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# MDR-Multi-hop Deterministic Energy Efficient Routing Protocol for Wireless Sensor Network

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***Abstract:*** *The inception of Wireless Sensor Networks (WSN) has brought convenience into many lives with an uninterrupted wireless network. The nodes transmit data consist of heterogeneous and battery-equipped sensor nodes (SNs) deployed randomly for network surveillance. Clustering algorithms are used with efficient routing protocols to manage the random deployment of nodes. The aggregation and dropping of redundant data packets enable flawless data transmission from cluster nodes to Base Station (BS) via Cluster Heads (CHs). Various Energy Efficient Routing Protocols have been proposed in previous years but failed to investigate protocol behavior in different environments. This paper proposed a dynamic and multi-hop clustering routing protocol with thorough behavior analysis, taking distance and energy into consideration and created a smooth routing path from the cluster nodes, CHs, Sub-CHs to the BS. After experimental analysis and comparison with the proposed process with the existing system LEACH, O-LEACH, EEE-LEACH, and ZSEP show a significant enhancement in a network lifetime performance, with improved data aggregation and throughput. The protocol shows deterministic behavior while traversing the network for data transmission, named Multi-hop Deterministic Energy Efficient Routing protocol (MDR).*

**Keywords:** *Energy efficiency, Multi-hop routing protocol, Wireless sensor networks, Network lifetime*

## I. INTRODUCTION

Wireless sensor networks (WSNs) are wireless networks that monitor physical or environmental conditions like sound, vibration, temperature, motion, pressure. WSNs generally consist of sensor nodes (SNs) that hold decent processing power but limited power source [8] [9] [10]. 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 the surrounding environment. Nodes are deployed randomly where meteorological conditions cannot be monitored by humans [12].

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. SN batteries' replacement is nearly impossible when nodes are deployed in hazardous environments like volcanoes and battlefields[13][14]. So, a longer life is required by the network to continue data transmission [15].

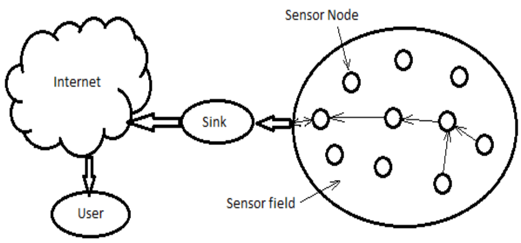


**Fig. 1: Basic Architecture of WSN**

Fig. 1 shows the basic architecture of WSN. The data flow from sensor node to sink node, where users can access it over the internet [16]. There are some parameters like Fault Tolerance [17] [18], Power Consumption [19] [20], Data Aggregation [21] [22], Quality of Service [23] [24], Data Latency [25], Load Balancing [26] and Node Deployment [27] [28] that must be considered while implementing the clustering protocols.

Cluster-based routing protocols provide an efficient solution by dividing the sensor network into small and manageable clusters [29] [30] to overcome the problem mentioned above. The protocols form a dynamic multi-hop routing path which makes communication between clusters and BS more effective [31]. As a result, low-energy consumption is achieved by aggregating the collected data from the same cluster [32]. Ultimately, the network's lifespan also increases by cluster load balancing [33].

## II. LITERATURE SURVEY

Khanoucheet al. [1] proposed the Energy-efficient Multi-hop Routing protocol based on Clusters Reorganization (EMRCR) with a three-phase structural design, i.e., cluster formation divides the zones into sub-zones and transmission of data through multi-hop inter-cluster routing. The proposed model does not consider the distance of sensor nodes from BS.

Cengiz et al. [2] proposed the optimal number of cluster-heads based on changing the number of cluster-heads and associated consumed energy. The energy change in total network consumption is calculated using the number of relay packets in intra-cluster and inter-cluster

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transmission. The proposed model finds that the change ratio of cluster heads energy, the change ratio of inter-cluster energy, and the change ratio of intra-cluster energy is based on the sensor energy model and relay packets by experiments.

