Energy Efficient Routing Algorithm Using Max-Heap Tree Based Structured Cluster for MANET

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Abstract- Mobile Ad hoc Network (MANET) is a network of mobile devices which has no centric device or base station. Self-configuring network of mobile nodes connected by wireless links. Each device in a MANET is dynamic and can move in any direction, and will therefore change its links to other nodes frequently. The moving nature of mobile nodes creates many difficulties in mobile ad hoc network like to manage topology is very difficult i.e. routing protocols are very important. Every device work as a host as well as a router it means it can receive data packet as well as forward it. Mobile nodes have limited energy resource; so energy efficiency and routing are the main obstacles in the growth of this network. One way to increase the network life time is to divide the network into small and self-manageable clusters. In this paper an attempt is made to propose an energy aware clustering algorithm for longer life of MANET; that selects an efficient cluster head with the help of Max-heap tree. The Clusters are designed using max-heap on the basis of energy level; the node which has the highest energy in the cluster will act as a cluster head until its energy level comes equal to or less than the threshold value.

Keywords- Mobile Ad-hoc Network (MANET), Cluster-Head (CH), Max-heap, Threshold value, Optimized link state routing (OLSR), Multi Point Relay (MPR).

I. Introduction

Mobile ad hoc network is a network of moving mobile nodes which has no centric device and base station. Mobile Ad-hoc Networks (MANETs) can be deployed at any location without pre-existing infrastructures and are very specific kind of wireless networks. In this type of network each device works as a host as well as a router because there are no routers and network devices are present (refer figure-1). Due to moving nature of mobile devices to maintain topology is very difficult in mobile ad hoc network. For maintaining dynamic topology routing protocols plays a very important role in MANET. There are four types of routing protocols that are known as proactive routing protocols, reactive routing protocols and hybrid protocols and hierarchical routing protocol. There are many characteristic of MANET like dynamic in nature, multi hop routing, no centralized coordination, limited resources etc. There are many important application of MANET they are used in different contexts such as collaborative, medical, military or

embedded applications [1]. Mobile ad hoc network are very useful network where we cannot establish a wired network and infrastructure is not present but due to many reasons like limited radio resources, bandwidth, and battery power makes a challenging issue in developing an energy efficient routing protocol [2].

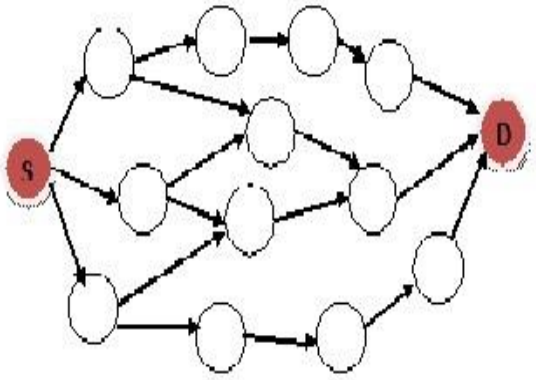

Figure 1: Mobile ad hoc network

There are many techniques in MANET for improving their performance; Clustering is one of the very important techniques in MANET for increases the lifetime of devices as well as network. This paper is organized as follows: In Section II, Clustering in MANET is discussed. Section III, related work is overviewed. Section IV describes proposed work. Section V, presents the methodology. Section VI presents case analysis and in section VII conclusion is discussed.

II. Clustering MANET

Clustering is a very important technique for managing the flat mobile ad hoc network in small groups, for efficient routing and monitoring the network is divided into small and manageable entities called clusters (refer figure-2)

