ISSN No. 0976-5697

Volume 3, No. 3, May-June 2012

International Journal of Advanced Research in Computer Science

RESEARCH PAPER

Available Online at www.ijarcs.info

Analysis and Comparison of Various Clustering Techniques for Group Management in Mobile Ad Hoc Networks

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Abstract: Mobile Ad Hoc Networks provide an attracting feature for applications which require rapid exploitation and dynamic reconfiguration. Group management presents a hopeful hypothesis for dynamic, mobile networks by assembling the mobile nodes in order to meet the target functional and non-functional properties. For comprehensive understanding, taxonomy of various clustering techniques and routing protocols, their properties and design features is presented as an outline brief survey. Clustering in mobile ad hoc networks aims to achieve system scalability with cluster heads responsible for maintaining the group. Distributive Mobility Adaptive Clustering algorithm (DMAC) is used to group the mobile nodes and provide communication in the network. The existing DMAC algorithm does not address the issue of updating a node leaving a cluster. A new procedure is incorporated in the existing DMAC algorithm to overcome the drawback. Further, the performance of DMAC algorithm is compared with Lowest ID (LID) and Weighted Clustering Algorithm (WCA). The simulation analysis shows that DMAC outperforms the other two in terms of throughput, packet delivery fraction and normalized routing load. This analysis would be a great source of information for researches with a focus on clustering for group management in mobile ad hoc networks.

Keywords: Clustering, Cluster Heads, Group management, Mobile ad hoc networks, DMAC.

I. INTRODUCTION

Mobile ad hoc network is a collection of mobile nodes using wireless network to communicate with each other without any predefined or static infrastructure. MANETs are deployable as quickly as possible at low cost. This is because of the independent behavior of the network that does not rely on any static infrastructure. This flexibility gives MANET a striking feature for use in many applications such as military services, disaster relief, emergency operations, vehicular networks, casual meetings, maritime communications, campus network, and so on.

The development of various applications in wireless networks is quite complex due to frequent changes in the topology of the network. Moreover, the mobile nodes would be available in a larger geographic area having more than k-hop distance between the sender and the receiver. In order to reduce this complexity clustering technique are used to aggregate all the mobile nodes present in a particular region of the network into different groups known as clusters [1].

A network can be organized efficiently by aggregating all the mobile nodes into various clusters. By incorporating clustering techniques, a denser network appears transparent which eventually reduces the transmission overhead and the size of the routing table [2]. Moreover, implementing different clustering techniques improves the throughput, scalability, spatial reuse and power consumption.

II. RELATED WORK

Deploying wide range applications using wireless technologies has become quite common in our daily lives which has made human life smarter. These applications have become familiar with the use of many portable devices like laptops, mobile phones, tablets etc. Route discovery, establishment and maintenance are essential for routing in ad hoc networks. Broadly, routing protocols in Mobile ad hoc networks have been classified into the following three categories.

A. *Table Driven Routing Protocols:*

This category of protocols updates the routes periodically to the nodes available in the network. Every node uses a routing table to store the location information of other nodes in the network and this information is then used to transfer data among different nodes in the network. Hence, these protocols have lower latency as routes are maintained at all times. These are also known as proactive protocols. List of some Table Driven Routing Protocols are:

a. Dynamic Destination-Sequenced Distance-Vector Routing Protocol
b. Wireless Routing Protocol
c. Global State Routing
d. Fisheye State Routing
e. Hierarchical State Routing
f. Zone-based Hierarchical Link State Routing Protocol

g. Cluster head Gateway Switch Routing Protocol

B. On Demand Routing Protocols:

This category of routing protocols establishes routes only when they require to route data. The route discovery process has longer transmission delays compared to table driven protocols. They are also known as reactive protocols. Few on demand routing protocols are:

a. Cluster based Routing Protocol
b. Ad hoc On-demand Distance Vector Routing
c. Dynamic Source Routing Protocol
d. Temporally Ordered Routing Algorithm
e. Associability Based Routing
f. Signal Stability Routing

C. Hybrid Routing Protocols:

These hybrid routing protocols are the combination of both Table Based and On Demand Routing Protocols. List of Hybrid routing protocols are:

a. Zone Routing Protocol (ZRP)
b. Enhanced Interior Gateway Routing Protocol (EIGRP)
c. Zone-based Hierarchical Link State (ZHLS) Routing Protocol
d. Preferred link–based routing (PLBR) protocols
e. Optimized link state routing (OSLR) protocol.

III. MOTIVATION & CONTRIBUTIONS

Although there are several surveys existing on various clustering techniques and different routing protocols, they are mainly focused on simple mobile ad hoc networks. This paper proposes an extensive analysis of various clustering algorithms and cluster-based routing protocols suitable for group communication in mobile ad hoc networks. Group management presents a promising hypothesis to ease the development of distributed applications for dynamic, mobile networks. This enables to assemble mobile nodes into various clusters to communicate with each other and shall be a source of input for research scholars to build new and challenging projects in this field. Our primary goal is to provide useful taxonomy of various clustering techniques and routing protocols in Mobile Ad hoc Networks (MANET) and compare DMAC with LID and WCA clustering algorithms.

IV. CLUSTERING ALGORITHMS

List of clustering algorithms:

a. Lowest ID Clustering Algorithm(LIC)
b. Lowest ID and highest degree heuristics
c. Distributed clustering algorithm(DCA)
d. Distributed Mobility Adaptive Clustering Algorithm(DMAC)
e. Weighted Clustering Algorithm(WCA)
f. Max-Min d-cluster formation Algorithm
g. Highest Connectivity Clustering Algorithm
h. K-hop Connectivity ID Clustering Algorithm (K-CONID)
i. Adaptive Cluster Load balance method
j. Adaptive multi hop Clustering
k. Mobility based d-hop Clustering Algorithm
l. Least Cluster Change Algorithm (LCC)
m. 3-hop between Adjacent Clusters
n. Passive clustering
o. Load Balancing Clustering(LBC)
p. Clustering for energy conservation
q. Entropy- based Weighted Clustering Algorithm
r. Vote-based Clustering Algorithm
s. Weight Based Adaptive Clustering Algorithm(WBACA)

A. Lowest ID and highest degree heuristics:

Lowest ID and Highest degree are the two most popularly used clustering algorithms for mobile ad hoc networks to compare heuristic performances. These two algorithms make use of node ID and node degree for selecting the cluster head and every node should be aware of its 1-hop neighbor's ID and degree which is calculated in terms of the number of nodes connected to it.

In Lowest ID algorithm, each node is assigned a unique ID, and often broadcast their ID to their direct neighbors. Each node compares its own ID with ID's of its neighbors. A node which has lowest ID among the neighbor's becomes the cluster head.

The Highest degree algorithm is based on connectivity between a node and its 1-hop neighbors. Every node broadcasts its connectivity value to its neighbors and the node with highest connectivity value is selected as a cluster head.

Some drawbacks present in these algorithms are the frequent change of cluster heads. In the case of lowest-ID, a highly mobile node with lowest ID among its neighbors can be selected as cluster head causing frequent re-clustering and undesired cluster head changes. This can be reduced by selecting a long lasting cluster head which keeps the cluster size constant.

B. Distributed Mobility Adaptive Clustering Algorithm (DMAC):

DMAC is a distributive mobility adaptive clustering algorithm which is well suitable for managing highly mobile networks in which the node with the highest weight is selected as a cluster head.

DMAC overcomes a drawback that is found in most clustering algorithms, that is all the other existing algorithms assume that during the setup time (while they are being grouped into clusters) nodes do not move. In real ad hoc situations this assumption cannot be made due to constant mobility of nodes. Hence, DMAC is more suitable for MANET's as it has an important feature of node mobility even during cluster formation in the initial setup phase.

During the execution of this algorithm, it is expected that each node has a weight and ID, where the weight of a node represents node mobility parameters. If a node has highest weight among its 1-hop neighbors then it becomes a cluster head, else it joins the cluster as a cluster member. DMAC is a message driven algorithm; it uses two types of messages. If a node joins a cluster it sends a 'Join message' to the cluster head and if it becomes a cluster head it sends a 'CH message' to all its neighboring nodes [4].

DMAC implements five procedures at each node; they are: an init routine, a link failure procedure, a new link procedure, a procedure on receiving a CH message, and a procedure on receiving a Join message [1]. When a cluster head receives a 'Join' message from an ordinary node, it indicates that it is joining its cluster. If an ordinary node receives a Join message from its cluster head that indicates this cluster head is giving up its role and it becomes the cluster head. On receiving 'CH' message a node checks if it will affiliate or not to the sending cluster head.

The adaptation feature of the clustering algorithm is made possible by allowing each node react to the failure or presence of a link with another node [1]. If there is a link failure between a cluster head and one of its node members, then membership of the node to the cluster is removed, and this node must define its new role. A node detects the presence of a new neighbor with the help of new link. In this case, the node checks whether the new node has larger weight than its current cluster head. If the new node has more weight than the cluster head, then the cluster head gives up its role to the new node and joins as a cluster member.

A major drawback of DMAC is, if the node density increases then cluster heads may become overloaded as they have to maintain the details of the data transfer of every member node in the cluster. A solution to this problem is, to limit the number of member nodes in a cluster and to split existing cluster into several smaller manageable clusters.

C. Weighted Clustering Algorithm (WCA):

WCA is a weight based distributed clustering algorithm. It selects a cluster head based on the parameters such as number of nodes it can handle, its mobility pattern, transmission power and the battery power. The cluster head selection procedure is invoked based on node mobility and when the current dominant set is incapable of covering all the nodes in the cluster. To ensure that the cluster heads are not over-loaded, a pre-defined threshold is used which indicates the number of nodes each cluster head can maintain. In WCA the node with the minimum weight is selected as cluster head [1].

The distance between members of a cluster head, must be less than or equal to the transmission range between them. No two cluster heads can be immediate neighbors. A cluster head consumes more battery power than an ordinary node because of its transmission overhead in transmitting the data and maintaining the cluster.

D. K-hop Connectivity ID Clustering Algorithm (K-CONID):

K-CONID is a combination of two clustering algorithms: the Lowest ID and highest degree heuristics. To select cluster heads, connectivity is considered as first criteria and lowest ID as the second. Using only node connectivity as criteria causes many links between nodes and using only lower ID criterion generates more clusters than necessary. So, both the criteria are considered in forming a cluster.

In K-CONID approach a cluster is formed with the nodes that are at the distance of at most k-hops from the cluster head. Initially a node starts the flooding process and sends the clustering request to all other nodes which are at a distance of k-hops. In the highest degree heuristic, node degree only measures connectivity for 1-hop clusters [3].

