AN ENERGY EFFICIENT CLUSTER HEAD SELECTION FOR FAULT-TOLERANT ROUTING IN MANET

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***Abstract*---Recent advances in Mobile Ad hoc Network (MANET) have led to many new techniques specifically designed for MANET where energy awareness is an essential consideration. In MANET, clustering is a key routing technique used to reduce energy consumption. The feasibility of a clustering method can be primarily determined by the complexity of the cluster head selection. Optimizing the cluster head selection allows the network to be more efficient by minimizing the signaling overhead and ensuring that the network connectivity is maintained despite topology changes. In this paper, energy efficient cluster head selection for fault-tolerant routing is proposed and evaluated. Main objective of this type of cluster head selection is to maximize the CHs energy and also reduce single link failure in MANET. Simulation results show that our proposed model could better implement fault tolerance and prolong the lifetime of the network**.

Keywords----MANET, Fault Tolerance, Clusters, Cluster Head, Life Time

I. INTRODUCTION

A. Mobile Ad Hoc Networks

MANET is an unstructured network that consists of group of communicating mobile nodes that form an arbitrary network topology by means of any of wireless communication media like Personal area networking (laptop, mobile, ear phone, wrist watch), military environments (soldiers, tanks, planes), civilian environments (taxi cab network, meeting rooms, sports stadiums, boats, small aircraft), emergency operations (search-and-rescue, policing and fire fighting).

B. Characteristics of MANETs

- *Dynamic topology*: MANET topologies can change often and unpredictability. Nodes are free to move randomly and it consists of both bi-directional and unidirectional links.
- *Bandwidth-constrained, variable capacity links:* The capacity of wireless-networks is significantly lesser than the hardwired systems. Considering the multiple access, fading, noise, and interference conditions, etc.
- *Energy-constrained operation:* All MANET nodes only depend on energy like battery, so energy-conservation is taken into care.
- *Limited physical security*: Wireless systems are less secure than the hardwired ones. The possibility of eavesdropping, spoofing and denial-of-service attacks should be considered. Decentralized nature of network control in MANETs provides additional robustness against the single points of failure of more centralized approaches to reduce threats in wireless networks.

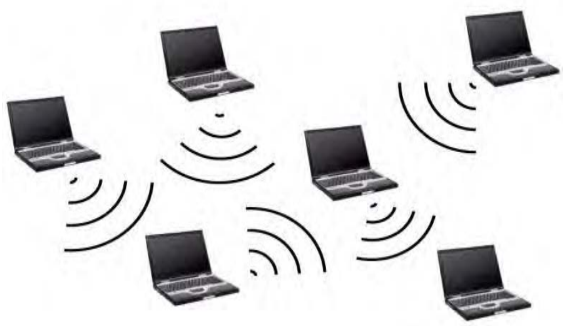

Fig.1: A Mobile Ad-Hoc Network

C. Topology Control

To reduce energy consumption and signal interference, it is important to select an appropriate transmission power for each node, a process called topology control. The topology control criteria such as k-connectivity, energy efficiency, scalability, network efficiency.

Topology control is one of the most important techniques used in ad hoc networks to reduce energy consumption which is essential to extend the network life time and reduce MAC (Medium Access Control) layer signal interference with a positive effect on the network capacity.

D. Clustering

Clustering is a division of the network into different virtual groups, based on rules in order to discriminate the nodes allocated to different sub-networks. Main goal is to achieve scalability in presence of large networks and high mobility.

Cluster-based routing is a solution to address nodes heterogeneity, and to limit the amount of routing information that propagates inside the network. It increases the routes lifetime, thus decreasing the amount of routing control overhead.

There are usually three types of nodes, named cluster heads, cluster members and cluster gateways respectively. The cluster Heads (CHs) are responsible for coordination among the nodes within their clusters (intra-cluster communication) as well as communicating with other cluster heads (i.e. inter-cluster communication). The cluster members (CMs) are ordinary nodes and need to transmit their information to their respective cluster heads, which aggregate the received information and then forward it to the sink. The cluster gateways are non-cluster heads with inter-cluster links, they can contact with neighboring clusters and forward information among them.