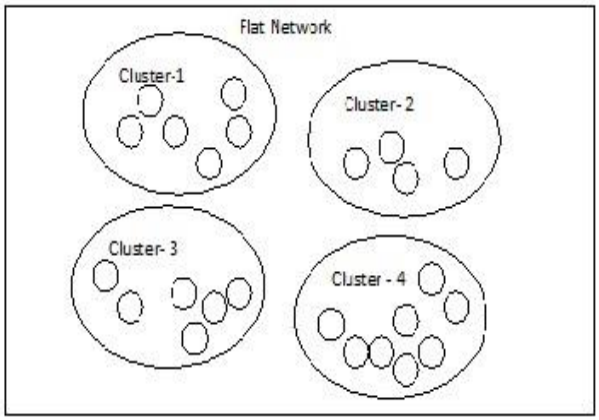

Figure 2: Cluster Based Mobile Ad-Hoc Network

In mobile ad hoc network there is no base station or center device but in cluster based networking center device is present, which work as base station and manage all the activities within cluster or outside the cluster. In some cases, the cluster is stationary, with the moving nodes around inside known as a stable cluster [3]. In other cases when a group of nodes have similar movement traces, the cluster moves as a whole known as a moving cluster. In both cases, two types of routing takes place one is inter cluster routing and other is intra cluster routing. In intra clustering routing communication between cluster head to member nodes and vice versa takes place and in inter cluster routing cluster head to gateway node and gateway node to other cluster head takes place to establish the communication between different clusters After dividing the flat network into clusters, each and every cluster divide their work into different nodes and center node work as a base station and provide the services to other nodes, inside the cluster there are three types of nodes present (refer figure-3) that are discussed

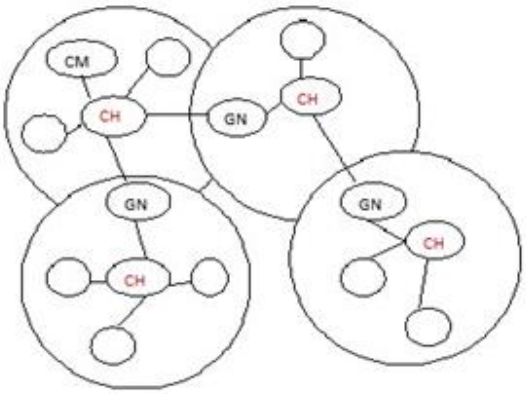

Figure 3: Cluster in MANET

The node which coordinates the cluster activities inside the cluster known as cluster head (CH), and this cluster head provide all the services to the member nodes. Within a cluster only one cluster head is possible at a same time below-

- Cluster Head
- Cluster Member or ordinary node
- Gateway node

cluster head may be change after some time by using different clustering algorithms. Cluster head

has all the information of their member's node and neighboring gateway nodes for establish the intra cluster and inter cluster communication. Within the cluster other nodes are known as ordinary nodes or cluster member. Each member node has direct access to the cluster head, ordinary nodes cannot communicate directly with other cluster member. They can communicate through a cluster head Gateway nodes are those nodes under which there are ranges of (more than one) cluster head, these nodes can transfer the data packet from one cluster to another cluster. If a member of cluster 'A' wants to send a data packet to the member of cluster 'B'. First of all member node of cluster 'A' send that data packet to its cluster Head which in turn check its entry tables to make sure that destination node is present within the same cluster or outside the cluster. Now if destination node is present within the entry table then cluster head directly sends that data packet to the destination otherwise it sends that data packet to the gateway node and gateway node forwards it to their neighboring cluster head. This process forwarding and receiving the data packets takes place for in cluster based routing, its comes under the hierarchical routing protocol and the best example of this type of routing is cluster based routing protocol.

III. Related Work

In mobile ad hoc network, limited battery power is a critical issue. There are many energy efficient solutions present; clustering is a one of the important technique for power saving. There are many clustering algorithms proposed by different researchers. These algorithms are based on different parameters and different strategies are used to select the cluster head (refer figure 4). Some of the researchers work for improving the clustering technique in order to increase the network performance is given below.

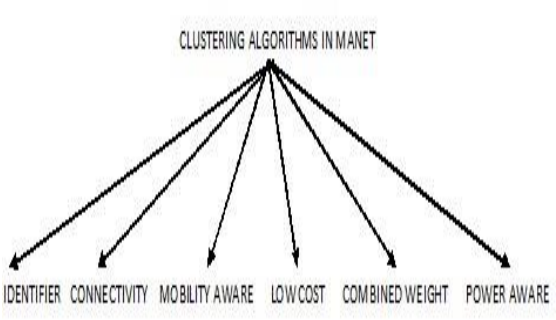

Figure 4: Clustering algorithms in MANET

Parameters use to design clustering algorithms are as follows-

- Identifier - In this algorithm identifier is the main cluster head selection parameter. Here each and every node has a uniqe ID and cluster head selection based on lowest ID.

- Connectivity - In this algorihtm highest connectivity is main parameter. Cluster head selection is based on the highest number of neighbouring nodes.

