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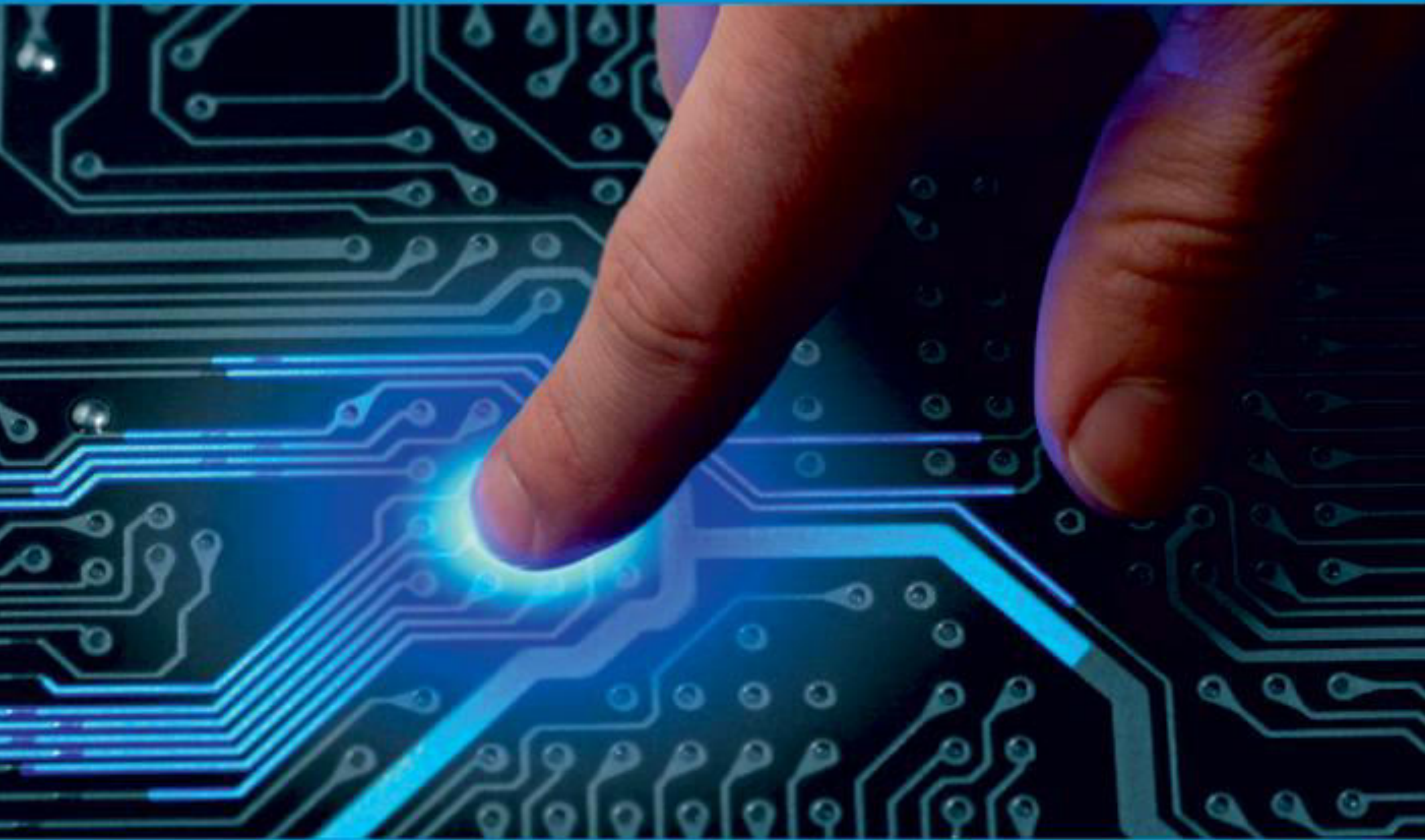