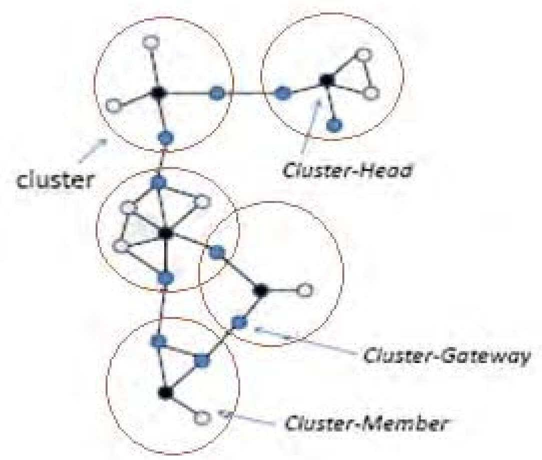

Fig. 2: Three types of nodes in clustering

Clustering methods allow fast connection and also better routing and topology management of mobile ad hoc networks. In this paper, we proposed energy efficient cluster head selection which provides fault-tolerant routing and network lifetime for large and dense MANETs. In MANET, fault-tolerant and energy efficiency are two important factors. The energy efficient cluster head selection can significantly improve the network lifetime and decrease the dead speed of the nodes. This type of cluster head selection can reduce the single link failure. Recovery time will increase when a link failure happen due to mobility and low energy of nodes in MANET. Here the local repair method is used to overcome that fault. Finally, the simulation results show that our proposed model could better implement fault tolerance and prolong the lifetime of the network.

II. RELATED WORK

A. Clustering In Manet

1) Location Based Clustering

In the location-based routing protocol, the location information of mobile nodes is used to confine routing space into a smaller range. In [12] Tzay-Farn Shih and Hsu Chun Yen have proposed a cluster-based routing protocol, named Core Location-Aided Cluster-based Routing protocol (CLACR). Here entire network is partitioned into square clusters. In each cluster, the selection of cluster head is done by a cluster head election algorithm. The number of nodes responsible for routing and data transfer is decreased considerably by the usage of the cluster mechanism. It also diminished the routing overhead and increased the route lifetime massively. Dijkstra algorithm used to compute the path in a cluster-by-cluster basis by the CLACR.

2) *Mobility Based Clustering*

In [13] S. Muthuramalingam et al proposed a modified algorithm that uses Weighted Clustering Algorithm (WCA) for cluster formation and Mobility Prediction for cluster maintenance. Cluster formation: At first, a beacon message is send by each node to notify its presence to its neighbors. A beacon message contains the state of the node. A neighbor list is built by each node based on the received beacon messages. The cluster head is elected based on the weight values of the nodes.

3) Neighbor Based Clustering

In [14] Hui –Yao et al proposed a Cluster-Based Multipath Dynamic Source Routing in MANET (CMDSR). In this technique, the hierarchy is used to perform Route Discovery and distributes traffic among diverse multiple paths.

Cluster Architecture: The CMDSR is based on the 3-level hierarchical scheme. The 0-node is the first level of the cluster. 1-cell cluster is the second level of cluster. Here each node of the cell is 1-hop away from the Cluster Head. The 2-server cluster gathers a set of cells of which the Server is the leader. The cluster changes due to the nodal mobility dynamically. Hence the cluster will be disassembled or reassembled and also the cluster members update at every turn.

4) Power Based Clustering

In [15] Pi-Rong Sheu and Chia-Wei Wang proposed an efficient clustering algorithm. Here it can establish a stable clustering architecture by keeping a host with weak battery power from being elected as a cluster head.

5) Artificial Intelligence Based Clustering

In [16] Chongdeuk Lee and Taegwon Jeong proposed a Fuzzy Relevance-based Cluster head selection Algorithm (FRCA). Here the algorithm selects the cluster head using fuzzy relevance for clustering in wireless mobile ad hoc sensor networks. In the network, the Fuzzy Relevance-based Cluster head selection Algorithm (FRCA) efficiently clusters and manages sensors using the fuzzy information of node status.