- Mobility aware - In this algorithm the information of mobility of each node is consider. Cluster head selection is based on the stability of the node.

- Low cost - In this algorithm There are many parameters are taken into consideration like energy, connectivity and mobility etc for cluster head selection.

- Combined weight - In this algorithm considers multiple parameter collectively like transmission power, receiving power, mobility, degree difference and battery power for efficient selection of cluster head.

Power aware - In this algorithm the main parameter is energy of the node. Highest energy of the node will be selected as a cluster head M. Gerla and J. T. Tsai [4] proposed an algorithm in which a minimum ID node is chosen as a cluster head. Thus, the IDs of the neighboring nodes of this cluster head will always be higher than that of the cluster head.

R. Agarwal et. al. [5] proposed an algorithm based on connected nodes. Which node has maximum number of connected nodes or neighbors nodes (i.e., maximum degree) is chosen as a cluster head. Cluster head have 1hop connectivity with the member nodes and each member node has 2-hop connectivity with another cluster member. Only one cluster head is allowed in a cluster at a same time. This algorithm has a low rate of changing of cluster head but the throughput is low and examined the important issues related to cluster-based MANETs, such as the cluster structure stability, the control overhead of cluster construction and maintenance, the energy consumption of mobile nodes with different cluster-related status, the traffic load distribution in clusters, and the fairness of serving as cluster head for a mobile node.

P. Basu, N. Khan et. al. [6], proposed a local mobility metric for the cluster formation process is used. The node with low speed relative to their neighbors has maximum chance to become cluster heads. For maintenance of a cluster, a timer is used to reduce the cluster head change rate by avoiding re-clustering.

M. Chatterjee, S. K. Das, et. al. [7], proposed to selects a cluster head according to their capability like mobility, transmission power and battery power etc. To avoid communications overhead, this algorithm is based on node mobility. To ensure that cluster heads will not be overloaded a pre-defined threshold is used which indicates the number of nodes each cluster head can ideally support. WCA selects the cluster heads according to the weight value of each node. The node with the minimum weight is selected as a Cluster head.

Yogendra Kumar Jain and rakesh Kumar Verma [8], have presented an approach to efficiently utilize node energy according to its energy parameter like transmission power, receiving power, ideal power and sleep power etc. Energy is the scarcest resource for the operation of the mobile ad hoc networks. Idle energy consumption is responsible for a large portion of the overall energy consumption in the wireless interfaces of the mobile nodes**.**

Jane Y.Yu and Peter H.J.Chong [9], have presented a comprehensive survey of clustering schemes for MANETs. The authors first provided fundamental concepts about clustering. Then they classified proposed clustering schemes into six categories based on their main objectives, which are listed as follows: Dominating-Set-based (DSbased) clustering, low maintenance clustering, mobilityaware clustering, energy efficient clustering, and load- balancing clustering, and combined metrics-based clustering. They also grouped the clustering cost terms into five categories: the required explicit control message exchange, the ripple effect of re-clustering, the stationary assumption, constant computation round, and communication complexity.

Abbasi and M. F. Younis [10] grouped taxonomy of relevant attributes into three types: cluster properties, cluster head capabilities, and clustering process. They highlighted their objectives, features, complexity and the effect of the network model on the presented schemes and summarized a number of schemes, stating their strength and limitations.

M. Anupama and B. Sathyanarayana [11], analyzed, compared and classified some clustering algorithms into: location based, neighbor based, power based, artificial intelligence based, mobility based and weight based algorithms.

A.Choukri, A.Hobbani and M. Elkoutbi [12], propose a novel hierarchical routing protocol based on clustering approach inspired on the heuristic Max-Min D-Cluster that have been improved and implemented on standard OLSR.

Sharmila John Francis and Elijah Blessing, Rajsingh [13], studied the performance of each clustering protocol and have analyzed against various crucial performance metrics. They have also compared it with other clustering protocols. Based on the performance comparison of various clustering protocols, the best clustering protocol is recommended which is more suitable for many application scenarios.

Kaouther Drira and Hamamache Kheddouci [14], have used Dominating nodes to form a tree structure inside the clusters; where the root of the tree is the cluster-head. The idea is to form a clustered network over which communication protocol can be efficiently designed.

