A Survey of Multicast Routing Protocols in MANET

Ganesh Kumar Wadhwani*
Neeraj Mishra**

Abstract

Multicasting is a technique in which a sender's message is forwarded to a group of receivers. Conventional wired multicast routing protocols do not perform well in mobile ad hoc wireless network (MANET) because of the dynamic nature of the network topology. Apart from mobility aspect there is bandwidth restriction also which must be addressed by the multicasting protocol for the MANET. In this paper, we give a survey of classification of multicast routing protocol and associated protocols. In the end, a comparison is also made among different classes of multicast routing.

Keywords: Multicast routing, mobile ad hoc network, tree based protocol, mesh based protocol, source-initiated multicast, receiver initiated multicast, soft state, hard state

I. Introduction

MANET is a collection of autonomous mobile nodes communicating with each other without a fixed infrastructure. MANET find applications in areas where setting up and maintaining a communication infrastructure may be difficult or costly like emergency search and rescue operation, law enforcement and warfare situations.

Multicasting is a technique for data routing in networks that allows the same message is forwarded to a group of destinations simultaneously. Multicasting is intended for group oriented computing like audio/video conferencing, collaborative works, etc. Multicasting is an essential technology to efficiently support one to many or many to many applications. Multicast routing has attracted a lot of attention in the past decade, due to it allows a source to send information to multiple destinations concurrently. Multicasting is the transmission of packets to a group of zero or more hosts called multicast group that is identified by a single destination address. A multicast group is a set of network clients and servers interested in sharing a specific set of data. A typical example of multicast groups is a commander and his soldiers in a battlefield. There are other examples in which multicast groups need to be established. Typically, the membership of a host group is dynamic: that is, the hosts may join and leave groups at any time. There is no restriction on the location or number of members in a host group. A host may be a member of more than one group at a time. A host does not have to be a member of a group to send packets to it. A multicast protocol has the objective of connecting members of the multicast group in an optimal way, by reducing the amount of bandwidth necessary but also considering other issues such as communication delays and reliability [1].

Ganesh Kumar Wadhwani*
Computer Science,
IITM

Neeraj Mishra**
Computer Science,
IITM

In MANET Multicast routing plays an important role in ad hoc wireless networks to provide communication among nodes which are highly dynamic in terms of their location. It is advantageous to use multicast rather than multiple unicast especially in the ad hoc environment where bandwidth is an issue. Conventional wired network multicast routing protocols such as DVMRP, MOSP, CBT and PIM don't perform well in MANET because of the dynamic nature of the network topology. The dynamically changing topology, coupled with relatively low bandwidth and less reliable wireless links, causes long convergence times and may give rise to formation of transient routing loops that rapidly consume the already limited bandwidth.

II. