

Energy Efficient Cluster based Routing Protocol

Rakhi Y Vasake¹ Prof. S. B. Takale² Dr. S. D. Lokhande³

¹M.E. Student (Communication Networks) ²Professor ³Principal

^{1,2}Department of Electronics and Telecommunication Engineering

^{1,2,3}Sinhgad College of Engg, Pune, Maharashtra, India

Abstract— This paper introduces the concept of Cluster based Ad-Hoc On Demand Distance Vector Routing protocol (CAODV) in Mobile Ad-hoc Networks (MANET). Energy perseverance is the main parameter to be considered in MANET. In our proposed 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, whereas intra cluster communication takes place using proactive protocol. Considerable energy efficiency can be achieved using clustering and hybrid routing.

Key words: MANET, CAODV, SEEC

I. INTRODUCTION

Mobile Ad-hoc networks (MANETs) are combination of mobile nodes and they lack centralised control or pre-existing fixed infrastructure. Such networks normally use multihop 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 utilised 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. The communication within the cluster will be carried out using proactive method whereas 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.

II. LITERATURE REVIEW

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 connectivity and size of the network may be restricted severely. A protocol that makes use of uni-directional links as well as bidirectional link scan significantly lessen the network partitions and enhance 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:

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:

- Destination Sequenced Distance Vector (DSDV)
- Optimised Link State Routing (OLSR)
- Cluster head Gateway Switch Routing (CGSR)
- Fisheye State Routing (FSR)
- Routing Protocol (WRP)

Different types of Reactive protocols are as follows:

- Ad hoc On Demand Distance Vector (AODV)
- Dynamic Source Routing (DSR)
- Associativity Based Routing (ABR)
- Temporally Ordered Routing Algorithm (TORA)

Different types of hybrid protocols are as follows

- Zone routing protocol (ZRP)
- 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.

A. Destination Sequenced Distance Vector Routing (DSDV):

The basic design aim of DSDV was to maintain the simple nature of the distributed Bellman–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.

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

AODV is an on-demand protocol, which initiates route request only when there is a need [3]. 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 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.

C. 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

- IARP for intra zone routing protocol
- IERP for inter zone routing protocol

Following are certain peculiar features of ZRP:

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

Hybrid method of routing is used in our proposed work. The zones are 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, whereas 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.

III. PROPOSED SCHEME

CAODV is extended version of AODV for making it more energy efficient. For this purpose, clustering algorithm

algorithm is introduced into AODV [1]. The aim of this algorithm is to divide the network into clusters and thus reduce the traffic load in the network.

A. AODV:

As explained in literature survey part B. In our work we have modified AODV and the explanation is given below.

B. Proposed Enhanced AODV with Clustering Approach:

During the route discovery process AODV floods the entire network with large number of control packets, and hence it finds many unused routes between the source and destination. This becomes a major drawback to AODV since this causes routing overhead, consuming bandwidth and node power.

The proposed enhancement to AODV optimizes AODV by reducing the number of control messages generated during the route discovery process. The optimization method uses the idea of clustering the nodes of the network and managing routing by cluster heads and gateway nodes. Routing using clusters effectively reduces the control messages flooded during the route discovery process by replacing broadcasting of RREQ packets with forwarding of RREQ packets to Cluster Heads. Figure 1 shows the cluster formation in a MANET:

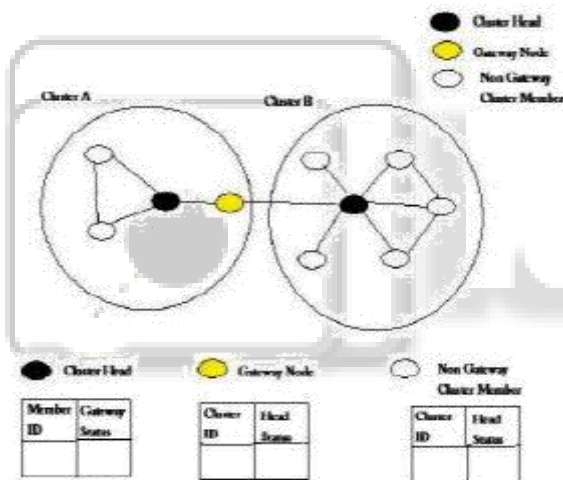


Fig. 1: Cluster with 10 nodes

The proposed algorithm for clustering in MANET can be done using three basic steps.

- Cluster Formation
- Cluster Routing
- route Maintenance

1) Cluster Formation

The neighbor table is basically used for supporting the process of cluster formation. In neighbor table the information about its neighbor nodes is stored such as their ID's, their role in the cluster (clusterhead or member node) and the status of the link to that node (uni-/bi-directional). The cluster formation is done using the Signal and Energy Efficient Clustering (SEEC) algorithm as described in [1]. The Periodic broadcasting of HELLO messages is used for maintaining the neighbor table. The information about the one node state, its cluster adjacency table, its neighbor table etc is maintained by the HELLO message.