Chaitali Uikey [15], Node Based Cluster Routing Algorithm (NBCRA), proposed a schema to improve the cluster stability and in-turn to improve the performance, through selecting better cluster-head. In this algorithm, node itself observes and accounts its movement. This information is used to select an cluster-head. Moreover, the proposed protocol have increases the stability of the cluster-head.

Chun-Chuan Yang and Yu-Chong Chang [16], have presented a stability based clustering scheme, clustering is a very important technique in mobile ad hoc networks to manage mobile nodes and provide better communication between nodes. A stability-based clustering (SBC) technique useful to reduce the overhead in the network in these technique nodes constructs stable enough clusters to reduced maintenance overhead. Therefore, SBC construct clusters in low-mobility situations and fewer clusters in high-mobility situations. The route finding mechanism combining both unicasting and broadcasting of route request packets is proposed for SBC.

Neha Gupta and Rajeev Kumar Singh et.al. [17], have presented a weight based clustering scheme, A clustering architecture increases network

lifetime, fault tolerance and results in more efficient use of network resources so in mobile ad hoc network clustering is very useful. The weight based clustering approach is based on combined weight metric that takes into account of several system parameters like the mobility, degree difference, transmission range and battery power of the node. One way to support efficient communication between nodes is to partition ad hoc networks into clusters. Various clustering Schemes have been proposed to form clusters. Proposed IWCA algorithm can enhance the trust of cluster formation followed by malicious node removal from cluster head or member selection

IV. Proposed Work

In this paper, a new energy efficient clustering algorithm that form structured clusters using max-heap tree is proposed. This provides the stable end-to-end communication and efficient energy saving routing protocol. In this approach, the concept of Lowest ID Clustering (LIC) algorithm is used. But the main drawback of lowest ID clustering algorithm is becoming of lowest ID node as cluster head; leading to dying of some nodes serving as cluster head for longer time; as cluster has highest transmission opportunity. In the proposed work, first of all the flat network is divided into self-manageable small groups called clusters or zone, here the author consider the stable cluster with moving nodes after creating the clusters an index number is assigned to every node of cluster with respect to its energy level, then all the nodes form a max heap tree with respect to their energy level and the node with higher energy level becomes a cluster head or the root of max-heap tree. The remaining nodes come under the root node or cluster head and form a connected max heap tree where cluster head has one hop connectivity to all their member nodes and as well as each cluster head gets connected with the other cluster head in the network for inter clustering communication. Here the range of clusters is fixed (one hop) or it can be considered as stable clusters with moving nodes. The nodes within cluster form a tree and the root with highest energy become the cluster head when the energy level of cluster head comes near to the threshold value then this cluster head is interchange with the other highest energy node or the present root node of the max heap tree.

Communication in the network will happen among cluster head directly, and there is no gateway node. Cluster head has 1- hop connectivity with all cluster members. For communication between cluster head to cluster head or inter clustering communication, Optimized link state routing (OLSR) protocol is used, for forwarding the information to the other cluster head members the multi point relay (MPR) plays a very important role for forwarding data packets in inter clustering communication. It select on which cluster head data should be forwarded so that it reduces the replication of data on same cluster head. With the use of MPR, the congestion in the network can be reduced and this can save the energy of remaining cluster head. With the life of this proposed technique the energy of nodes can be saved and the network lifetime is increased.

V. Methodology

In mobile ad hoc network; nodes has limited energy or battery power. Hence energy conservation is a very important issue for new researchers. In this proposed algorithm the energy of routing can be conserved with the help of effective selection of Cluster Head. This clustering algorithm can be implemented; first by dividing the whole network into manageable number of clusters and applying the concept of max heap tree within the cluster for selecting and interchanging the cluster head. There are many important steps of this cluster based routing as given below, which takes place for implementation:

- Formation of cluster
- Selection of cluster head
- Interchanging of cluster head
- Intra-cluster communication
- Inter-cluster communication

1. Formation of Cluster

Formation of clusters is an initial step for cluster based routing in this technique divide the whole network into fixed clusters with moving nodes. Nodes can move within and outside the cluster, or new nodes can also come inside the clusters. If a cluster again divide into some clusters known as sub clustering and if two or more clusters merge within a single cluster known as super clustering.

2. Selection of cluster head

Now calculate the energy of each node of cluster in joule and assign an index number for identification (refer figure5).