K-CONID simplifies connectivity for a k-hop neighborhood. When k=1 connectivity is same as node degree. Each node in the network has an ID and a connectivity value (d). A node is selected as a cluster head if it has the highest connectivity. In case of equal connectivity, the node with lowest ID is selected as a cluster head.

V. CLUSTERING PROTOCOLS

The maintenance of mobile ad hoc networks becomes more manageable by dividing the network into various clusters. Cluster-based routing is an appropriate scheme for developing efficient routing algorithms in MANETS; it can make a dynamic topology appear less dynamic. In order to implement a hybrid routing scheme, efficient clustering algorithms must be designed. Routing is based on the implementation of a hierarchical approach in which the network is structured into subsets of nodes, known as clusters and this topology reduces the network traffic, because a node only needs to have knowledge of the routing information within its cluster and not of the entire network. Few examples of cluster based routing protocols are CEDAR, CGSR, CBRP etc., [5]

A. Core Extraction Distributed Ad hoc Routing (CEDAR):

CEDAR is a QoS routing algorithm of cluster-based structure. It reacts quickly and efficiently to the dynamic network. It produces good stable acceptable routes with a high probability. CEDAR has three key components, Core Extraction, Link state propagation and Route Computation.

a. Core Extraction:

CEDAR uses core based infrastructure for QoS routing. Every node in the ad hoc network performs route computations and topology management. The core of the network is formed by distributed and dynamic set of hosts. Each core host maintains the local topology of the hosts in its domain, and also performs route computation on behalf of these hosts.

b. Link state propagation:

The bandwidth availability information of stable links in the core graph was achieved by QoS routing in CEDAR. The information about stable high bandwidth links can be made known to nodes far away in the network, while information about dynamic links or low bandwidth links should remain local. The non-local information over core nodes can be propagated by using slow-moving increase waves and fast-moving decrease waves which denote corresponding changes in available bandwidths on links.

c. Route Computation:

Initially route computation establishes a core path which provides the directionality of the route from dominator of the source to that of the destination. CEDAR iteratively tries to find a partial route from source to the domain of the farthest possible node in the core path (which then becomes the source for the next iteration) [6] satisfying the requested bandwidth, using only local information. The route is computed by using the core path as the guideline and the computed route is a shortest-widest path (path with the least number of hops).

CEDAR does not require high maintenance overhead even for highly dynamic networks. It can support all the requirements of QoS in the real time environment. Its disadvantage is if the network size increases then routing update sharply increases which leads to low network scalability and its performance becomes worse in terms of bandwidth [5].

B. Cluster head Gateway Switch Routing (CGSR):

CGSR is a clustered multi-hop mobile wireless network with several heuristic routing schemes. The mobile nodes are grouped into clusters and cluster head is elected. If a node is in the communication range of two or more clusters it is called gateway node. In a dynamic network cluster head scheme can cause performance ruin due to frequent cluster head elections, so CGSR uses Least Cluster Change (LCC) algorithm. In LCC, when two cluster heads come within direct transmission range of each other, then one cluster head must give up its role. This results in frequent cluster head changes within the network.

CGSR combines hierarchical routing mechanism and is more effective than flat routing protocols. CGSR uses DSDV routing algorithm fundamentally and it also modifies DSDV by using hierarchical cluster head to gateway routing approach to route traffic flow from source node to the destination node. Initially, a data packet sent by the sender node is routed to its cluster head and then it is forwarded to another cluster head through the gateway node. Finally, the data packet is then transmitted to the destination node. In this approach, each node maintains "cluster member table" in which the destination cluster head is stored for each mobile node in the network. Each node also maintains routing table in which source node determines the next hop to reach the destination node. The cluster member tables are updated by the nodes upon reception of such a table from the neighbor nodes.

The main drawback of CGSR is slow data transmissions due to the frequent change of cluster heads in the network and the nodes will be busy in selecting another cluster head instead of transmitting data [5].

C. Cluster Based Routing Protocol (CBRP):

CBRP (Cluster Based Routing Protocol) [5] is a reactive routing protocol, and it is similar to DSR. Cluster head selection, Cluster formation, data transmission are three techniques in CBRP. Each node maintains neighbor table, and bidirectional links within 2 hops as database. Lowest ID algorithm is used to elect cluster head in CBRP. All the mobile nodes in the wireless networks are partitioned into various clusters and a cluster head is elected for each and every cluster for routing process. In CBRP cluster head manages all cluster members and finds adjacent clusters through the gateway node for routing. Each node uses "neighbor table" in which neighbor node's information like node ID, their role in the cluster i.e., cluster member or cluster head and the status of the link to that node (uni/bi-directional) is maintained. Further, the neighbor table is maintained by broadcasting HELLO messages which contains information about node state, its neighbor table and its cluster adjacency table periodically.

CBRP uses two data structures to support the routing process, the Cluster Adjacency Table (CAT) and the two-hop topology database [7]. The CAT stores information about the bi-directional and uni-directional links of neighboring clusters. The two-hop topology database is built from the information received by HELLO messages [7]. CBRP performs routing process in two steps. Initially Route Discovery is done by using source routing, the sender node broadcasts a route request package (RREQ) with unique ID containing the destination node's address, the neighboring cluster head (including the gateway nodes) and the cluster address list which consists of the addresses of the cluster heads forming the route.