Nam et al. [3] proposed the Energy-efficient data transmission required by WSN because of battery constraints. Energy consumption is independent of the number of clusters used; the number of clusters that work in a local cluster made by CH influences sensor nodes' energy consumption.

Liu et al. [4] proposed the hierarchical clustering 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, the proposed model avoids over-fitting and under-fitting CHs in a network.

Yang et al. [5] 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, improvement in its survival rate, and disperse nature in the dead node location is noticed. Also, its average power is increased, and the life cycle is extended.

Kumar et al. [6] proposed the distance-based routing algorithm that divides the whole network into smaller and manageable clusters with cluster heads to handle the data transmission. The proposed system enhances the lifetime of wireless networks by saving the energy of sensor nodes. After collecting the sensed data, it transmits to the base station.

M. Ye, C. Li, G. Chen and J. Wu [7] 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, balancing the load among cluster heads increase CHs, handles by routing the packets to the base station.

Arunmugam, G.S., Ponnuchamy, T. [11] 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.

## III. 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. WSN had limited functionality and usually deployed in smaller field size that was less dependent on AI (artificial intelligence), Cloud. With the advancement of technology and IoT(Internet of Things), the demand for sensors increased significantly, but the base of the algorithm remained the same. Most of the authors still consider the standard parameters used in LEACH and investigate the performance of protocols on this basis.

Our investigation shows that the slightest change in the parameter makes a significant impact on the performance. Table 1 summarizes the initial parameters to implement the proposed model for both scenarios, including the topography, number of nodes, the energy distribution of each node, number of packets, and number of rounds. Apart from the number of nodes and topography, i.e., 100, 300, and 1000 nodes and 100x100, 300x300, and 500x500 topography, everything is standard.

**TABLE I**
**Initial parameters of the proposed model**

| Parameter | Description | Value |
|---|---|---|
| Topography | Dimensions of Field | 100m x 100m, 300m x 300m, 1000m x 1000m |
| N | No. of Nodes | 100, 300 and 1000 |
| Rounds | Max no. of Rounds | 10000 |
| Eo | The 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 |

The proposed routing protocol is named MDR and aims to improve energy efficiency in WSN by ensuring distributed load balancing across the network. The protocol functionality can be described in two phases. Phase one comprises selecting optimal CHs, and phase two comprises how transmission is being done through the node to CHs via automated selected SCHs and how the transmissions are done between the CHs to Base Station via cluster routing.

For the research purpose, the methodology is distributed into two 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 nodes, and Distance between cluster heads.

***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 a central location to neighboring nodes [16]. This value can be obtained based on the formula below:

$$\mathrm{ACD_i} = \frac{\sum_{i=1}^{n} \mathrm{D_i}}{\mathrm{n}} \qquad \text{(eqn.1)}$$

$D_i$ is the distance to the ith node, and n is the number of nodes in the cluster [12].

***Residual Energy (RE):*** The second parameter ensures that the nodes selected as subsequent CHs must have enough residual energy that is not less than 0.2 so that it takes more energy to carry out data aggregation and forwarding than required for data sensing. A CH must have enough energy to carry out its functionality which is estimated using the equation below.

$$\mathrm{RE} = \frac{\mathrm{TNT+TNR}}{\mathrm{N}} \qquad \text{(eqn. 2)}$$

Where N is used to represent the initial energy of the node from the beginning of node life, TNT is the total number of packets transmitted, while TNR is the total number of packets received[11]

***Distance Between Cluster Head:*** After the desired node is chosen as a CH candidate node, it is then checked to know how close it is to the previous cluster head(s) by ensuring that the distance is less than two cluster radius ranges (2CRR) which is the distance of each cluster in the network[27]. This ensures 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:

$$\mathrm{CRR} = \sqrt{(\mathrm{L} * \ \mathrm{W})/((\mathrm{N} * \mathrm{p}) * \mathrm{pi})} \qquad \text{(eqn.3)}$$

Where L and W [26] represent the network's length and width, N is the number of sensor nodes in the network, p is the percentage of cluster heads, and pi is equal to 3.142.