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Analysis of Various Routing Protocols for Heterogeneous Wireless Sensor Networks

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ABSTRACT: Wireless Sensor Networks are now widely used in various fields like industrial monitoring, habitat monitoring, environment monitoring, surveillance etc. As these networks are energy limited, researchers are working on these networks in making them more energy efficient. A lot of energy efficient heterogeneous routing protocols have been proposed in recent years to increase the stability and overall lifetime of the network. This project surveys different energy efficient clustering protocols for heterogeneous wireless sensor networks and compares these protocols on various parameters like Count of Cluster Heads, Number of dead nodes, Number of alive nodes and Number of packets transfer from source to destination and identifies which protocol is efficient among them.

KEYWORDS: Heterogeneity, Clustering, Energy-Efficient Protocols, WSN, Routing protocols, Heterogeneous WSN.

I. INTRODUCTION

A heterogeneous wireless sensor network (WSN) refers to a network composed of sensor nodes that have varying capabilities, features, and characteristics. In a heterogeneous WSN, the sensor nodes differ in terms of their processing power, energy resources, communication range, sensing capabilities, and functionality. In a typical heterogeneous WSN, there may be different types of sensor nodes deployed, each serving a specific purpose or task. For example, some sensor nodes may have higher computational capabilities and memory, allowing them to perform complex data processing tasks. These nodes are often referred to as "cluster heads" and play a crucial role in aggregating and processing data from other nodes in the network. Other sensor nodes in the network, known as "ordinary" or "regular" nodes, may have more limited processing power and energy resources. These nodes typically collect and transmit data to the cluster heads for further processing and analysis. The regular nodes may focus on specific sensing tasks, such as temperature monitoring, motion detection, or environmental sensing.[1]

Clustering in wireless sensor networks (WSNs) refers to the process of dividing sensor nodes into groups or clusters based on certain criteria. The main objective of clustering in WSNs is to improve network efficiency, conserve energy, and facilitate data aggregation and communication within the network. Clustering allows for better organization and management of sensor nodes, enabling more efficient data routing and reducing the overall energy consumption.[2]

The motivation being that the more complex hardware and the extra battery energy can be embedded in a few cluster head nodes, thereby reducing the hardware cost of the rest of the network. However, fixing the cluster head nodes means that role rotation is no longer possible. Stable Election Protocol (SEP), Distributed Energy Efficient Clustering (DEEC), Developed DEEC (DDEEC) and Enhanced DEEC (EDEEC) are well known heterogeneous WSNs

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protocols. Low-Energy Adaptive Clustering Hierarchy (LEACH) is used for homogeneous protocol in which all the nodes have same energy level. There are number of rounds for communication of information.

II. LITERATURE SURVEY

Various algorithms for WSNs are designed to improve the performance of energy consumption, throughput, reduces the delay, and increase the lifetime of the network.

In [17], authors Zain Ul Abidin Jaffri, Muhammad Asif, Md. Sadek Ali proposed the protocol called Threshold based energy aware zonal efficiency measuring hierarchical routing protocol (TEZEM). The main purpose is to enhance network efficiency by improving the CH selection process by distributing the entire network division into several zones. TEZEM is a very effective and efficient method for CH selection as it guarantees an equal number of CHs in each round. The proposed protocol maximizes the lifetime of a network keeping in view the quality of service and enhances network efficiency by improving the CH selection process by distribution the entire network division into several zones. The drawback is that the efficiency of protocol is still to be validated in real scenario.

In [18], authors Salam Mahdi Azooz, Jaber. Majed, Raed Khalid Ibrahim, Adnan Hussein Ali proposed optimum clustering in multi-path and multi-hop protocols as a feasible option for reducing energy consumption and extending the lifetime of wireless sensor networks. The authors compared the low energy adaptive clustering hierarchy (LEACH) clustering method, with the new technique, optimal real time clustering (ORTC) and from the analysis, LEACH should only be favoured in cases of small network where the whole number of nodes is lower than fifty nodes. ORTC should be chosen for application in a large network.