6) Weighted Based Clustering

In [17] R. Pandi Selvam and V.Palanisamy presented a flexible weight based clustering algorithm in mobile ad hoc networks. The proposed algorithm is a 2-hop clustering algorithm. The performance of the proposed clustering algorithm showed that it outperformed the existing LID, HD and WCA to make the number of clusters.

B. Cluster Head Selection

CH selection has been studied much in the existing of wireless *ad hoc* networks. It was showed in [7, 8] that using clusters for data-aggregation in large-scale sensor networks can significantly improve the sensors' lifetime. In [7], Heinzelman *et al* propose LEACH (a protocol) that allows nodes to select CHs using a distributed algorithm. Each sensor has its turn as CH to balance their energy consumption. Chen *et al* [8] improve this approach by first estimating the optimal number of clusters to efficiently utilize the data correlation of sensors. A new random CH selection algorithm is then proposed, to minimize the distance between the CHs and their members.

Koshy *et al* [9] show that information entropy can also serve as a metric to form clusters. Low level activities of nodes are more likely to become CHs. This method may produce stable CHs.

In [10], Xia *et al* propose a distributed CH selection protocol that creates clusters of nodes having similar sensed data in to optimize the data aggregation at the CHs. The cluster, located at any distance up to *h* -hops away from the CH.

Chinara *et al* propose [6] an interesting survey on clustering algorithms, ranging from nodes' ID-based selection to mobility and connectivity metric-based selection. They show that though ID-based selection produces a fast and stable cluster setup, it suffers from rigidness of the CHs' structure, because the same nodes are often selected independent of the network topology. It may require a larger cluster setup time.

On the selection of cluster head in MANET [1], this paper investigates the problems of cluster head selection for large and dense MANETs. It consist of (1) the *distance-constrained selection,* where every node in the network must be located within some distance to the nearest cluster head; and (2) the *size-constrained selection,* where each cluster is allowed to have a limited number of members.

In [2], vennila *et al* proposes a QoS based clustering technique for multicasting security in MANET. In this technique, the nodes with maximum available bandwidth and residual energy are elected as cluster head (CH) which acts as multicast group leader. Each CH computes the trust value of its members using success/failure ratio of data or control packets. The node that desires to join the multicast group should requests its CH.

In [3], Mao YE *et al* propose and evaluate an energy efficient clustering scheme (EECS) for periodical data gathering applications in WSNs. In the cluster head election phase, the cluster head is elected by localized competition, which is unlike LEACH, and with no iteration, which differs from HEED.

C. Fault-Tolerant Routing

Nargunam and Sebastian's fully distributed cluster-based (FDCB) [4] algorithm addresses QoS routing in MANETs. In this paper, the focus was on FDCB routing protocol which avoids the conventional clustering algorithm. Here each cluster member maintains the QOS parameter table. This paper does not discuss how failure handled and also latency in route discovery.

In [17], Muhammad *et al* propose a Zone-based Fault-Tolerant Management Architecture (ZFTMA) for WSNs. The proposed architecture is composed of two novel contributions: an energy efficient network self-organization scheme and a fault management architecture that offers efficient fault detection and recovery mechanisms to make the network fault-tolerant.

The EFDCB (Extended Fully Distributed Cluster Based) routing protocol [11] combine both GDMAC and FDCB protocols and uses CFSR for QoS routing. Fully Distributed Cluster-Based (FDCB) algorithm addresses Quality of Service routing in the MANET. Generalized Distributed and Mobility Adaptive Clustering (GDMAC) provides fault tolerance with Quality of Service in the MANET. EFDCB uses a cluster-head model to mitigate connection failures. This model employs cluster state knowledge sharing with to make the cluster-head aware of supported QoS connections in the cluster. The cluster head has complete "cluster-state" knowledge. It contains connectivity awareness for all cluster nodes. The demerit of this paper is decrease the QoS collision due to network failures. And also EFDCB is maintained both to repair existing paths and to initiate new ones. So more memory required in CH.