**Phase 2:** In MDR, whenever a node sensed the data, it transmits information continuously to a nearby node, forming a transmission chain until the data reached to cluster head [25]. The same Cluster Head forms Cluster Head's chain, and data transmission allows the sink in the most energy-efficient manner. This approach makes the network more scalable and suitable to face real-world challenges.

Our proposed MDR is based on a 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 are shown in fig. 2.

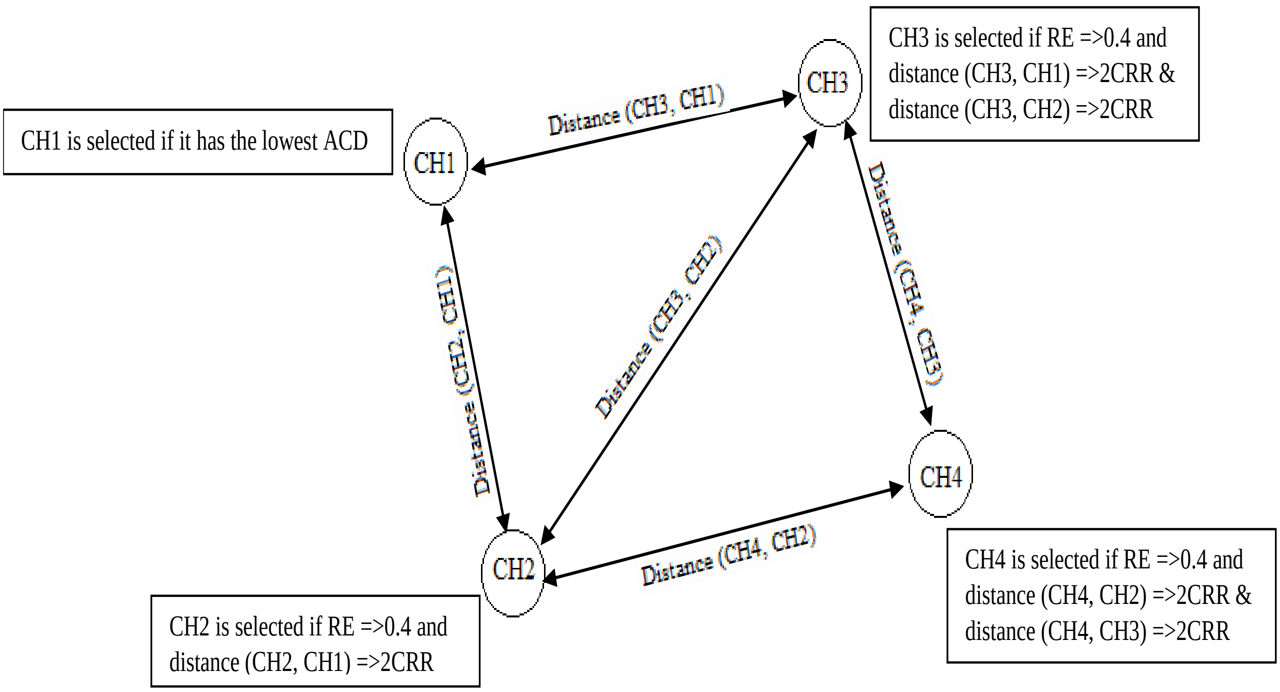


**Fig. 2 shows the Cluster Head selection methodology**

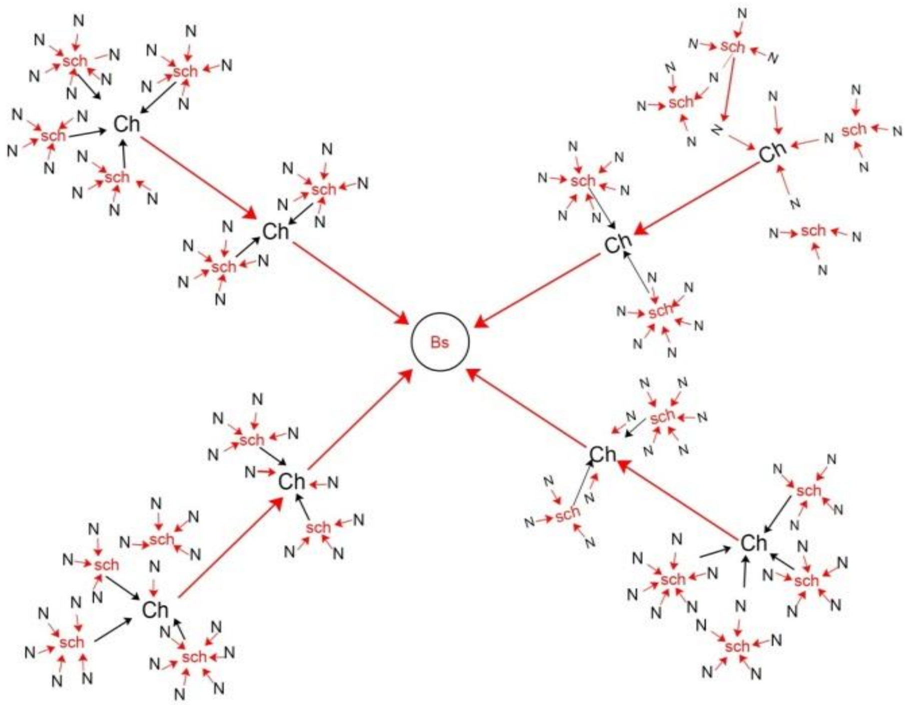

**Fig.3 Network communication between nodes to Sub-Cluster Head (SCH), SCH to CH (Cluster Head), and Cluster Head to Base Station**

## IV. RESULT & DISCUSSION

In this section, analyze the proposed protocol and make comparisons with the existing protocols with simulations. All simulations have been done in MATLAB. We start investigating the performance of protocol considering the same scenario as being proposed by the authors. With field size, 100 X 100 and 100 nodes are placed randomly in the field [23].

Experimental analysis shows the scalability and real-world challenge problem for the scenario with field size 300 X 300 and 1000 X 1000 with the number of nodes 300 and 1000. Considering the rest of the parameters as standard and distribution of node in the network as random, with mobility of node either very low or stationary, further ignoring any energy dissipation because of signal interference of dynamic channel condition.

To justify the MDR's performance is better than the existing protocols, the protocol compared in terms of network lifetime [14], packets to Base Station, and network energy dissipation with LEACH, O-LEACH, EEE-LEACH, and ZSEP, keeping all simulation conditions the same.

Fig. 4 represents the comparison-based performance analysis with respect to the network lifetime of the node. Fig. 4 shows the performance of the protocol in field size 100 X100 with 100 nodes. As shown in the figure, the proposed MDR protocol outperforms the rest of the protocol in terms of network lifetime [22].

