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Hybrid Routing Protocol in MANET using Clustering Approach

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Abstract:
This paper introduces the concept of Cluster Based Hybrid Routing protocol(CBHRP) in Mobile Ad-hoc Networks (MANET). Energy conservation is the main parameter to be considered in MANET. In our work, attempt is made to achieve energy efficiency by clustering and hybrid routing. The MANET is first divided into clusters and then cluster head is elected such that its energy level and signal strength is maintained above some pre defined threshold value. The head selection and its maintenance is done using the Signal and Energy Efficient Clustering(SEEC) algorithm. Once head is selected, routing is carried out such that inter cluster routing is done using reactive protocol, where as intra cluster communication takes place using pro active protocol. Hence the name cluster based hybrid routing protocol. Simulation results show that considerable energy efficiency is achieved using clustering and hybrid routing.

Keywords : *CBHRP, MANET, SEEC, hybrid routing*

1. Introduction

Mobile Ad-hoc networks (MANETs) are combination of mobile nodes and they lack centralized control or pre-existing fixed infrastructure. Such networks normally use multi-hop paths and wireless radio communication channel. Hence, communication between nodes is established by multi-hop routing. New nodes join or leave the network at any instant. Topology changes constantly due to this dynamic behaviour . Therefore performance of network falls with changing topology. A wireless ad hoc network is self-organizing, self- adaptive and self disciplining. In ad hoc networks, the node use exhaustible energy such as batteries. So, advanced power saving techniques is necessary. A variety of techniques can be used to deal with power insufficiency. In this paper, we have implemented one such method.

In a dynamic topology, such as mobile ad hoc networks (MANETs), nodes can freely move; this often leads to breakage in links and also the invalidity of the previously founded routes. It is a complex problem that any dynamic wireless routing protocol has to solve. In any network, nodes can be both the source as well as destination nodes. However, in MANETs, nodes can also be an intermediate node; thus, they will be responsible for relaying packets to and from the neighbouring nodes. This specific co-operative ability of MANETs is very useful in emergency situations where communication infrastructures are lost and a network needs to be setup quickly. MANETs can be a cheap and provide efficient solution to deploy in rescue or military operations. Such deployments will only benefit from these self-healing capabilities of MANETs if a robust routing protocol is implemented.

Battery consumption and throughput are two major problems in MANETs. In dynamic topology of MANETs, few nodes may relay more traffic than others, mainly because of their location in the network; such nodes will drain their energy reserve sooner than the others. Traffic concentration also increases radio jamming, delay, and packet loss. Besides, battery consumption leads to an earlier node failure, network partitioning, and downfall of the route reliability.

Thus, for MANETs a routing protocol is needed such that it is robust, simple to understand and most importantly energy efficient. In this paper will implement an energy efficient protocol based on cluster head mechanism. Our project aims at forming a cluster and then selecting a cluster head such that node with maximum energy and fulfilling some other pre-defined criteria is selected as the head of the cluster which maintains all the information within the cluster and the neighbouring cluster in the network and then adopting a routing protocol such that overall power in the network is fairly utilized and the network life is extended, thereby making the routing process in the network energy efficient. A hybrid routing protocol will be used which will use both reactive and proactive approaches, making the best use of both these approaches. The communication within the cluster will be carried out using proactive method where as among clusters, it will be carried out by reactive approach. This avoids the need of route discovery in the cluster again n again. Also, energy of head is less consumed. So energy of overall network is conserved

2. Literature Survey

MANET has a dynamically changing topology as the nodes are mobile. This behaviour requires routing protocols that dynamically discover routes rather than conventional distance vector routing protocols. Also, IP sub-netting is inefficient as MANET lacks in fixed structure. Then there is power depletion of nodes due to large number of message passed during cluster formation and limitation of battery power. Links in MANET are not symmetric at all times. If a routing protocol is dependant only on the bi-directional links, the d connectivity and size of the network may be restricted severely. A protocol that makes use of uni-directional links as well as bidirectional linkscan significantly lessens the network partitions and enhances routing performance.
Types of routing protocols for MANET:

1. Proactive Protocol**:** Proactive protocols maintain topology information by exchange of information with the other nodes of the network on a regular basis. Proactive routing protocols try to maintain consistent and up-to-date routing information between each and every pair of nodes in the network. This is done by propagating, proactively, route updates at fixed intervals. As the resulting information is normally maintained in tables, the protocols are sometimes also referred to as table-driven protocols.
2. Reactive Protocol: Reactive protocols do not maintain any route information in advance, it finds a path only when there is a need to find route from source to destination. Once a route is discovered, it is maintained by the node until either the destination becomes inaccessible or until the route is no longer used or has expired.
3. Hybrid Routing Protocol (CBRP): This is the combination of both proactive and reactive protocols. The hybrid protocols makes use of best features of both proactive and reactive routing which helps to overcome the frequently changing topology problem in MANET.

Different types of Pro-active protocols are as follows:

1. Destination Sequenced Distance Vector (DSDV)
2. Optimized Link State Routing (OLSR)
3. Cluster head Gateway Switch Routing (CGSR)
4. Fisheye State Routing (FSR)
5. Routing Protocol (WRP)

Different types of Reactive protocols are as follows:

1. Ad hoc On Demand Distance Vector (AODV)
2. Dynamic Source Routing (DSR)
3. Associativity Based Routing (ABR)
4. Temporally Ordered Routing Algorithm (TORA)

Different types of hybrid protocols are as follows

1. Zone routing protocol (ZRP)
2. Greedy Parameter Stateless Routing (GPSR)

The following are few of the most commonly used protocols used for routing in MANET. DSDV and OLSR are proactive protocol where as AODV and DSR are reactive protocols. ZRP is hybrid routing protocol. The operation of these protocols is briefly mentioned below.

2.1. Destination Sequenced Distance Vector Routing (DSDV)

The basic design aim of DSDV was to maintain the simple nature of the distributed Bellmann–Ford and also to avoid the looping problem, using the concept of sequence number, in the routing tables. It made use of full dump and update increment to reduce the traffic load. Due to this, the avoidance of infinite loop was achieved. In DSDV, each node transmit a sequence number which is linked to destination usually originated by owner, where it is periodically increased by two and transmitted along with any other routing update messages to all nodes in the neighbourhood. A non-owner node then updates a sequence number of a route when link break on that route is detected. The owner nodes use the even numbers and non-owner nodes uses odd numbers as their sequence number.

2.2. Ad-hoc On Demand Distance Vector Routing (AODV)

AODV is an on-demand protocol, which initiates route request only when there is a need. When a source node needs a route to certain destination, it broadcasts a route request packet (RREQ) to its neighbours. Each neighbour checks its routing table to see if it already has a route to the destination. If it does not have a route to this destination, it will re-broadcast the RREQ packet and let it propagate to other neighbours. If the receiving node is the destination or has the route to the destination, a route reply (RREP) packet will be sent back to the source node. Routing entries for the destination node are created in each intermediate node on the way RREP packet propagates back. A hello message is a local advertisement for the continued presence of the node. Neighbours that are using routes through the broadcasting node will to mark the routes as valid. If hello messages from a particular node stop coming, the neighbour can assume that the node has moved away. When that happens, the neighbour will mark the link to the node as broken and may trigger a notification to some of its neighbours telling that the link is broken. In AODV, each router maintains route table entries with the destination IP address, destination sequence number, hop count, next hop ID and lifetime. Data traffic is then routed according to the information provided by these entries.

2.3. The Optimized Link State Routing (OLSR)

It is a proactive protocol. It is a modification in traditional link state routing, to be used for MANET. The main feature of OLSR is its multipoint relays (MPRs) which reduce the control overhead in the network and the size of link state updates in the network. Each node computes its own MPRs from its set of neighbours. The MPR set is chosen such that when a node broadcasts a message, the retransmission of that message by the MPR set will ensure that the message is received by each of its two-hop neighbours. Thus, whenever message is broadcasted by the node, only those neighbours in its MPR set will rebroadcast the message. Other neighbours not in the MPR will not rebroadcast the message. Moreover, during exchange of link state routing information, a node will only lists its connections to those neighbours that have selected it as an MPR. This set of neighbours is termed as MPR Selectors.