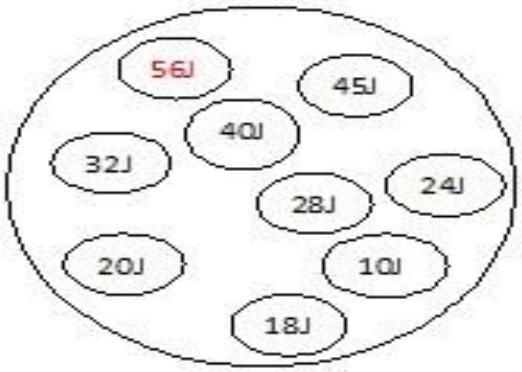

Figure 5: Energy Level of Cluster Nodes

According to the energy level of each node construct a max-heap tree. The highest energy node will be at the root position of max-heap, which will serve as a cluster head (refer figure-6).

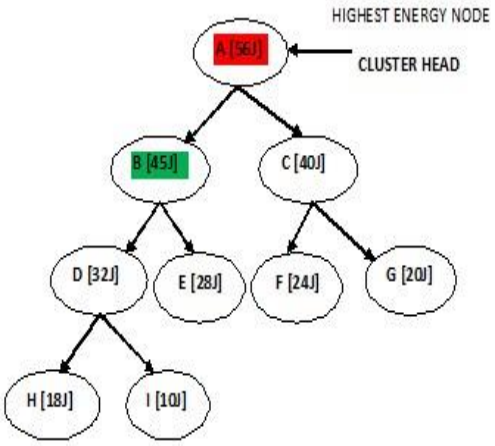

Figure 6: Energy Based Heap Tree

3. Interchanging of cluster head

When the energy of cluster head decreases as compared with the subsequent nodes at lower level then the tree balancing algorithm will run to balance the max heap tree (refer figure-7), here tree balancing takes place and the position of cluster head will change. Whenever the energy of cluster head is below down the threshold level then the role of cluster head is changed with the existing root node of the cluster head.

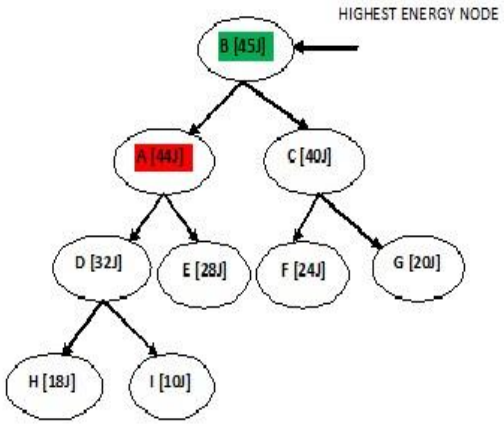

Figure 7: Position changing of Cluster Head

For example the threshold value for this condition is 20J then all selected cluster head work as a cluster head until their energy level is higher than 20J, whenever the energy level of cluster head decrees from 20J the role of cluster head change with the latest root of the max heap tree (refer figure-8). In this figure when the energy of CH equal to the threshold value present root became cluster head and this process continue until and unless all presented nodes work as a cluster head and the cluster head will work as the head until its energy is higher than the other nodes and this process continues. By using this mechanism cluster head will never die due to exhaust of battery power because always higher energy node work as a cluster head.

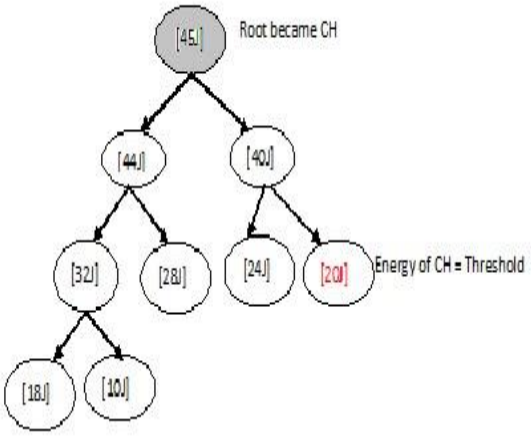

Figure 8: Interchange of cluster head

4. Intra-clustering Communication

In the cluster, the Cluster Head (CH) has 1-hop connectivity with every member node in a tree. So CH can directly communicate with member

nodes but member nodes cannot communicate directly with other members of cluster (refer figure 9). CH is always on active mode and the member node which is not working is kept on sleep mode. If any node wants to forward a packet to one of the sleep node then CH sent an acknowledgement to sleep node and it changes its mode to active mode, after finishing their communication it will again comes on sleep mode.