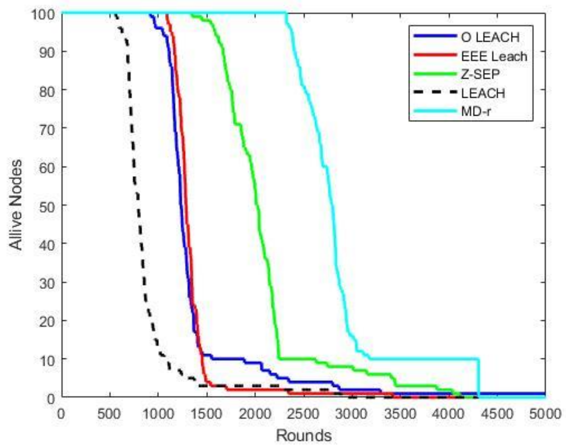


**Fig. 4 Alive nodes vs. rounds for smaller field sizes (100X100) and 100 nodes.**

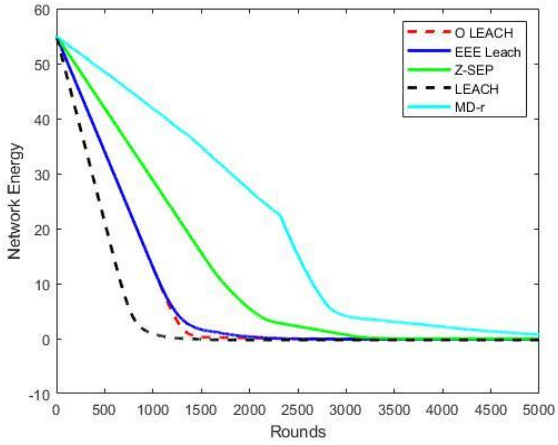


**Fig. 5. Energy dissipations of the network in field size 100 X 100 and 100 nodes.**

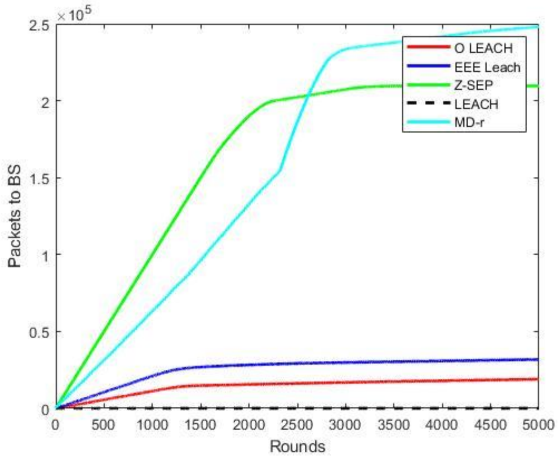


**Fig. 6. Packets to Base Station with rounds over the field size 100 X 100 and 100 nodes.**

From the small (100 X 100 field size) scenario network analysis, it is visible that our proposed protocol shows the most stable network performance.

In the next section, move towards validating the performance of MDR for variable field size. Investigate the performance for a larger network size with more nodes, considering the scenario for field sizes 300X300 and 1000X1000.