2.4. Dynamic Source Routing Protocol (DSR)

It is a reactive protocol. It computes the route to destination only when a packet is needed to be sent. The node broadcasts a route-request in the network and finds the required route from the responses received. This protocol is composed of two main processes working together to allow the discovery of source routes in the network and its maintenance. In the route discovery phase, when a node A wants to send data to the node B, it will find a route to B. Route Discovery is used only when A tries to send data to B and has no information on a route to B. The second process is route maintenance in which with the change in the network topology, the existing routes cannot be used. In such cases, the source A can use an alternative route to the destination B, if it knows one, or invoke Route Discovery.

It was observed that AODV performs better on larger number of nodes while, DSR performs better on lesser number of nodes, with the same scenario [2]. It was seen that performance of AODV routing protocol is best in terms of its ability to preserve its connection with help of periodic message exchange. From the performance analysis, it was observed that DSDV are more appropriate for smaller networks where changes in the network topology are limited.

However, none of these protocols can be used on networks of large size, because they produce too much traffic control which would require too large routing tables. One solution proposed for routing on large network is to introduce a hierarchical routing by grouping entities into clusters. And thus we use hybrid routing protocols by combining the best of both reactive and pro active protocol.

2.5. Zone Routing Protocol (ZRP)

It divides the network into number of zones in a distributed manner. If the destination node is in same zone as source node, proactive protocol is used to deliver information by using already stored routing table. If not, reactive protocol takes will check each successive zone in the route to see if destination node is within that zone. This will reduce processing overhead for those routes. Once confirmed about the zone of destination node, information will be delivered using reactive protocol. ZRP is divided into two types

1. IARP for intra zone routing protocol
2. IERP for inter zone routing protocol

Following are certain peculiar features of ZRP:

1. Flooding of traffic is less during route discovery phase.
2. It reduces the delay.
3. Reduces the number of control overheads.
4. Offers link repair.

Hybrid method of routing will be used in the paper. The zones will be in the form of clusters i.e. hierarchical type of division. Each cluster will select its own cluster head (CH). So when a node has to send information to another node, it will broadcast route request in the network specifying the destination address. The CH then will check if the destination node comes under its region. If yes, then proactive method of routing will. If not, it will search for the cluster under which the destination node falls and then by reactive approach method, the information will be delivered from the source to the destination node. In this, nodes maintain proactive routing information for destinations in their immediate neighbourhood i.e. intra cluster and use reactive routing method for destinations that are further i.e. inter-cluster. Purely proactive or reactive protocols perform well in a limited region of network setting. However, the diverse applications of ad hoc networks across a wide range of operational conditions and network configuration pose a challenge for a single protocol to operate efficiently. Reactive routing is well suited for networks where the call-to-mobility ratio is relatively low, where as Proactive routing is suitable for networks where this ratio is relatively high. The performance of either class of protocols falls when the protocols are applied in regions of ad hoc networks space between the two extremes. So the best characteristics of both the approaches are used to achieve better energy efficiency. In our paper, we will be using cluster based hybrid routing protocol as explained below.

3. Proposed Approach

3.1. Cluster Based Hybrid Routing Protocol (CBHRP)

The network will be divided in clusters by combining the nodes within the distance of 2-hop diameter. A cluster head will be selected out of the nodes which will maintain information like cluster membership, cluster nodes and routing information within and among the clusters in the neighbourhood. Figure 1 shown below depicts the cluster topology in the network.

Following are some of the terms used in CBHRP:

1. Node ID: This is the unique id for every node in the network. The IP address for every node is its node ID.
2. Cluster head (CH): The node which controls all the operations in a cluster is the cluster head.
3. Cluster gateway: It is a node which is not a head but has inter-cluster wireless links. Thus, it can deliver information between clusters.