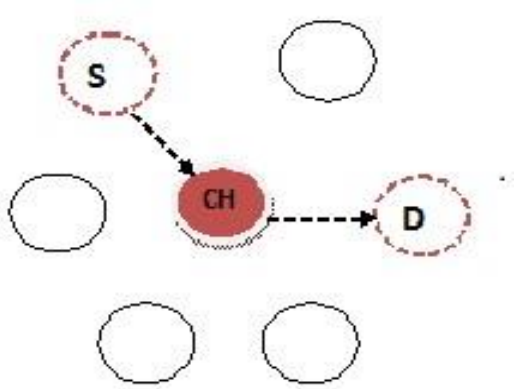

Figure 9: Communication within Cluster

5. Inter-clustering communication

In inter clustering communication cluster head to cluster head communication takes place with the help of proactive routing protocol (refer figure 10). In this approach optimized link state routing (OLSR) protocol would be used for maintaining the all possible paths [18]. The concept of MPR (multi point relay) has a special feature to reducing replication and make sour that data packet is forwarded to all necessary nodes. So that here MPR selects the cluster head through which the data packet would be forwarded, which would minimize the congestion by reducing the number of forwarding nodes, and saving the energy of other CH and increases the lifetime of cluster head member.

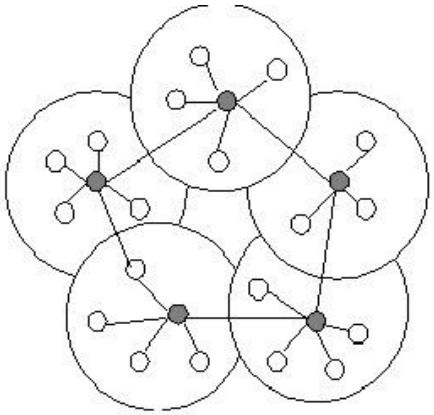

Figure 10: CH to CH communication

ALGORITHM FORMULATED

Cluster Creation ()
Start
For I =0 to n // n is number of node s
Begi n
Define E [1], E [2], E [3]… E [N]; //Assign the energy of each node and E shows the energy level Heap Creation Algorithm ()
Root <- E [A] [highest energy node]
Left <- E [L]
If E[left] > E[root]
{
Interchange E[left] <-> E[root];
}
Right <- E[R]
If E[right] > E[root]
{
Interchange E[right] <->E[root];
}
Repeat until all the nodes within cluster comes under heap tree
Root <- Cluster head;
Cluster head energy <= Threshold value:
Interchange Cluster head <-> Root node of max heap tree;
E [Max] <- Cluster Head
// Root node of heap is always select as a cluster head when the energy level of existing CH is less than or equal to the threshold value.
// Cluster node can never depart due to energy lost.

VI. Case Analysis of Algorithm

In this approach of heap based clustering algorithm there could exist many cases within cluster which may affect the working of cluster-

CASE-1: A new node enters in a cluster

When a new node enters in a cluster (refer figure 11), tree

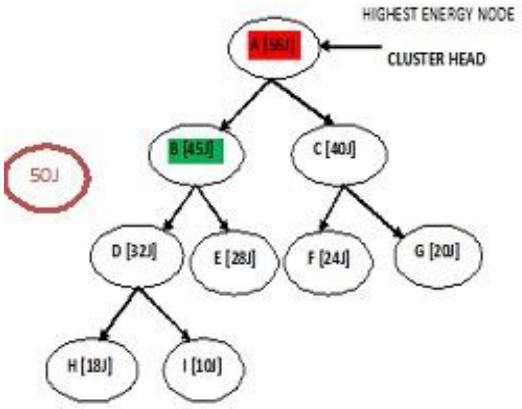

Figure 11: New node enter in cluster balancing is required immediately and placement of the new node at an appropriate position in the max-heap. This node also has 1- hop connectivity with CH. Newly arrived node can also become the cluster head, if it has higher energy as compared to existing cluster head.

