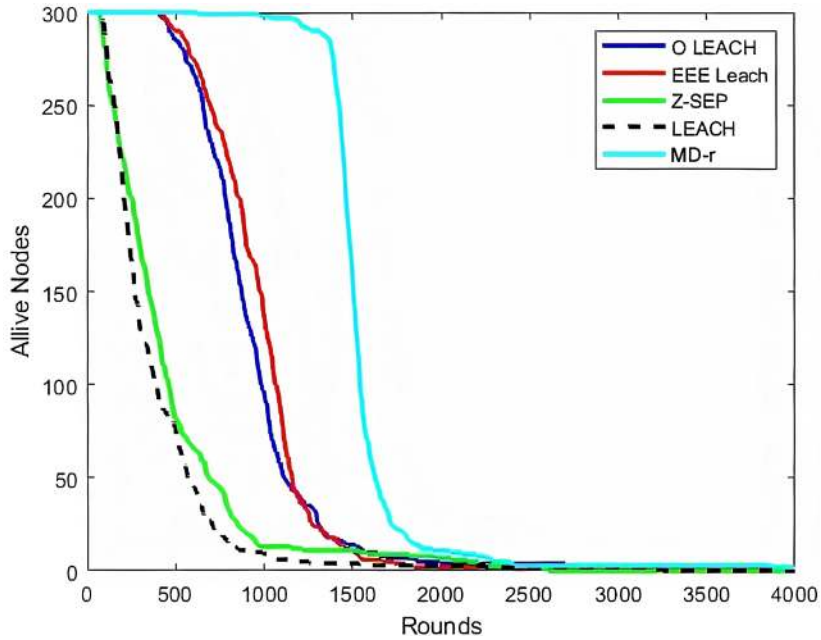

Figure 7. Alive nodes vs. round. For medium field size (300 * 300) and no. of nodes are 300.

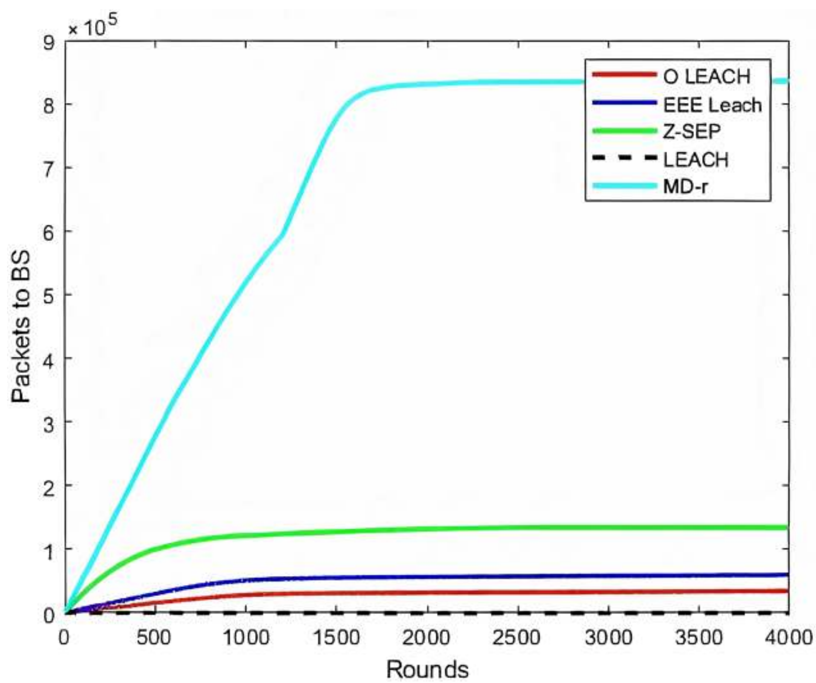

Figure 8. Packet to base station with number of rounds over the field size 300 * 300 and node no. 300.

rounds over and in **Figure 9**, shown the energy dissipations of network the field size 300 * 300 with 300 nodes. As shown in the figures, the proposed MDR protocol in a medium field has better results compared to the other protocols.

As shown in **Figures 10-12** which represents the analysis of the proposed MDR protocol in a large field where a very stable behavior is seen for this type of network.