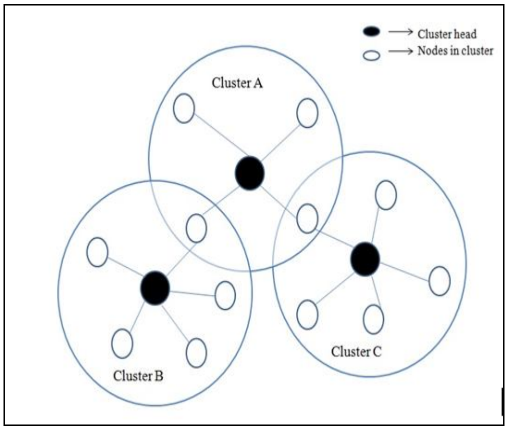

Figure 1: Clusters in a network

There are three tables maintained in CBHRP. One is the neighbour table which maintains information about link states and the neighbour's state and the second table is maintained by cluster head which stores information of its neighbouring clusters along with all information in the cluster. The third table is Cluster Adjacency Table (CAT) which has information about neighbouring cluster heads. Following are the formats of the table

1. Neighbour table : It stores information about the neighbour node, its status and its role .

Neighbour ID	Link status	Role

Table 1: Format of neighbour table

2. Head table : It stores information about the node ID, signal strength and power level of nodes in a cluster.

Node ID	Signal strength	Power strength

Table 2: Format of head table

3. Cluster adjacency table (CAT) : It keeps information about adjacent clusters, gateways connecting the clusters and status of the link between them.

Adjacent cluster ID	Gateway	Link status

Table 3: Format of CAT

Once these tables are obtained, routing will be carried out using the reactive or pro active protocols depending upon the relative position of the source and destination node.

3.2. Selection of Cluster Head and Its Maintenance

The smaller life span of cluster head is one of the biggest disadvantage of the protocol mentioned above. The extra power consumption causes the death of the cluster head. This is avoided in this algorithm. The main aim of the SEEC algorithm is prevention of death of the cluster head by selecting another node as cluster head when the signal strength or power level goes below pre decided threshold value.

Formation of cluster: During this process, each node broadcasts a HELLO message including its node ID, signal strength, power level in its cluster. Each node will compare its signal strength with others. The node with lowest id declares itself as the head and broadcasts decision message specifying it's ID. After cluster formation, and selection of cluster head care will be taken that that it stays alive and re election of cluster head is avoided when level of battery power or signal strength reaches pre decided minimum threshold value.

Figure 2 shows topology of the cluster. Node 1 is head of cluster A, node 11 is head of cluster B, node 21 is head of cluster C. The communication between between nodes in same cluster is carried out by the cluster head. The communication between nodes in different clusters, called as inter-cluster communication takes place through cluster gateways with the help of cluster heads of the respective clusters. The information about the changing topology and cluster heads is maintained in tables and updated periodically.

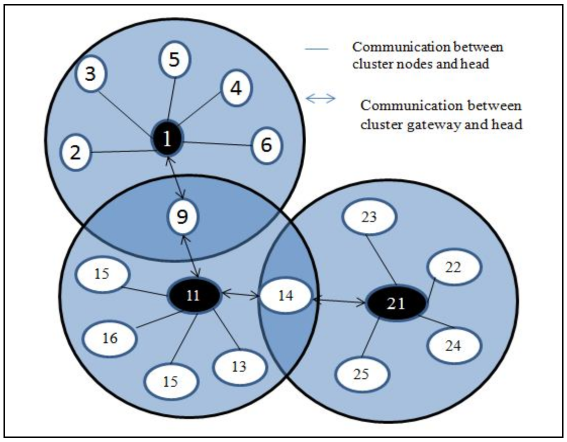

Figure 2: Cluster topology

Figure 3, explains the flow of SEEC algorithm. The node with the lowest ID is selected as the cluster head CH initially and its information is stored as the first entry in the head table HT. In the head table, information about every node in the cluster is stored. The HT has three parameters node id, signal strength and power level. The threshold values for SST ant PLT are decided initially. The HT is refreshed after equal intervals and then accordingly sorted. Also, initialization of routing table is done for the cluster head CH. If the value of signal strength or power level of cluster head falls below the above pre decided threshold value, the next node in the head table becomes the cluster head and then again head table and routing table is updated. And then routing is carried out in the MANET as per the cluster head's routing table applying hybrid routing mechanism.