In [19], authors Uzam Majeed, Aqdas Naveed Malik, Nasim Abbas, Wasseem Abbas presented an energy-efficient distributed congestion control protocol for wireless multimedia sensor networks (DCCP). The main feature of proposed DCCP protocol is that, it improves the performance of numerous videos sent over a network. In DCCP, buffer occupancy change rate and buffer occupancy were used to deal with congestion at each node. The traffic congestion map was used to calculate the best path. Therefore, the traffic was balanced on different routes, which reduces the end-to-end delay.

In [20], authors Trupti Mayee Behera, Umesh Chandra Samal, Sushanta Kumar Mohapatra, Mohammad S. Khan, Bhargav Appasani surveyed LEACH-based classical and bio-inspired protocols which helps researchers to understand routing protocols with diverse architectures, novel strategies, and enhanced performance. The authors conclude that the LEACH-MAC protocol can be used in networks where life is a major issue. I-LEACH protocol can be beneficial in large scale as well as small networks. Similarly, the LEACH-KH protocol yields a high packet-delivery ratio and can be adopted in networks where reliability is the prime factor.The primary issue is that the frequent updatinglocations of the sensor nodes and BS's position deplete the network energy.

In [21], authors Muhammad Bilal, Ehsan Ullah Munir and Fawaz Khaled Alarfaj proposed a heterogeneity-aware, threshold-based hybrid clustering and routing algorithm, that significantly improves the lifetime and the stability period of wireless sensor networks (WSNs) as compared to existing routing protocols, such as threshold-sensitive stable election protocol (TSEP), threshold distributed energy-efficient clustering (TDEEC), low-energy adaptive clustering hierarchy (LEACH), hybrid centralized clustering path planning algorithm (HADCC), LEACH-centralized and energy efficient sensor network (TEEN). The main feature is that, the proposed model contains a hybrid approach that provides a cluster head selection at two levels and adds flexibility in cluster formation based on the sensor node's position, initial energy, residual energy, and cluster head selection history.

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Year	Author name	Technique used	Parameters	Advantages	Limitations
2022[17]	Zain Ul Abidin Jaffri, Muhammad Asif, Md. Sadek Ali	Threshold based energy aware zonal efficiency measuring hierarchical routing protocol(TEZEM)	Number of nodes, Distribution of nodes, BS position, Network size, Initial Energy of node, Number of nodes deployed, Data packet.	Maximize the lifetime of a network keeping in view the quality of service, Enhance network efficiency by improving the CH selection process by distribution the entire network division into several zones.	The efficiency of protocol is still to be validated in real scenario.
2022[18]	Salam Mahdi Azooz, Jaber. Majed, Raed Khalid Ibrahim, Adnan Hussein Ali	Multipath and Multihop protocol	Simulation area, Channel type, BS location, Energy Model, Transmitted Amplifier, Data aggregation, Received Energy.	Work efficiently depending upon a dead node.	Based on the finding of the network simulation, Energy consumption has been lowered by adapting the newly suggested protocol on wireless sensor network design.
2022[19]	UzamMajeed, Aqdas Naveed Malik, Nasim Abbas, Wasseem Abbas	Distributed Congestion Control protocol(DCCP)	Number of nodes, Simulation time, Routing protocol, Data packet size	DCCP protocol improves the performance of numerous videos sent over a network. The traffic congestion maps used to calculate the best path.	end – to- end delay of the wireless video transmission.
2022[20]	Trupti Mayee Behera, Umesh Chandra Samal, Sushanta Kumar Mohapatra, Mohammad S. Khan, Bhargav Appasani, NicuBizon, and PhatiphatThounthong	LEACH-based and bio-inspired protocols	Longevity, scalability, and packet delivery ratio.	Extends the network's lifespan also saves energy.	Frequent updating locations of the sensor nodes and BS's position deplete the network energy.
2022[21]	Muhammad Bilal, Ehsan Ullah Munir and Fawaz Khaled Alarfaj	A heterogeneity-aware, threshold-based hybrid clustering and routing algorithm.	Stability in dense and larger network areas.	Improves the lifetime and the stability period of wireless sensor networks. Also provide a better cluster head selection and controlled network traffic.	Practical implementation is still to be conducted.