III. PROPOSED WORK

A Network Model

In Mobile ad hoc networks, energy efficiency and fault-tolerant are two important factors. In this paper, we focus on energy efficient cluster head selection for fault-tolerant routing in MANET which provides efficient communication between source and destination. Here we investigate the energy efficient CHs selection in a distributed environment such as MANET. Single link failure (fault) may occur because of maintain one cluster head at long time, so here energy efficient cluster head selection is created. Energy is the major concern in networks. Here all possible nodes will act as cluster heads for every 30 or 35 mints. The energy may get wasted due to long time of one cluster head action. Here once a node is elected a cluster head it is desirable for it to stay as a cluster head up to some maximum specified amount of time (i.e. 30 or 35 mints). Some link failure may happen during data transmission and some threat can come from mobility and dead speed of nodes, the local repair method is used to overcome that link breakage. Energy efficient cluster head selection can significantly improve the network life time and routing. It provides efficient fault-tolerance in MANET.

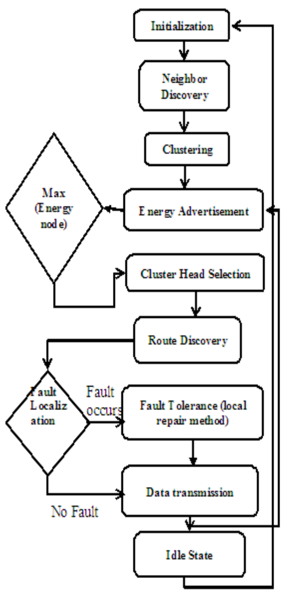

Fig. 3: Overall Network Model for Fault-Tolerant Routing

Figure 3 shows flow diagram for the network model. Initially the network has formed. Then node has created as per the network need. Each node participates to discover the neighbor. Clustering is used to group the network nodes into a number of overlapping clusters. Then energy advertisement made by the nodes within the clusters. The cluster head selection process done by using some conditions. At first the maximum energy level of node acts as cluster head. Find the route to where the data is send from the source. For each transmission of data, the network has checked whether the route is correct or not. If any link failure may happen during data transmission and some threat can come from mobility and dead speed of nodes, the local repair method is used to overcome that link breakage.

B. Methodology

Energy Efficient Cluster Head Selection: Clustering provides an effective way to improve the network lifetime in wireless environment. Here all possible nodes will act as cluster head at certain period of time. Main goal of this scheme is to avoid single link failure and cluster head load is reduced. The cluster head saves energy and thus prolonging network lifetime.

1) The Cluster Head Election follows some Steps:

- We should setup the threshold value (i.e. only the above threshold value nodes act as cluster head).
- To measure the energy level for nodes.
- To setup counter time (i.e. once a node is elected a cluster head it is desirable for it to stay as a cluster head up to some maximum specified amount of time (30 or 35 mints)).
- At first, the maximum energy levels of node act as cluster head.
- After time out we should measure next maximum energy level of node, then the maximum energy level node act as next cluster head.
- Suppose new node arrived, we should measure the energy level of that node also.
- Likewise the above threshold value nodes are act as cluster head.