3.3. Routing in the Network

After the election of the cluster head and obtaining its routing table from the above SEEC process, communication within nodes can be done using the hybrid theory. A simple function is proposed to carry out the routing. If the source node and the destination node are in the same cluster then proactive routing can be used while if they belong to different clusters then routing can be carried out through their respective cluster heads by the reactive approach of routing.

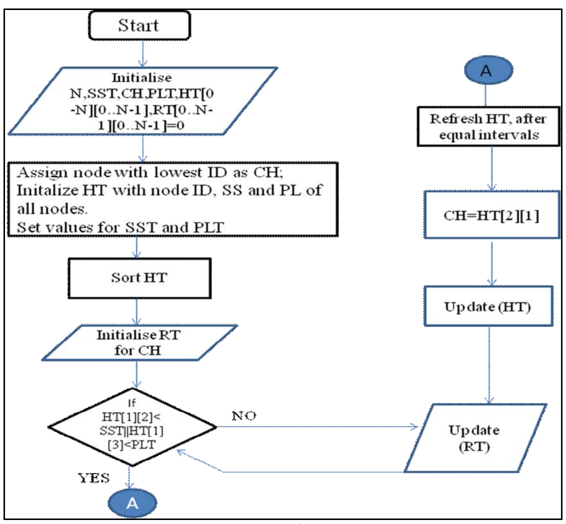

Figure 3: Flowchart for SEEC algorithm

For E.g., in Figure 2, the routing between node 13 and 25 will be done by reactive approach through the cluster heads, while communication between node 2 and 6 will be carried out by proactive routing method by the cluster head which maintains fixed routing table for nodes within its cluster.

The proposed function is as follows :

```
Let S be source node & D be destination node;
Routing ( )
if (cluster_id_S==cluster_id_D)
{
        Proactive routing;
}
else
        Reactive routing;
end.
```

3.4. Cluster Based Hybrid Routing Protocol (CBHRP)

The network will be divided into number of clusters in a distributed manner, as shown in Figure 1. A head will be then selected in every cluster which will maintain information about all nodes in its cluster. The algorithm mentioned above will maintain the same CH as long as it satisfies the required criteria. The routing table for every CH in the network will be updated. Once the CH is elected ND its routing table is obtained from the above algorithm, the packets will be routed in the network depending on the process mentioned above.

Node Id	Signal strength(%)	Power strength(%)
11	90	90
16	87	80
13	78	80
15	70	68
14	71	51
12	60	50
9	46	43

Table 4: Consider node 11's head table

Neighbourhood ID	Neighbour status	Link status
9	Member	Bi
13	Member	Bi
12	Member	Bi
16	Member	Bi
15	Member	Bi
14	Member	Bi

Table 5: Consider the neighbourhood table maintained by node 11

Adjacent cluster ID	Gateway	Link status
1	9	Bi
21	14	Bi

Table 6: Consider node11's adjacency table :

Figure 4. Examples of tables maintained by cluster nodes

Considering the cluster with node 11 as head. Node 11 will be the head as long as it signal strength value and power level values are above the specified threshold value. Once this value falls down, the next entry in the table i.e. node 16 will become the head of that cluster. This election and maintenance is done as per the SEEC algorithm mentioned above. Once cluster head is selected routing can be initiated. Now suppose node 16 has to send a packet to node 13. It will contact its head i.e. node 11. Node 11 will check if the destination node 16 is in its cluster or not from its head table. Since it appears in its own cluster, the packet will be routed using proactive routing. Now if node 16 has to send a packet to node 25, it will again contact its head i.e. node 11. Node 11 will search for the cluster to which the destination node belongs, and then it will contact its head through the gateway by referring the cluster adjacency table. In this case, node 11 will contact node 21 through node 14. Once the destination cluster is found, delivery will be done using reactive routing.