III. HETEROGENEOUS NETWORK MODEL

In this section, we describe the network model. Assume that there are N sensor nodes, which are uniformly dispersed within a M X M square region (Fig: 2). The nodes always have data to transmit to a base station, which is often far from the sensing area. This kind of sensor network can be used to track the military object or monitor remote environment. Without loss of generality, we assume that the base station is located at the center of the square region. The network is organized into a clustering hierarchy, and the cluster-heads execute fusion function to reduce correlated data produced by the sensor nodes within the clusters. The cluster-heads transmit the aggregated data to the base station

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directly. To avoid the frequent change of the topology, we assume that the nodes are micro mobile or stationary as supposed in. [22]

In the two-level heterogeneous networks, there are two types of sensor nodes, i.e., the advanced nodes and normal nodes. Note E_0 the initial energy of the normal nodes, and m the fraction of the advanced nodes, which own a times more energy than the normal ones. Thus there are mN advanced nodes equipped with initial energy of E_0 (1 + a), and (1- m)N normal nodes equipped with initial energy of E_0. The total initial energy of the two-level heterogeneous networks is given by:

$$E_{total} = N(1-m)E_0 + NmE_0(1+a) = NE_0(1+am) \quad \text{.....................} (1)$$

Therefore, the two-level heterogeneous networks have am times more energy and virtually am more nodes. We also consider the multi-level heterogeneous networks. For multi-level heterogeneous networks, initial energy of sensor nodes is randomly distributed over the close set [E_0, E_0 (1 + a_{max})], where E0 is the lower bound and a_{max} determine the value of the maximal energy. Initially, the node s_i is equipped with initial energy of E_0 (1 + a_i), which is a_i times more energy than the lower bound E_0.

The total initial energy of the multi-level heterogeneous networks is given by:

$$E_{total} = \sum_{i=0}^{N} E_0(1+a_i) = E_0(N + \sum_{i=0}^{N} a_i) \quad \text{.................} (2)$$

As in two-level heterogeneous networks, the clustering algorithm should consider the discrepancy of initial energy in multi-level heterogeneous networks.