During route discovery this protocol minimizes flooding traffic and speeds up the process. This protocol has two new features like route shortening and local repair which are maintained by 2-hop topology. Route shortening feature shortens the source route of the data packet that is being forwarded to the destination and updates the better route. Local repair patches a broken source route and avoids route rediscovery.

CBRP has some limitations and problems. If the network size and the number of clusters in the network increases the overhead per packet increases due to source routing and the transmission time also increases. The maintenance of uni-directional links is difficult in CBRP, because for a network with 802.11 link layer technologies these uni-directional links are not supported; it supports only bi-directional links. So a node would be able to send its acknowledgement back to the sender by using multiple hops. CBRP has small routing control overhead, less congestion control when compared to other existing algorithms.

D. Hybrid Cluster Routing Protocol (HCR):

In, HCR (Hybrid Cluster Routing Protocol) [8] all the mobile nodes are structured into a hierarchical composition of clusters using a stable distributive clustering algorithm. Each cluster comprise of a cluster head, gateway nodes and ordinary nodes. The cluster head is in charge of updating the global topology information and membership information of nodes present in its cluster. HCR protocol divides network into two levels. Inter-cluster routing (routes each packet to nodes between clusters) and Intra cluster routing (routes packet within a cluster node by node).

Route discovery and Route maintenance are the two procedures in HCR routing. When a source node sends data packet to the destination, it checks the routing table for an active route to the destination. If the source node does not find any active route to the destination then it performs route discovery procedure to acquire a route to the destination. Route discovery procedure in HCR performs inter-cluster route discovery and intra-cluster route discovery. Route maintenance delivers the data packets from source to the destination in the case of changes in cluster-level routing information. HCR proposes a scheme named 'global repair' to recover such data packets and update invalid routing information.

HCR improves the performance of routing with better scalability, robustness and adaptability to denser and dynamic networks when compared with other routing protocols such as AODV, DSR, and CBRP. HCR manages better stability among routing overhead and latency delay [8].

E. Cluster based Inter-Domain Routing (CIDR):

CIDR (Cluster based Inter-Domain Routing) is the inter domain routing protocol like BGP, a Border Gateway Protocol. But BGP is not applicable to MANETs because its design is based on static internet. It does not dynamically discover group members and also cannot scale to mobility. CIDR protocol obtains efficient communication among MANETs and achieves scalability in large networks by using clustering techniques. The cluster head in the subnet acts as local DNS for own cluster and also neighboring clusters. It generates clusters by group affinity. In each domain, distributed clustering algorithm discovers set of "travelling companions" [9] (group in which nodes stick together for some time). The packets to isolated nodes are routed using cluster-head broadcast routes, and packets to local destination are routed using the local routing algorithm.

The three key design challenges in the inter-domain routing among MANETs are dynamic topological changes, membership management and heterogeneous intra-domain routing.

a. Network Topology Dynamics:

MANETs are different from wired networks; the networked devices are focused to their mobility patterns and can split from the current routing domain and merge with a different domain. Firstly, the network dynamics causes problem in sustaining routing loops in path vector based routing like BGP. This problem can be circumvented by reassigning new IDs after splitting the domains. Secondly, it is not a trivial task to detect the "domain split" (one part of the network is unable to connect to other part of the network) in an efficient way. To detect these splits, error notifications in routing protocols may be applied.

b. Membership Management:

In Border Gateway protocol (BGP) each domain has its own class of hosts with IP address with a same prefix. The domain splits cannot use the original prefix because it causes conflict in the routing table establishment. To overcome this problem, CIDR protocol allows the gateways in the partitioned domain to promote membership information in the form of membership digest, which contains both the IP address prefix and the member node's IDs.

c. Heterogeneous Intra-domain Routing:

MANET's have different intra-domain routing protocols. The assumptions of BGP are Internal Gateway Detection, in which the internal gateways within the same domain can detect the presence of each other and Internal Network Knowledge, in which the gateways know the reachable destinations and the internal routes to the destinations within the same domain.

The idea of Cluster based networking is to form self-organizing clusters and a routing backbone among cluster heads. Cluster based networks can achieve a scalable routing in a single domain. CIDR has achieved more scalability in the large networks, the robustness to mobility and the independency of underlying intra-domain routing protocols.

F. On-demand Clustering Routing Protocol (OCRP):

OCRP constructs a set of virtual clusters based on the data carried by data packets, so that the clustering becomes a hierarchy of network communication and eliminates the time consumed for clustering before data transmission [10]. OCRP includes two fields on MAC packet, clustering state and ID of the node. Every node abstracts the clustering state from the MAC packet to reduce time consuming and communication overhead for clustering. OCRP protocol overcomes large overhead produced by traditional hierarchical approaches. It combines clustering phase with routing phase by sharing the same algorithm by saving a large amount of control overhead for routing.

OCRP is an on-demand clustering protocol mainly based on 2-hop structure. The properties of 2-hop clustering are, if the cluster head is at the center of a cluster, it can communicate with any node with a single hop. Cluster heads are not directly linked and any two nodes in a cluster are a maximum of 2 hops away. The main advantages of OCRP include:

a) Clustering without explicit and special packets.
b) Clustering without explicit phase that is usually before data transmission.
c) No clustering rule can be applied for electing cluster head such as LID algorithm.
d) No need of collecting complete neighbor information.