Below are the nodes states using which the process of clustering is performance on each node.

- Undecided State: This means that current mobile vehicle node is not still belonging to any specific cluster. This happens usually if the new node entered into the MANET. If such node receives the HELLO message from the clusterhead as well as there is bi-directional link between them, then it changes its state cluster member which indicated by the clusterhead. Else that node looks up in its neighbour table in case it has any bi-directional links. Therefore if the node has any bi-directional links then it becomes the clusterhead of its own cluster and forms the new cluster. Else if it does not have any links, then it is still remains as undecided state node.
- Clusterhead State: If the existing clusterhead node detecting the any bi-directional link to another clusterhead node in the network, then it changes its state to the member only if another detected clusterhead has less ID. Else it remains the clusterhead, whereas the other node changes its state. This is kind of special case in which re-organization of cluster many resulted, as showing in figure 2.
- Member State: If the mobile member lost its current clusterhead, then it searches another bi-directional link to another mobile node. If any link detected by it, then it changes its state to the clusterhead, if it has less ID, else switching to state of undecided node. Every vehicle node in network is at least belonging to one clusterhead.

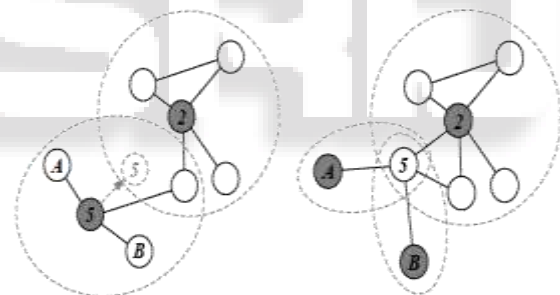


Fig. 2: If the clusterhead 5 moves into the cluster 2, then cluster 2 gives the role to 5 as clusterhead due to the higher ID.

2) Cluster Routing:

For the clustering routing there are two data structures used such as two-hop topology database and cluster adjacency table (CAT).

The information about neighbouring clusters is maintained by CAT. It stores the information like whether they are connected either bi-directionally or uni-directionally. Therefore we can call cluster as:

- Bi-directionally linked: If the two nodes in cluster is having the bi-directional link, or if there are two opposite uni-directional links at least among two nodes. This is showing in figure 2 below.
- Uni-directionally linked: it is simply means that there is just one uni-directional communication link between two nodes. Showing in figure 3..

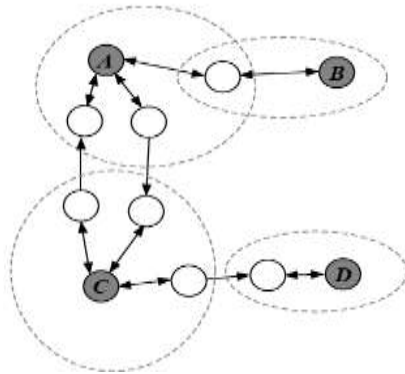


Fig. 3: Clusters A, B and A, C are bi-directionally linked, clusters C, D are unidirectionally linked.

The information which is received from the HELLO messages is used to build the two-hop topology database. This contains the nodes which are having at most two hops distance. First, it discovers a route from a source node S to a destination node D, afterwards it routes the packets.

a) Route discovery

The process of route discovery is done based on source routing methodology. In modified AODV protocol only clusterheads are flooded with route request package (RREQ). Gateway nodes receive the RREQs as well, however without broadcasting them. The received data is forwarded by them to next clusterhead. Using this approach the network traffic is reduced.

At the start node S is broadcasting the RREQ packet with the unique ID which is containing the destination's address, the neighbouring clusterhead(s) which includes the gateway nodes to reach them and the cluster address list which consists of the addresses of the clusterheads forming the route.

If the RREQ reaches the destination node D it contains the loose source route [S,C1,C2, . . . ,Ck,D] (figure 3). D sends a route reply message (RREP) back to S using the reversed loose source route [D,Ck, . . . ,C1, S]. Every time a cluster head receives this RREP it computes a strict source route, which then consists only of nodes that form the shortest path within each cluster (figure 4).

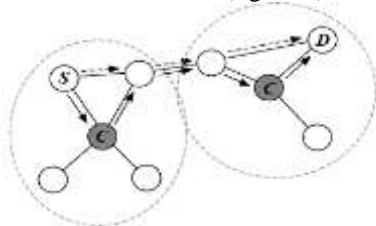


Fig. 4: The non dashed arrows are indicating the loose source route and dashed arrows indicating the strict source route from source node S to destination node D.

b) Routing and Updatons

Because of node movement, it may happen that nodes many be fails or disappear, in such case route repair functionality needs to maintained by routing protocol. In cluster based AODV we have added two such functions such as route maintenance and route shortening.

3) Route Maintenance

a) Local Repair:

If a connection between two nodes fails, the HTR is able to repair the route. Therefore one of the following nodes of the route has to be in the two-hop topology database of the

node, which discovered the broken link as showing in figure 4 below. If the node is unable to repair the route, the route has to be recalculated.