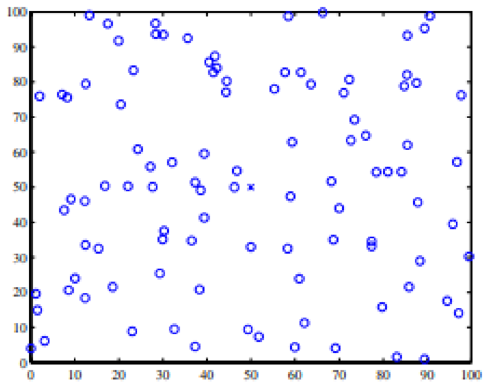

Fig: 1. 100-node random network

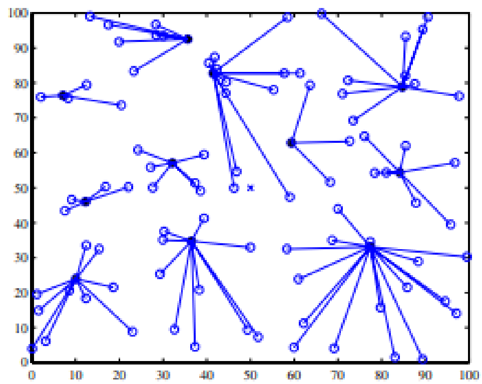

Fig: 2. Dynamic cluster structure

IV. HETEROGENEOUS ROUTING PROTOCOLS

1. DEEC (Distributed Energy-Efficient Clustering)

In DEEC, the cluster heads are elected by probability based on the ratio between residual energy of each node and the average energy of the network. The epochs of being cluster heads for nodes are different according to their initial and residual energy. The nodes with high initial and residual energy will have more chances to be the cluster heads than the nodes with low energy. So, the advance nodes have more chances to be cluster heads than the normal nodes. The round number of the rotating epoch for each node is different according to its initial and residual energy, i.e., DEEC adapt the rotating epoch of each node to its energy. The nodes with high initial and residual energy will have more chances to be the cluster-heads than the low-energy nodes.[22]

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2. **DDEEC** (Developed Distributed Energy Efficient Clustering)

This protocol was 30% better than SEP and 15% better than DEEC in terms of Network lifetime and Stability period. This protocol also works at two levels of energy.

It overcomes the drawbacks of the DEEC protocol. DEEC is based on clustering, when the cluster heads are elected by a probability based on the ratio between residual energy of each node and the average energy of the network. The round number of the rotating epoch for each node is different according to its initial and residual energy. DEEC adapts the rotating epoch of each node to its energy. The nodes with high initial and residual energy will have more chances to be cluster heads than the nodes with low energy. Thus, DEEC can prolong the network lifetime, especially the stability period. This choice penalizes always the advanced nodes, especially when their residual energy depletes and becomes in the range of the normal nodes. In this situation, the advanced nodes die quicker than the others. The DDEEC thus balances the cluster head selection overall network nodes following their residual energy.[22]

3. **EDEEC** (Enhanced Distributed Energy Efficient Clustering)

EDEEC protocol which works on the same principle of DEEC but adds a third type of node called super node which has (1+b) times more energy than normal node. Advance nodes have (1+a) times more energy than normal nodes. Due to this third node, the heterogeneity of the network increases from two to three. Traditionally as per previous protocols, in this protocol too, cluster head selection uses the same threshold technique, and the advance and normal nodes have same probabilities. EDEEC (Enhanced Distributed Energy Efficient Clustering) is a protocol designed for Heterogeneous Wireless Sensor Networks (WSNs) to improve energy efficiency and prolong the network lifetime. WSNs consist of a large number of low-power wireless sensors that are deployed in a geographical area to monitor and collect data.[22]

4. **EDDEEC** (Enhanced Developed Distributed Energy Efficient Clustering)

This protocol also works at three levels of heterogeneity and overcomes the drawbacks of EDEEC protocol. In EDEEC protocol, the super nodes have more energy than the advance nodes which have more energy than the normal nodes. The probability of the super, advance and normal nodes to be cluster heads shown in above equation clearly shows that super nodes have higher probability to be cluster head than the advance nodes which have more probability than normal nodes. So, after becoming cluster heads again and again, after some rounds, the energy of super nodes will become equal to that of advance nodes because cluster heads consume more energy than the other nodes in the cluster. At this time, as the energies of the super and advance nodes becomes equal, but due to higher probability, the super nodes will become CH.[22]

V. RESULTS AND DISCUSSIONS

Parameters Considered-The various parameters considered for the comparison of the various protocols are:

- Count of Cluster Heads
- **N**umber of dead nodes
- **N**umber of alive nodes
- **N**umber of packets transfer from source to destination

Count of Cluster Heads-The network nodes are organized into clusters, with each cluster having a cluster head responsible for managing communication within the cluster. Cluster head selection involves the process of choosing a node from among the alive nodes to act as the cluster head. The selection is usually based on specific criteria, such as remaining energy level, proximity to other nodes, or communication capabilities. Efficient cluster head selection is crucial for balancing the energy consumption across the network and optimizing communication.