OCRP eliminates the clustering overhead and manages the routing overhead more effectively than AODV protocol and it can with stand for large ad hoc networks.

G. Secure Clustering Scheme Protocol:

In Secure Clustering Scheme Protocol [11] all the nodes within the network are grouped into several clusters. Trust values between the nodes can be analyzed such that node with more trust connections can be elected as cluster head and the nodes which have trust connection with cluster head are called core nodes. Cluster head and core nodes together form service group. Each node will distribute a secret share and the secret share can also be authenticated by the node itself.

This protocol has forward secrecy and backward secrecy. Man in the middle attack can be avoided by generating keys of nodes and cluster among service group members. This secure clustering scheme protocol is safer and more efficient.

H. Multi-hop Clustering Protocol:

Multi-hop clustering protocol [12] produces small number of multi-hop clusters with large size. It reduces cluster overhead and extends cluster head lifetime. This protocol achieves scalability and efficient routing**.** 3hBAC (3-hop between Adjacent Cluster heads) forms 1-hop non overlapping cluster structure with 3-hops between neighboring CHs.

Multi-hop clustering protocol is more feasible for some dense scenarios, where mobile nodes are highly connected [12]. This protocol forms a multi-hop cluster structure with 6 hops between neighboring CHs. The cluster size performance is better than 3hBAC, and it can maintain clusters with relatively large size in cluster maintenance.

I. Two-Level Cluster based Routing Protocol:

Two –Level Cluster based Routing Protocol [13] is based on parameterized hexagon like topology model, traffic model and mobility model. Routing protocols in MANETs can employ two types of routing structure: flat or hierarchical and two different groups proactive and reactive. Hierarchical routing protocols attain much less routing overhead and provide better scalability in large scale MANETS. And these two groups of protocols can be summarized as generic proactive routing protocol in which route is generally available when needed and the generic reactive routing protocol utilizes a broadcast route discovery mechanism.

J. Dynamic Clustering Routing Protocol:

Dynamic Clustering Routing Protocol [14] is proposed to solve the expansibility problem of traditional flat routing protocols. This protocol creates clusters dynamically to solve the conflict between expansibility of flat routing protocols and clustering overhead of clustering routing protocols. Energy consumption model has been improved with dynamic clustering routing protocol.

This mechanism has high routing efficiency, good expansibility and adaptive control action and it runs effectively with best effort traffic.

K. Virtual Structure Routing Protocol:

Virtual Structure Routing (VSR) is a new routing protocol based on virtual topology. It includes a backbone and clusters. The backbone is used to collect traffic control and to reduce overhead for route discovery. Clusters are used by the VSR to define a route as a list of cluster IDs. Hence routes are more robust, and the cluster topology is more stable than physical topology. VSR combines the properties of both intra-cluster routing and inter-cluster routing. Finally, all the routes are computed dynamically.

The goals of all these protocols include efficiency, scalability, providing more security and safe data transmissions, reduce traffic overload, prevents loops, avoid data collisions etc., Due to limited resources such as network bandwidth, memory capacity, and battery power, efficiency of routing schemes in ad hoc mobile networks becomes more important and challenging.[15]

VI. TAXANOMY OF CLUSTER ROUTING PROTOCOLS

Comparing and analyzing cluster based routing protocols is essential as comparisons help researchers and designers to understand the characteristics and features of different cluster based routing protocols. Therefore, we present characteristics of the protocols that are mainly related to the information which is exploited for MANETS.

Cluster based routing protocols have more advantages in ad hoc networks when compared to flat network topology. Clustering offers an improved control and reduced number of messages that propagate through the network in order to achieve a sensing task.

CBRP has better performance than AODV because of its clustered architecture. In CBRP header node maintains the information of its domain nodes and interconnects with other header nodes via gateway or distributed gateway nodes. Thus the routing overload is mainly suffered by the header and the system is more extensible than AODV. CBRP has more routing overload and system congestion probability than AODV [16]. When compared with other routing algorithms CBRP has small routing control overhead and low network congestion control [5].

HCR has improved scalability, robustness and adaptability under denser and dynamic networks when compared with other routing protocols such as AODV, DSR, and CBRP. The performance of HCR is suitable for a larger network, because of its reduced routing overhead, efficient route discovery schemes and global repair scheme. AODV has vaguely lower delay than DSR, CBRP and HCR routing protocols, due to increased connections in the network. The routing overhead of HCR is lesser than that of generic on demand routing protocol.

OCRP manages routing overhead more efficiently than AODV and it is adaptive for denser networks. OCRP has better feasibility in decreasing routing overhead than AODV routing protocol. If the number of nodes increases, then the forwarding packets that have been forwarded in OCRP are lesser than that of AODV and keep increasing slowly [10].

Cluster Based Location Aware Routing Protocol for Large scale Heterogeneous MANET (CBLARHM) has better performance than CBRP and VSR (Virtual Structure Routing). VSR has large routing packets but fewer control packets than CBRP, so the delay is shorter than VSR. The Control overhead of CBLARHM is lower than that of CBRP and VSR. The larger the size of the network, the overhead of CBLARHM is lower relative to CBRP and VSR.