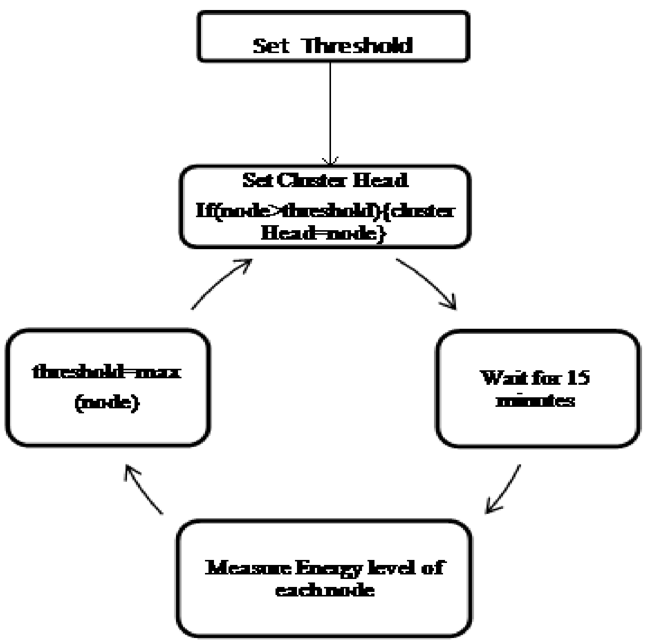

Fig. 4: Flow Diagram for Cluster Head Selection

2) Energy Measurement of a Node

The initial energy of every node was set to 100 Joules. Initially we measure the energy level for nodes. A high energy level of node was chosen to prevent ‘node deaths’. In case of low initial energy levels, it was observed that few nodes, which actively participated in control and data sensing operations, exhausted their battery power after some time. They were then unable to participate in further operations. The maximum energy level and above threshold value of node acts as CH. Once a node is elected as CH, which act as certain period of time (i.e. 35 mints). After timeout only we should measure next maximum energy level of node, and then next maximum energy level node act as next CH. Suppose new node arrived, we should measure the energy level of that node also. Likewise the above threshold value node act as CH. Time for transmission of a data packet was taken as 0.005. 6nJ energy is used for data aggregation.

3) Threshold Setup

It selects above threshold value nodes as cluster heads and rotates this role to balance the energy dissipation of the MANET nodes in the networks. Data collection is CH to sink and performed periodically. The energy efficient cluster head selection operation is divided into rounds. Each node decides whether or not to become a cluster-head for the current round based on the energy calculated (i.e. the above threshold value of energy level nodes only act as cluster head) by the suggested percentage of cluster-heads for the network (determined in advance) and the number of times the node has been a cluster-head so far. Here we should measure the energy level for nodes. If the node energy is greater than a threshold value $\theta(N)$, the node becomes a cluster-head for the current round. The threshold is set as

$$\theta(N) = \frac{q}{1 - q \times \left(R \times mod \frac{1}{q}\right)} \forall N \in G$$

Where q, R, and G represent, respectively, the desired percentage of cluster-heads, the current round number, and the set of nodes that have not been cluster-heads in the last 1/q rounds. Using this threshold, each node will be a cluster head, just once at some point within 1/q rounds. Here the above threshold value nodes act as cluster head. Once a node is elected a cluster head it is desirable for it to stay as a cluster head up to some maximum specified amount of time (i.e.30 or 35 mints).

To ensure an even energy load distribution over the whole network, additional parameters should be considered to optimize the process of cluster-head selection. Our aim is to achieve energy efficiency in terms of network lifetime, not only in terms of energy consumption. So we mainly reduce the fault in MANET. Using this threshold each node decides whether or not to become a cluster-head in each round

$$\theta(N) = \left(\frac{q}{1 - q \times \left(R \times mod \frac{1}{q}\right)} E_{residual}/E_{initial}\right)$$

Where the $E_{residual}$ is the remaining energy of the node and $E_{initial}$ is the initial energy of the node before the transmission.

4) Time Setup

Time is denoted by Δ. once a node is elected a cluster head it is desirable for it to stay as a cluster head up to some maximum specified amount of time (i.e. Δ=30 or Δ=35 mints).

5) Pseudo Code for CH Selection

Pseudo code for energy efficient cluster head selection is shown in fig. 5. The main parameters are energy (E), threshold (Θ (N)), and time (Δ). The above threshold value nodes act as cluster head at certain period of time. Below energy level of node acts an operational node that participates in any communication or sensing activity.

```
Initialize: Θ(N)<-Threshold,CH<-ClusterHead
Begin Process
While(2>1)
Begin While
        Begin setClusterHead(node[],Θ(N))
        for(N=0;node[N].value>Θ(N)&&N<node[
        N].length;N++)
        Begin for
                CH=node[N];
                Θ(N)=CH;
        End For
        End setClusterHead(node[],Θ(N))
        sleep(35 min); //wait for 35 minutes
        //measure energy level of node in the
        MANET
        Begin measureEnergy(node[])
        Begin for (N=0;N< node[N].length;N++)
        node[N].value= CurrentEnergy(node[N]);
        End for
        End measureEnergy(node[])
        //check for presence of new node
        if(Manet.newNode())
        Begin if
         node.add(Manet.newNode())
        End if
End While
End Process
```