Number of dead nodes-The count of dead nodes refers to the number of nodes in the network that have depleted their energy and can no longer function or participate in the network operations. The count of dead nodes in EDEEC can be determined by monitoring the energy levels of each node in the network. As nodes consume energy over time, their energy levels decrease, and when they reach a critical threshold, they are considered dead. The network or cluster monitoring mechanism keeps track of the energy levels and identifies the nodes that have crossed the energy depletion threshold. The count of dead nodes is important for evaluating the overall energy efficiency and lifespan of the network. It helps in understanding the network's resilience to energy constraints and assists in developing strategies for node replacement, energy replenishment, or network reconfiguration to maintain network connectivity and performance.

Number of alive nodes-In a Wireless Sensor Network (WSN), a live node refers to a sensor node that is currently active and functioning properly. It is important to note that the specific number and configuration of live nodes in a WSN can vary depending on the network's design, deployment, and operational conditions. The count of alive nodes represents the number of functional and operational sensor nodes within the network. These nodes have sufficient energy and resources to perform their tasks, communicate with other nodes, and contribute to the network's operations. Monitoring the count of alive nodes helps in understanding the network's stability and availability. The number of live nodes in a WSN is dynamic and can change over time based on the network's conditions and operational factors.

Number of packets transfer from source to destination-Packet transfer from a source node to a destination node follows a multi-hop routing approach across the respective heterogeneous levels. The source node initiates the packet transfer by forwarding it to the cluster head at its respective level. The cluster head then determines the optimal path for the packet to traverse through the network's levels, considering factors such as energy efficiency, network congestion, and QoS requirements. Intermediate nodes at each level act as relays, forwarding the packet towards the destination node. The packet transfer process aims to ensure reliable and efficient delivery while leveraging the heterogeneous characteristics of the network.

COMPARISON OF RESULTS

1. Number of Rounds vs. Count of Cluster Heads

Here in Fig: 3 the parameter considered is “Count of Cluster Heads”. A cluster head is a node which is responsible for maintaining clusters, collecting data from nodes in the cluster and communicating with sink. The main function of cluster head is to provide efficient data communication between sensor nodes and the base station. So, the cluster head should have high energy as compared to other nodes. We can infer that in EDDEEC protocol the cluster head remain alive till the end of the cycle. Thus, EDDEEC protocol is efficient.

2. Number of Rounds vs. Number of dead nodes

Here in Fig: 4 the parameter considered is “number of dead nodes”. The total number of sensor nodes that have consumed all of their energy and are not able to do any kind of functionality. As the result the dead node count is reduced significantly so that the network longevity is increased. From the simulation result, we can see that in EDDEEC protocol has less number of dead node count compared to other protocols. Thus, EDDEEC protocol is efficient.

3. Number of Rounds vs. Number of alive nodes

Here in Fig: 5 the parameter considered is “number of alive nodes”. The total number of sensor nodes that have not yet depleted all of their energy. As the result the alive node count is increased significantly so that the

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network longevity is increased. From the simulation result, we can see that in EDDEEC protocol has constant number of alive nodes after some rounds compared to other protocols. Thus, EDDEEC protocol is efficient.

4. Number of Rounds vs. Number of packets transfer from source to destination.

Here in Fig: 6 the parameter considered is "number of packets transfer from source to destination". The source node initiates the packet transfer by forwarding it to the cluster head at its respective level. The cluster head then transfer to destination. The results show that EDDEEC goes linearly for some rounds. It is clear from the results that data that are received by the base station per round is more as compared to others. Thus, EDDEEC protocol is efficient.