A. Quality of Service:

MANET is a temporary network formed by a number of mobile nodes without any centralized administration. Because of its dynamic nature and random topology, MANET's routing protocol design is different from other networks. The dynamic nature of these ad hoc networks provides support of Quality of Service (QoS) a challenging and difficult task where nodes may leave and join the network or move around at any time. When QoS is considered, some protocols may be inadequate or unfeasible due to the lack of resources, excessive computation overhead, and the lack of knowledge about the global network. Many techniques implement clustering solutions for scalability, load balancing and fault tolerance purposes where they can meet QoS requirements partially such as availability, timeliness, security and trust of the applications.

The protocols improve the performance of MANET's by increasing the route lifetime to improve the network stability and developing a reliable cluster based routing protocol to support the QoS requirements. . MQCAP is an efficient multicast routing protocol based on clustering with QoS constraints, such as delay, bandwidth and delay jitter. MQCAP can maximize the lifetime of QoS multicast routing for mobile ad hoc networks. MQCAP is an example for QoS cluster based routing protocol in MANETs.

B. Energy Efficiency:

MANETS are a set of nodes that form a temporary network without any centralized administration. Any form of infrastructure and nodes are typically powered by batteries with limited energy supply. The reduction of energy losses depends upon a number of parameters and variables such as nominal circuit voltage, the installed transformer capacity, the number of transformation points, the load level etc., Therefore, the given energy constraints play an important role in MANETS. They maximize the lifetime of its nodes and thereby of the network itself. Multilayer cluster based Energy Efficient Cluster Head Communication Protocol (MEECHCP) is an example of energy efficient cluster based routing protocol.

C. Location for Clustering Protocols:

The location based routing protocol uses the location information of mobile nodes to limit routing space into a smaller range that reduces routing overhead and the broadcast messages. A location aided cluster based routing protocol called Core Location-Aided Cluster based Routing Protocol (CLACR) reduces routing overhead, instead of flooding route request packets in the entire network CLACR uses Dijkstra's algorithm, where only cluster heads, source and destination nodes participate in routing procedure which reduces the routing overhead.

VII. ENHANCED DMAC ALGORITHM

In the existing DMAC algorithm, if any node leaves a cluster, it is not updated in either the neighbor node's routing table or in cluster head's routing table. This creates routing overhead in routing the data packets to the node which is not present in the cluster. In order to overcome this drawback, a new procedure called "Leave message" has been incorporated into DMAC clustering algorithm to make it more effective. According to this procedure, if a node is willing to leave a cluster it should intimate to its cluster head by sending "Leave message".

VIII. COMPARISON OF DMAC WITH LOWEST-ID AND WEIGHTED CLUSTERING ALGORITHM

Distributed Mobility Adaptive Clustering Algorithm (DMAC) is compared with Lowest ID and Weighted Clustering Algorithm (WCA) on various QoS parameters like Packet Delivery Fraction (PDF), Throughput, Normalized Routing Load and Mobility.

A. Packet Delivery Fraction (PDF) Comparisons:

The ratio of the data packets delivered to the destination node to those generated by the CBR (Continuous Bit Rate) sources is known as packet delivery fraction.

When the number of nodes in the network is high, the topology is dense and the connectivity is rich. The packet delivery fraction for DMAC, WCA and Lowest ID algorithms decreases as the number of nodes increases.

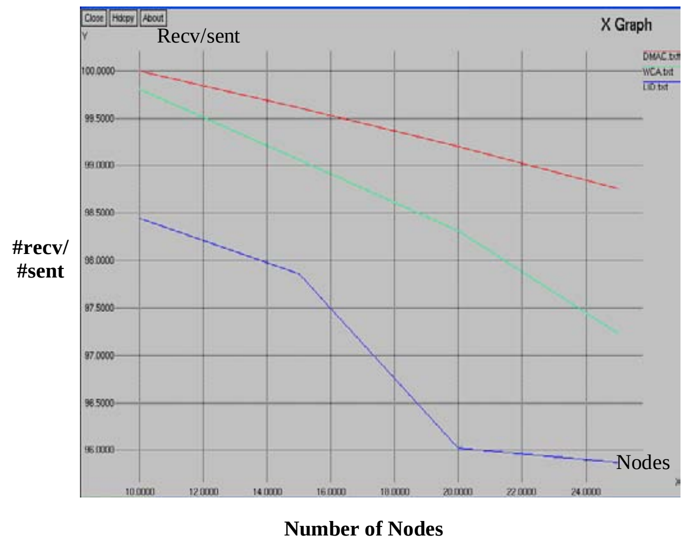

Figure 1: Effect of increase in the number of nodes on PDF(Packet Delivery Fraction)

From the figure1it is observed that as the number of nodes increases in the network the effect of packet delivery fraction on all the three clustering algorithms decreases. The performance of DMAC overtakes Lowest ID clustering algorithm and WCA.

B. Mobility Comparisons:

Mobility shows how fast the nodes are moving. When the nodes move at high speeds, all the clustering algorithms suffer a decrease in throughput as shown in figure 2. Higher speeds of the mobile nodes cause frequent link changes and connection failures.

If the node mobility increases then the routing overhead also increases and the packets that cannot be delivered by the MAC layer are dropped.