The process mentioned above brings out the communication between the nodes in the MANET. In case of intra cluster routing DSDV protocol is used and for inter cluster routing AODV protocol is used as per the requirements and size of the MANET. Also, two nodes in the same cluster can communicate directly once they take permission from the CH, thus load on the CH is reduced to some extent which adds to cluster head maintenance. The use of hybrid routing affects the overall network life span. Due to the use of proactive routing within clusters, control overheads in the network are reduced since the routes are fixed within cluster and there is no need to discover routes within the cluster by the cluster head continuously. So the energy of the head is also conserved making the overall MANET more energy efficient

4. Simulation Setup

We have used network simulator (NS-2.34) for our work. We evaluate the proposed routing protocol i.e. CBHRP and compare it with the unclustered network incorporating DSDV protocol. The performance of the CBHRP and DSDV protocol is evaluated in terms of throughput. The network throughput is the average of successful message delivery over a communication channel. This data may be delivered over a physical or logical link, or pass through a certain network node. The throughput is usually measured in bits per second or data packets per time slot.

5. Simulation results

In our work, we consider a network with 16 nodes. Initially 4 clusters are formed and a head is elected for each of them. Fig 4 shows the formation of clusters and the heads elected. The cluster heads communicate directly to each other.

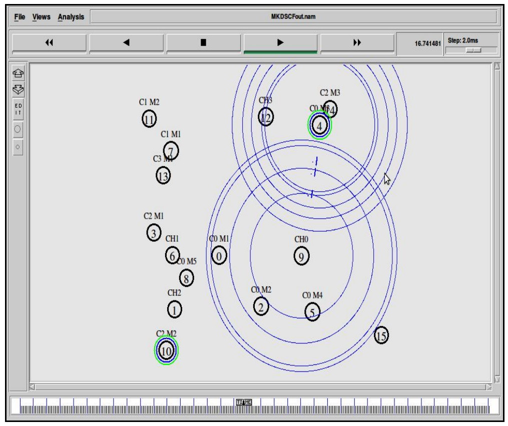

Figure 4: Cluster Formations in NS2

The following figure 5 shows the graph of throughput plotted with CBHRP(green) in one case and DSDV(red) protocol in another. From the graph it is seen that considerably higher throughput is obtained with our proposed protocol.

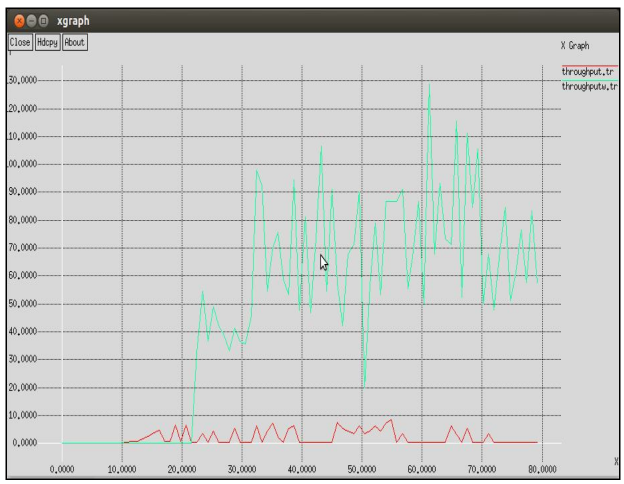

Figure 5: Throughput comparisons in CBHRP and DSDV protocol

6. Conclusion

The SEEC algorithm will keep the cluster head alive always & it also avoids re election of cluster head. So it will take care of cluster head by maintaining battery power level and signal strength both. SEEC algorithm will offer longer lifetime of network and will consume less amount of energy. In later stages, we will also try to find more efficient algorithm for the cluster head maintenance phase. This algorithm basically helps to select a cluster head and keeps it alive for a longer time, thereby increasing network life with less energy consumption. The CBHRP, as seen from the simulation results, increases the throughput. It makes use of both reactive and pro active routing as and when needed, thereby reducing traffic in the network. Thus overall battery consumption is reduced using SEEC algorithm and CBHRP increased the efficiency.

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