Table 2 and **Table 3** show the performance of energy dissipation and network

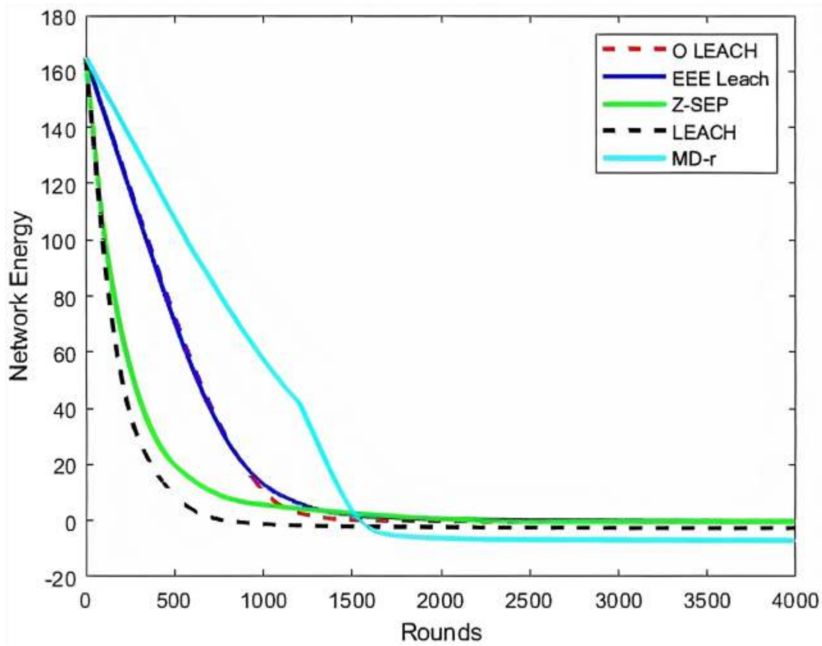

Figure 9. Energy dissipations of network in field size 300 * 300 and 300 nodes.

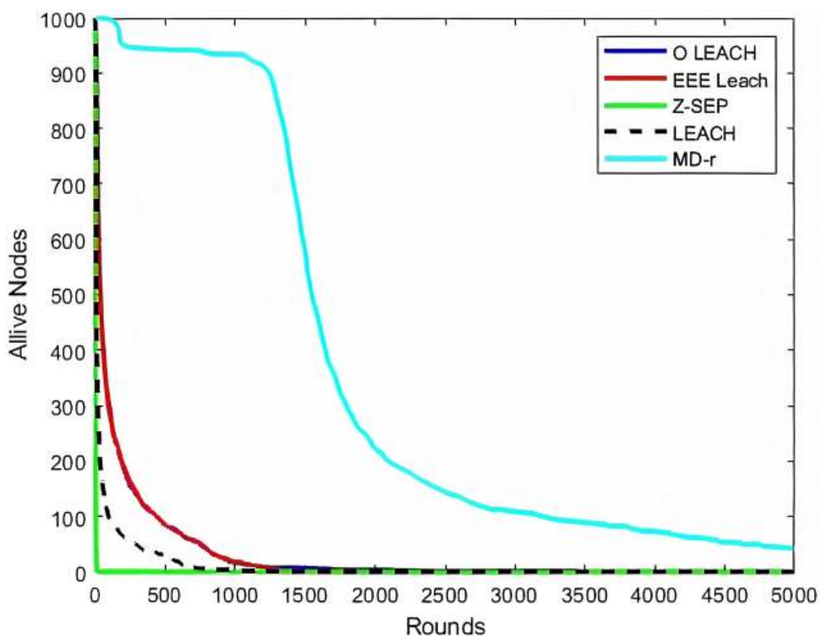

Figure 10. Alive nodes vs. round. For large field size (1000 * 1000) and no. of nodes are 1000.

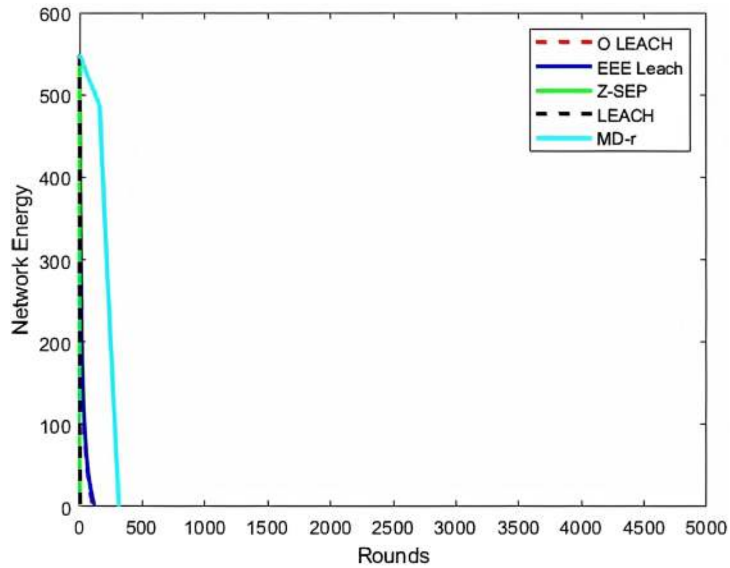

Figure 11. Energy dissipations of network in field size 1000 * 1000 and node no. 1000.