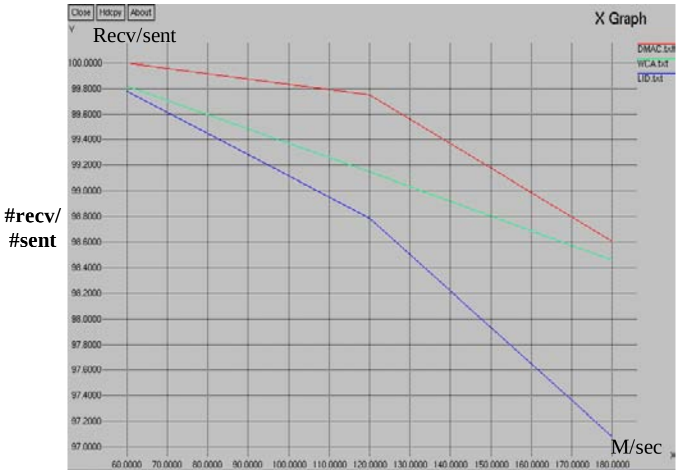

Figure 2: Effect of increase in mobility on PDF (Packet Delivery Fraction)

From the figure 2, it is observed that as the mobility increases from 60,120 to 180m/sec for a scenario with 10 nodes, there is decrease in the packet delivery fraction. DMAC outperforms the other two clustering algorithms WCA and Lowest ID.

C. Throughput Comparisions:

The ratio of the data packets delivered to the total number of packets sent is known as throughput.

The throughput of DMAC algorithm is compared with the LID and WCA algorithms in both the cases such as; increase in the number of nodes present in the network and also increase in the mobility of the nodes.

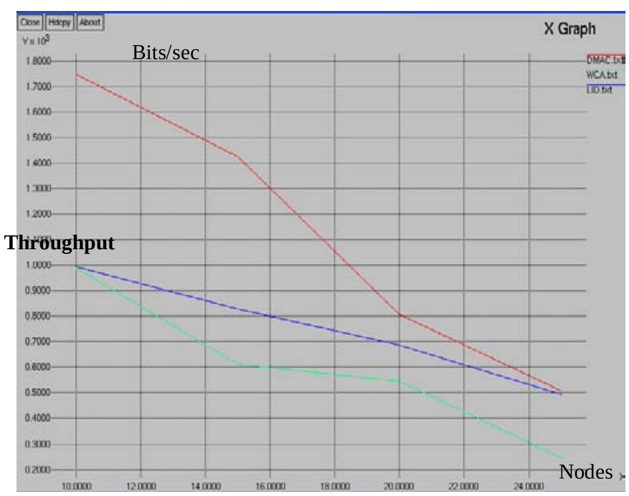

Figure 3: Effect of increase in the number of nodes on Throughput

From the figure 3 it is observed that, as the number of nodes increases in the network the effect of throughput on all the three clustering algorithms decreases. DMAC outperforms the other two clustering algorithms.

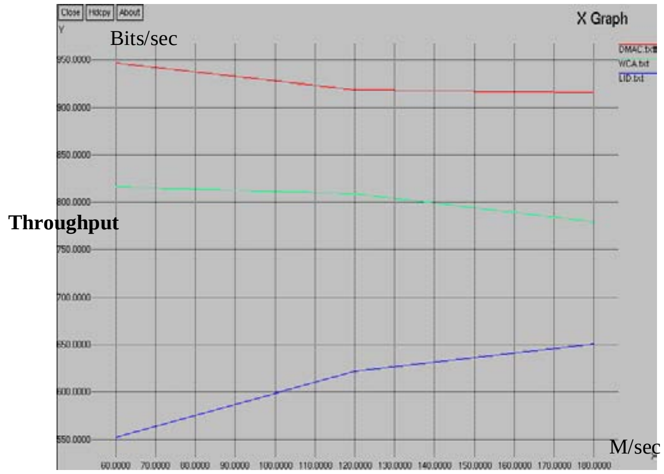

Figure 4: Effect of increase in mobility on Throughput

From the figure 4 it is observed that as the speed of the mobile nodes increases from 60,120 to 180m/sec then DMAC clustering algorithm executes higher performance than the other two clustering algorithms.

D. Normalized Routing Load Comparisons:

The number of routing packets transmitted per data packet delivered at the destination is known as Routing Load.

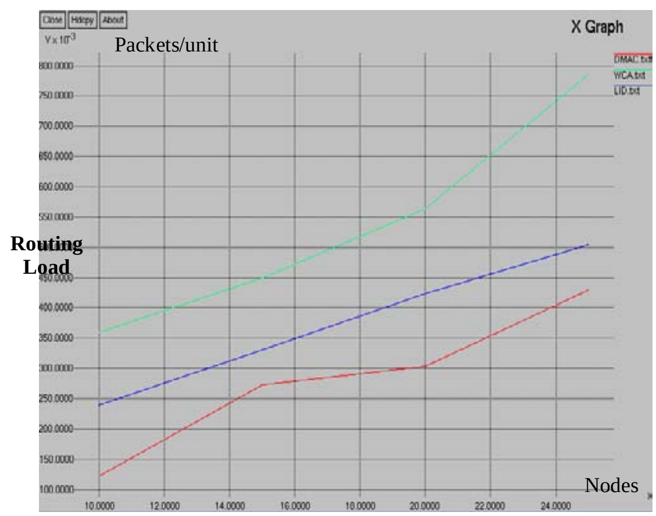

Figure 5: Effect of increase in the number of nodes on Normalized Routing Load

Figure 5 shows that, as the number of nodes in the network increases the effect of Normalized Routing Load also increases for all the three clustering algorithms. DMAC algorithm is more efficient compared to Lowest ID and WCA clustering algorithms.