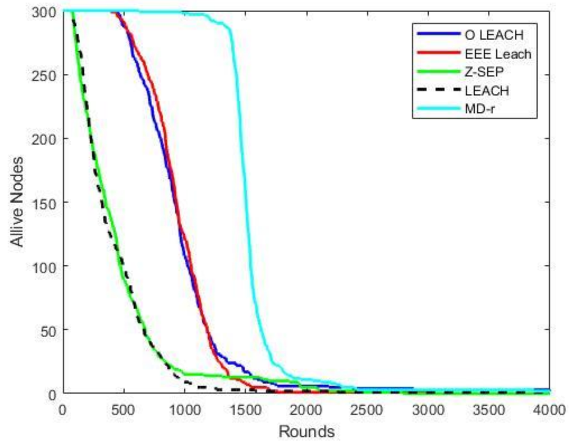


**Fig. 7. Alive nodes vs. rounds for medium field size (300X300) and 300 nodes.**

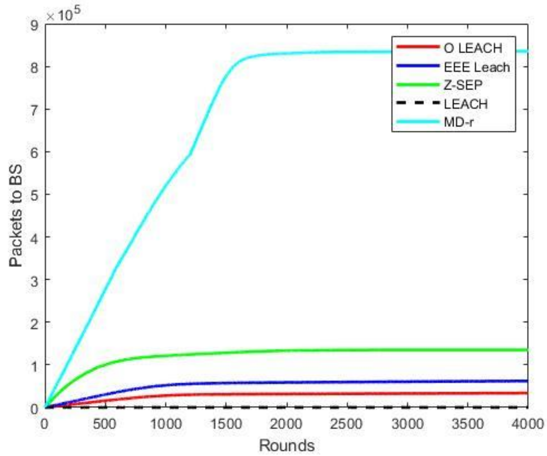


**Fig. 8. Packets to Base Station with rounds over the field size 300 X 300 and 300 nodes.**

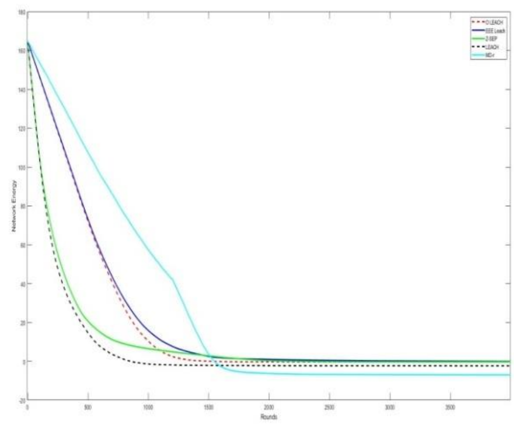

**Fig. 9. Energy dissipations of the network in field size 300 X 300 and 300 nodes.**

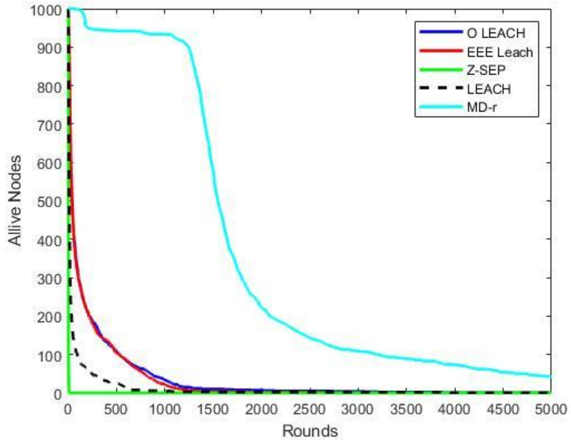


**Fig. 10. Alive nodes vs. rounds for large field size (1000X1000) and 1000 nodes.**

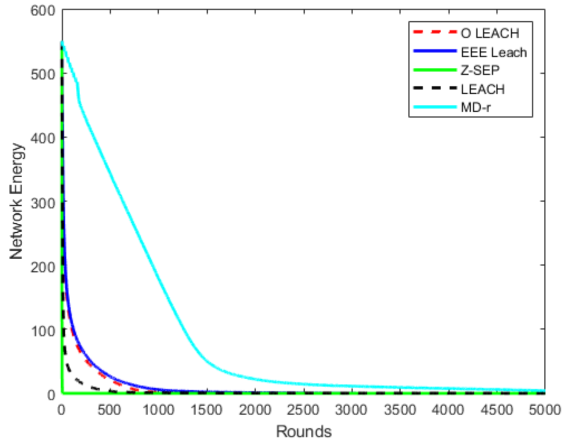


**Fig. 11. Energy dissipations of the network in field size 1000 X 1000 and1000 nodes.**

Table 2 and Table 3 show the performance of energy dissipation and the network lifetime of the protocols. It is visible that the proposed protocol shows very consistent behavior in all field sizes and makes a very stable network type. While in the case of ZSEP (Zonal-Stable Election Protocol), protocol performance is significantly impacted when increasing the field size. For a very large field size, the initial 10% of nodes died at very initial rounds, ultimately impact the network synchronization. In the case of MDR, an increase in field size does not impact the stability of the network. In the case of other protocols O-Leach, EEE Leach, 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.

**Table 1 Energy dissipation comparison of all field sizes of all the protocols**

| | Field size 100*100 with 100 nodes | | | Field size 300*300 with 300 nodes | | | Field size 1000*1000 with 1000 nodes | | |
|---|---|---|---|---|---|---|---|---|---|
| Protocol | 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 2 Network lifetime comparison of all field sizes of all the protocols**

| | Field size 100*100 with 100 nodes | | | Field size 300*300 with 300 nodes | | | Field size 1000*1000 with 1000 nodes | | |
|---|---|---|---|---|---|---|---|---|---|
| Protocol | 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 |

## V. CONCLUSION & FUTURE WORK

This research paper presented a simulation-based study of existing energy-efficient protocols invariant field sizes and the number of nodes. The simulation performance of existing protocols shows a significant downgrade in performance, proving that none of the protocols is scalable enough to adapt to different environments and statistically designed for fixed field sizes with a constant number of nodes. Keeping all these limitations into consideration, I developed the protocol for a homogeneous network based on multi-hop sub-clustering and clustering routing to transmit the data to the 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 the future focused on end-to-end delay and security.

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