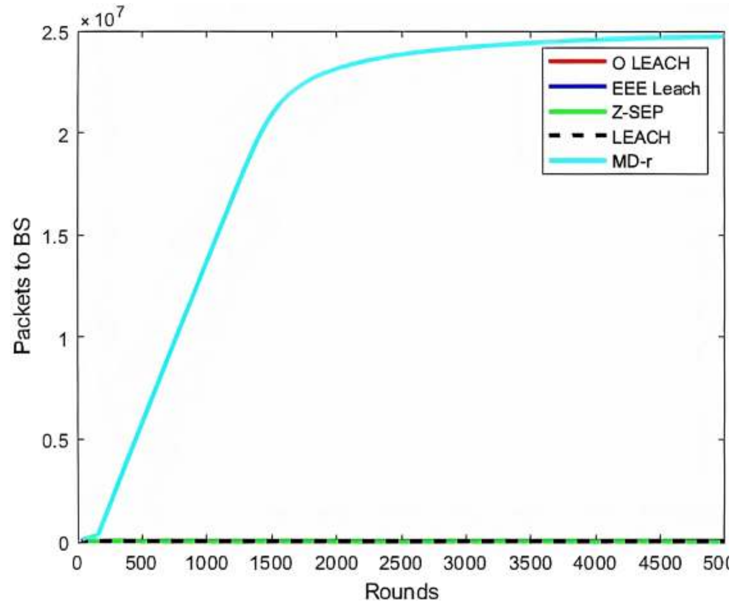

Figure 12. Packet to base station with number of rounds over the field size 1000 * 1000 and node no. 1000.

Table 2. Energy dissipation comparison of all field sizes of all the protocols.

Protocol	Field size 100 * 100 with 100 nodes			Field size 300 * 300 with 300 nodes			Field size 1000 * 1000 with 1000 nodes		
	10%	50%	90%	10%	50%	90%	10%	50%	90%
Oleach	132	656	1185	90	444	919	4	19	234
EEEleach	132	654	1196	91	451	962	4	21	273
ZSEP	213	1057	2001	27	147	644	2	2	3
Leach	83	411	763	28	145	469	3	8	43
MDR	423	1966	2837	148	737	1389	126	708	1468

Table 3. Network lifetime comparison of all field sizes of all the protocols.

Protocol	Field size 100 * 100 with 100 nodes			Field size 300 * 300 with 300 nodes			Field size 1000 * 1000 with 1000 nodes		
	10%	50%	90%	10%	50%	90%	10%	50%	90%
Oleach	1098	1245	1923	583	947	1269	12	42	535
EEEleach	1164	1322	1456	609	946	1259	12	40	526
ZSEP	1667	2075	2895	113	349	882	2	3	43
Leach	674	808	1088	133	323	755	3	11	95
MDR	2416	2803	4306	1396	1506	1707	1147	1541	2933

lifetime of all the protocols respectively. It is clearly visible that the proposed protocol shows very consistent behavior in all field sizes and makes very stable network type. While in case of ZSEP, as we increase the field size, protocol performance is significantly impacted. For a very large field size, the initial 10% nodes died at very initial rounds which ultimately impact the network synchronization. In case of MDR, increase in field size does not impact the stability of the network. In case of other protocols OLeach, EEELeach and Leach, on increasing the field size ten times, the performance of protocols in terms of network stability decreases ten times while taking the other parameters remain same.

5. Conclusion and Future Work

In this article, we start with simulation study of existing energy efficient protocol with variant field sizes and number of nodes, then the simulation performance of existing protocols show significant downgrade in performance, proving the fact that none of the protocol is scalable enough to adapt to different environments, and statistically designed for fixed field sizes with constant number of nodes. Keeping all these limitations into consideration, we designed the protocol for homogeneous network based on multi-hop sub clustering and clustering routing to transmit the data to base station. Simulation results show that the proposed protocol has shown better performance in every field size, and eventually improves performance as we move towards larger field sizes unlike the other protocols whose performance decreased as we increase the field size. Prolonged lifetime and better throughput are the parameters we have considered in this research, further investigation of the protocol in future will be focused on end to end delay, and security.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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