From the figure 6 it is observed that the as the number of packets increases from 10,20 to 30 packets/unit the routing load for all the three clustering algorithms increases. DMAC clustering algorithm exhibits better performance than Lowest ID and WCA.

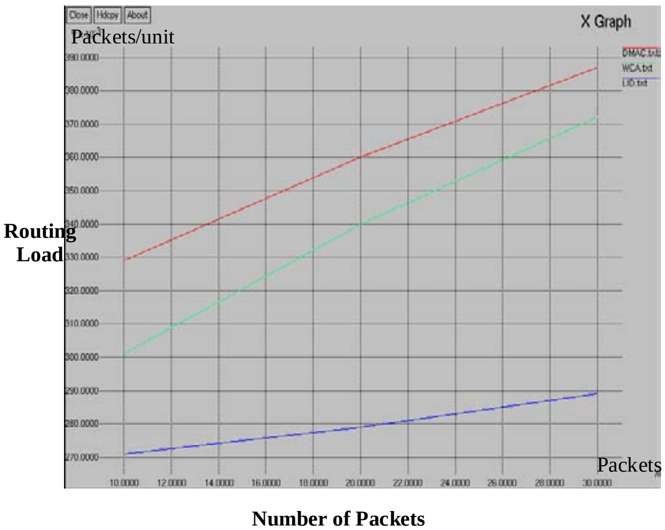

Figure 6: Effect of increase in packets on Normalized Routing Load

From figure 6 after incorporating a new procedure called "Leave message" in DMAC algorithm the routing load decreases. Whenever any cluster member is willing to leave a cluster, it should intimate to the cluster head by sending "Leave message", this reduces the packet failures during the transmission of data packets from source to the destination. Upon execution of this new procedure in the DMAC algorithm achieves reliablity and saves battery power.

Figure 7 shows the efficiency of the DMAC algorithm before and after incorporating the "Leave messages". The routing load increases with the increase in the number of nodes, and DMAC algorithm without leave messages have more routing load which leads to more packet failures.

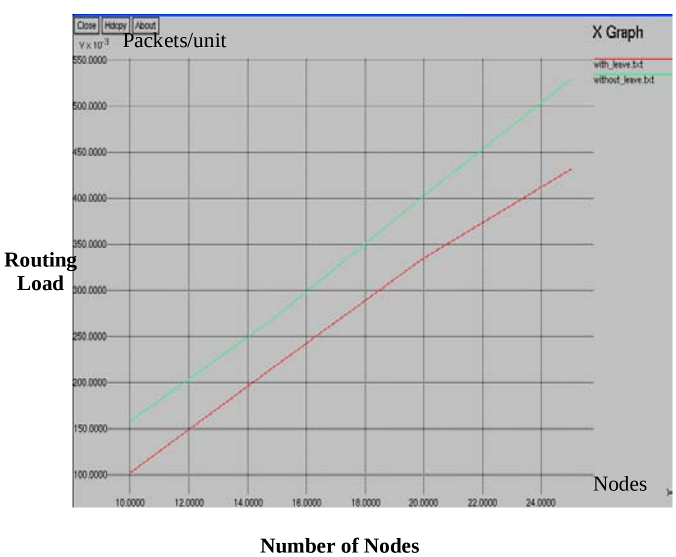

Figure 7: Effect of Normalized Routing Load on DMAC algorithm with and without Leave message

From the figure 7 it is observed that after incorporating "Leave Messages" in the DMAC clustering algorithm efficiency is increased.

Comparision of DMAC, Lowest ID and WCA clustering algorithms in terms of parameters such as packet delivery fraction, throughput, routing load and mobility, shows that DMAC has more efficiency and performs better than the other two algorithms.

IX. PERFORMANCE CRITERIA

A number of cluster based routing protocols are anticipated for MANETS to meet specific QoS requirements. Performance evaluation is based on packets delivered, end to end delay and routing load for a given traffic and mobility model. The performance of cluster based routing protocols can be evaluated based on number of hops per route, traffic received and sent, route discovery time, total route requests sent, total route replies received, control traffic received and sent, data traffic received and sent, retransmission attempts, average power, throughput, bandwidth, routing overhead, congestion control, power control, traffic control and resource utilization and so on. A minimum spanning tree is constructed on the network and on the cluster in which each node requests to discover its neighbors and the identity of its neighbor clusters. Global knowledge is not required to make the spanning tree. The cluster head overload can be reduced by constructing minimum spanning tree in the network.

X. CONCLUSION

MANET consists of a collection of mobile nodes with dynamic topology. This atmosphere increases a difficulty in offering services like routing a data packet, tracing the mobility of nodes, etc. General solution to solve this problem is to assemble all these mobile nodes into different groups by partitioning the network into various clusters. Clustering can efficiently support a wide variety of applications even with higher node density. A new procedure with leave message has been incorporated in the existing DMAC clustering algorithm to achieve better performance in clustering the mobile nodes in the network. The performance of DMAC is compared with the other clustering algorithms with parameters such as packet delivery ratio(pdf), routing load, throughput and efficiency as the speed and number of the mobile nodes in a cluster increases.

XI. REFERENCES

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