Fig. 5: Pseudo Code for Energy Efficient Cluster Head Selection

C. Local Repair Method

If any link breakage occurs, instead of finding alternate route again from source to destination, in order to avoid that problem here local repair method is proposed. The local repair method is, if any of intermediate nodes fails due to mobility, the node broadcasts a repair-request message to its neighbors asking if any of them can take over for the defunct intermediate node. The neighbor node which has the similar resources will reply to the intermediate node. The intermediate node will again check whether the corresponding neighbor has all the necessary resources. If yes, it establishes the path to that neighbor node and it sends a message to the source. Neighbor node will establish the path to the destination. After the successful path establishment, a validation message will send to the source from the destination.

IV. IMPLEMENTATION

The energy efficient cluster head selection must increase the network lifetime and also decrease the fault during this experimentation. Here AODV (Ad hoc On-Demand Distance Vector) protocol used to provide efficient communication between source and destination. AODV allows mobile nodes to obtain routes quickly and does not require nodes to maintain routes with nodes that are no longer active within the system. Instead of building a route for every destination within the network, a node only creates and maintains a route as it is needed.

A. Simulation Parameters

The simulation parameters for the evaluation of the energy efficient cluster head selection shown in table I. fixed network size is 1000×1000 m^2 and 100 nodes created. The initial energy of every node was set to 100 Joules. Energy for data aggregation is 6nJ. The data packet size is 1460 bits and data transmission time is 0.005. Here AODV routing protocol is used.

Table I. Summary of the parameters used in the simulation experiments

Parameter	**Value**
propagation	Two ray ground
Field size	1000m×1000m
Number of nodes	100
Initial energy of MANET node	100J
Data packet size	1460 bits
Simulation time	50
Transmission time	0.005
The energy for data aggregation	6nJ/bit/signal
Sleep power	10mW
Routing protocol	AODV(routing protocol)

B. Simulation Results

To validate the performance of our proposed model, we simulate, using NS2. Fig 6 shows transmission of packets at each simulation rounds. Here the packets are transferred between source and sink. The proposed model is compared with LEACH. Time for transmission of a data packet was taken as 0.005. 6nJ energy is used for data aggregation. In proposed model, each round the source send the packet to sink successfully. Compare to LEACH the proposed model packet transmission is high.

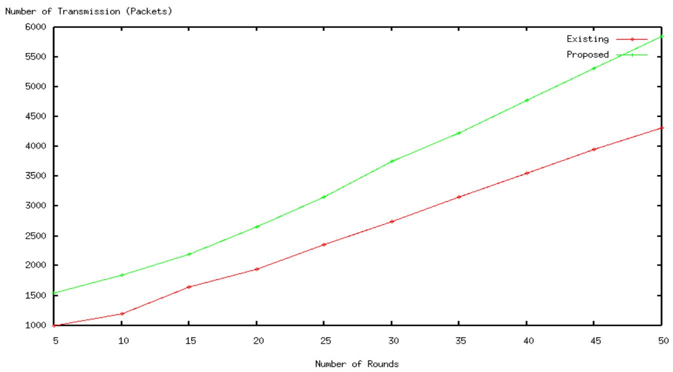

Fig. 6: Average Tansmission Vs Simulation Rounds

Energy efficient cluster head selection increase the network lifetime. Fig 7 shows network lifetime. Here each node to become a CH. So it maximize the CH energy and incease the network lifetime.

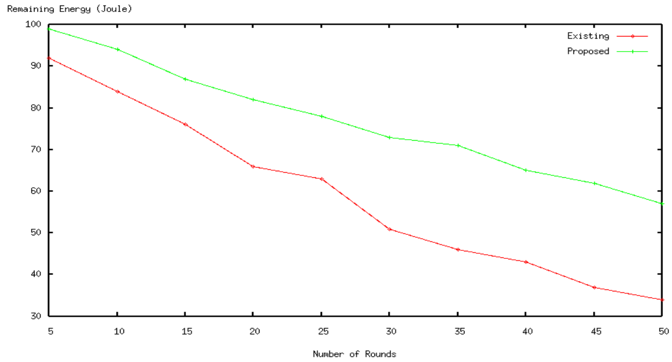

Fig. 7: Network Lifetime Vs Simulation Rounds

Fig 8 shows energy consumption. Here energy consumption is less.