CASE-2: An existing node depart from the cluster

There are many reasons of departing the node from a
cluster-

- Battery of a node is exhaust
- Node is not reachable
- Malfunctioned nodes
- High mobility
- Link breaks
- Attacker node

When an existing node departs from the cluster it also generates three cases-

CASE-2.1: A leaf node departs from the cluster: When a leaf node departs from the cluster then there is no need to balance the tree because a change in the leaf node doesn't affect the structure of the max-heap (refer figure 12). All the reasons are possible for departing leaf node which is given above.

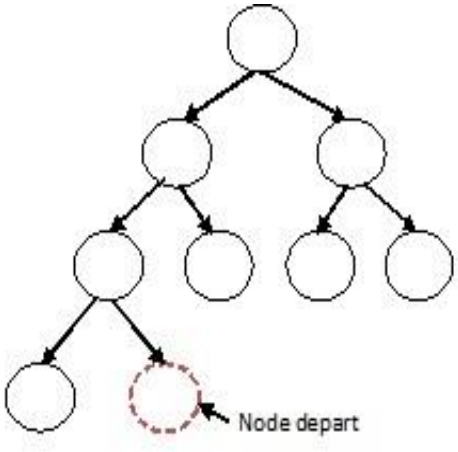

Figure 12: leaf node depart

CASE-2.2: An intermediate node departs from the network:
When an intermediate node departs from the cluster then tree balancing is needed, because it can violate the property of max-heap (refer figure 13). In this figure if the intermediate node departs then their child nodes has no connection with the cluster head and they cannot communicate with any one node in the network. So that re clustering or tree balancing takes place immediately. Here also all the reasons are possible for departing but the battery exhaust has rare chance to happen because intermediate nodes have sufficient energy level as compare to leaf nodes.

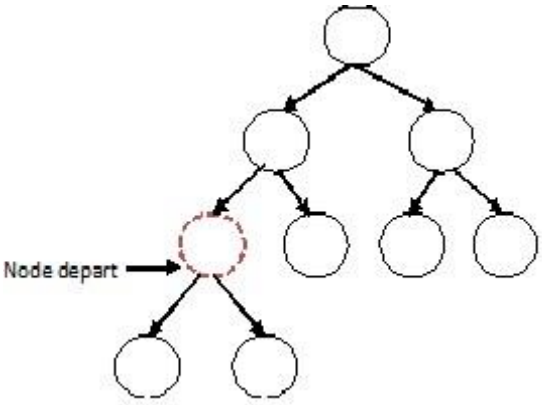

Figure 13: Intermediate node depart

CASE-2.3: Cluster head departs from the network: When the cluster head departs from the network, it's a very critical case because cluster head is a supervisor node of the cluster if it departs then all services stops. Then, there is a need to select cluster head immediately. Now tree balancing is required in the remaining nodes to form a max-heap tree. If cluster head node depart then to maintain routing table is very difficult because all the information about neighbor nodes is lost so to maintain routing table and gathering information

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takes some time so that it's a very critical case. It is to be noted that CH can never depart due to battery loss because cluster head has highest energy level among the nodes in the cluster.

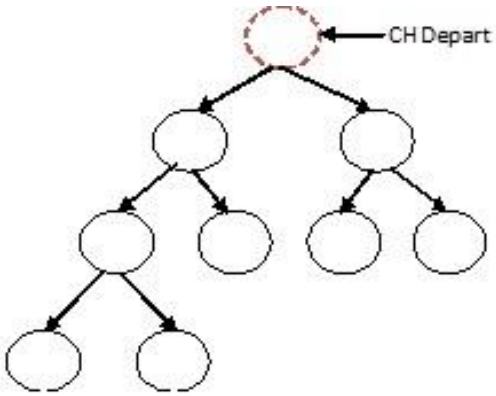

Figure 14

VII. Conclusion

In this paper a new concept for energy efficient routing algorithm based on clustering technique using a max-heap is proposed. Small manageable cluster are formed using max heap tree and the head of the cluster are formed based on the energy level of nodes, where highest energy level node becomes the cluster head. It is believed that this new routing protocol will be energy efficient routing protocol for MANET. The clustering techniques are useful for minimizing the power consumption and maximize the network lifetime. There are different clustering algorithms present in mobile ad-hoc network for selecting the cluster head on the basis of selection schemes. This paper proposes new improved mechanism for selection of cluster head by choosing the root node of max-heap, which has highest energy. The battery of CH will never exhaust so the working of cluster does not suffer due to CH services, in turn network will sustain for longer duration.

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