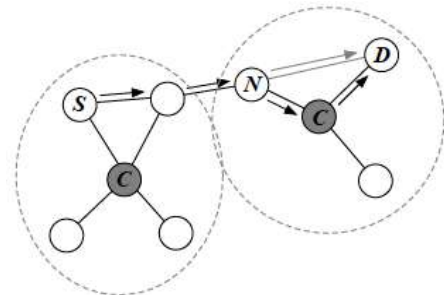


Fig. 5: The broken route between N and D (gray arrow) was repaired by using the cluster head

b) Route Shortening:

Sometimes a node may discover a connection between itself and another succeeding node of the route, which is not its direct successor or a connection between two following nodes, respectively. This can be done by examining the information stored in the two-hop topology database. If so, it shortens the route by excluding the redundant node(s) from the route (figure 6)

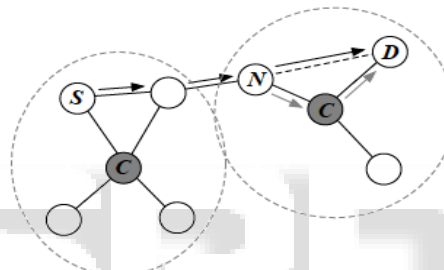


Fig. 6. Node N discovered a new connection between itself and D (dashed line) and shortened the route.

In both cases, Local Repair and Route Shortening, the destination node is informed about the changes by receiving a gratuitous route reply packet from the node, which performed the changes.

IV. PERFORMANCE EVALUATION

We evaluate the performance of existing approach AODV and the modified approach i.e. CAODV with different number of sensor nodes. In this experiment, total 6 network scenarios are prepared that vary according to number of sensor nodes. Simulations are carried using NS2. Following table shows the parameters and the value set for our simulation.

Number of Sensor Nodes	50, 100, 150, 200, 250, 300
Traffic Patterns	CBR
Network Size	1000 X 1000
Mobility Speed	1 m/s
Simulation Time	100 s
Transmission Packet Rate Time	10 m/s
Pause Time	1.0s
Routing Protocol	AODV/CAODV
MAC Protocol	802.11
Transmission Protocol	CBR

Table 1: Performance Evaluation

A. Average Energy Consumption

The percent of energy utilized by a node as compared to its initial energy state is called average energy consumption of a node. Initial energy allotted to each node is 100 joules. When the simulation process ends, the initial and final values of energy are calculated of the node. Following graph shows the comparison of average energy consumption for AODV and CAODV protocol. The unit for average energy consumption shown on the x axis is Joules.

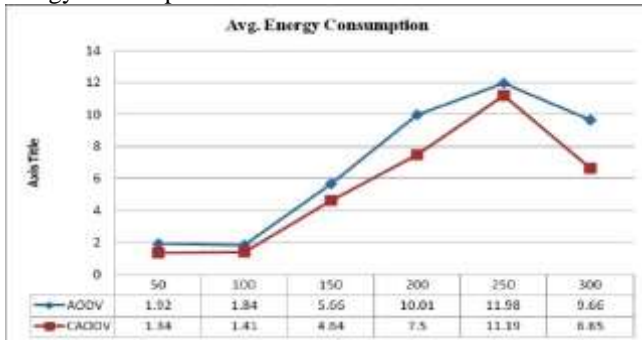


Fig. 7: Graph 1: Average Energy consumption comparison

B. End to end delay

This metrics calculates the time between the packet origination time at the source and the packet reaching time at the destination. Here if any data packet is lost or dropped during the transmission, then it will not consider for the same. Sometimes delay occurs because of discovery of route, queuing, intermediate link failure, packet retransmissions etc are considered while calculating the delay. Following graph shows the comparison of end to end delay for AODV and CAODV protocol. The unit for end to end delay shown on the x axis is seconds.

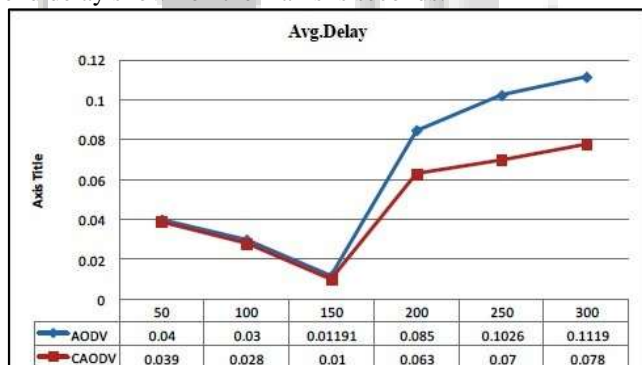


Fig. 8: Graph 2: end to end delay comparison

V. CONCLUSION

In our work we have implemented the CAODV protocol by modifying the AODV protocol. The routing overhead in AODV consumes bandwidth and node power. This drawback is overcome using clustering approach in our work. Further hybrid routing makes the data transfer faster and efficient. The simulation results show fair improvement in the average energy consumption and the delay response of the network.

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