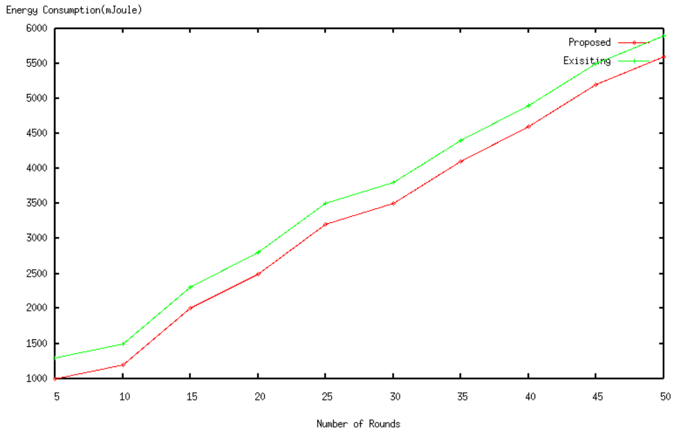

Fig. 8: Network Energy Consumption Vs Simulation Rounds

Fig 9 shows the number of data received to sink. The cluster-heads are selected based on threshold value in our model. This reduces the energy loss due to transmission for the nodes expected to transmit frequently, thereby delivering the more amount of data with less energy dissipation.

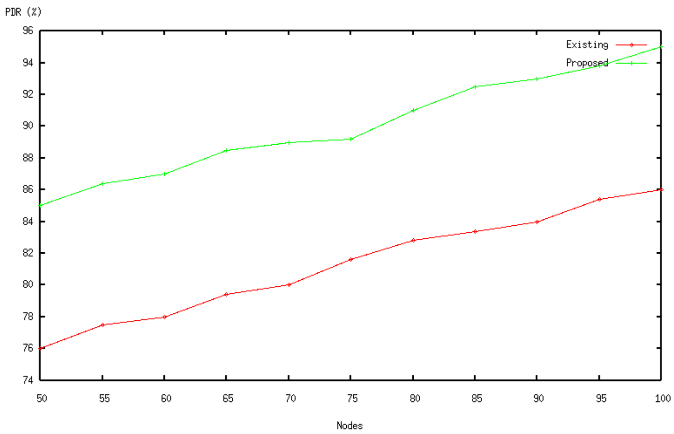

Fig. 9: Packet Delivery Ratio Vs Number of Nodes

Fig 10 shows end to end delay at various simulation rounds. Here less delay compare to LEACH. The local repair method used to provide efficient packet transmission without any link failure in MANET.

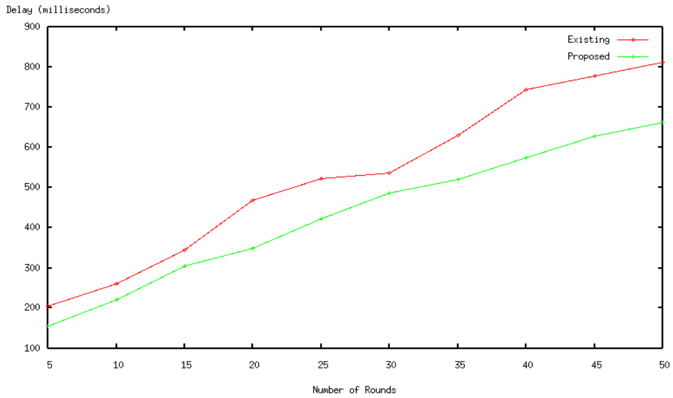

Fig. 10: End To End Delay Vs Simulation Rounds

V.CONCLUSION

This paper presents energy efficient cluster head selection for fault-tolerant routing in MANET, which mitigates single link failure. Energy efficient clustering in MANET is a very important because it can improve network life time and fault-tolerance in MANET. We also presented a local repair method to provide link breakage avoidance. We used analysis and simulation to show how well these techniques perform in dealing with a fault-tolerance.

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