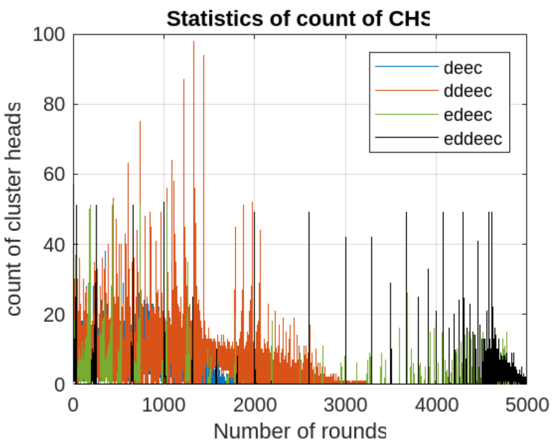

Fig: 3. Comparison of count of CHS

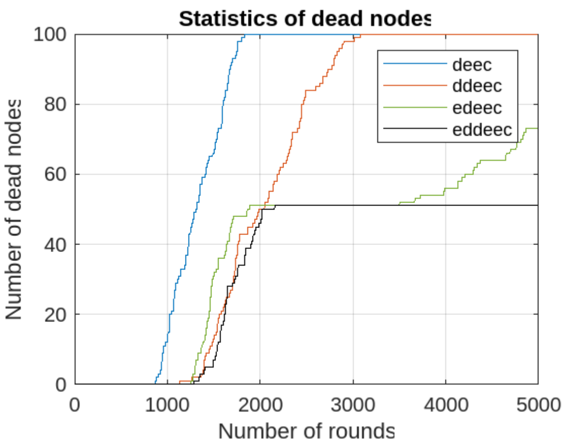

Fig: 4. Comparison of count of dead nodes

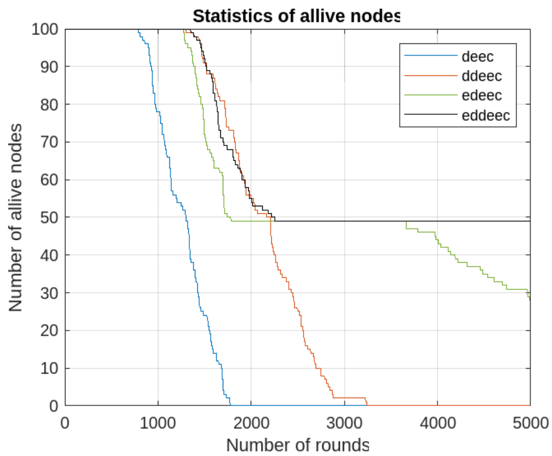

Fig: 5. Comparison of alive nodes

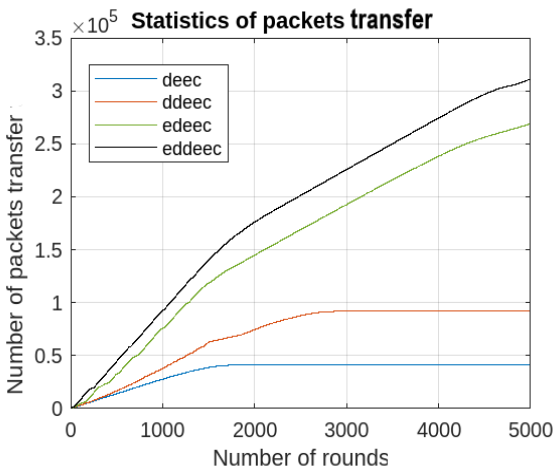

Fig: 6. Comparison of packet transfer

VI. CONCLUSION AND FUTURE SCOPE

In this project, we have chosen DEEC, DDEEC, EDEEC and EDDEEC heterogeneous protocols for wireless sensor network as they have higher stability and gives more network lifetime as compared to other protocols. The main concern of this project is to examine the count of cluster heads, number of dead nodes, number of alive nodes, time required for packet to travel from source to destination and compare the performances of these heterogeneous protocols.From the simulation results, we notice that EDDEEC is more efficient than other protocols.

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Our further work will mainly focus on how to further balance the energy consumption of every node by using the unequal clusters and on the moving heterogeneous sensor nodes. Furthermore, the whole energy problem is to be relieved in the network. We will also compare these heterogeneous routing protocols with more parameters like Network Scalability, Network reliability, Network Throughout and so on.

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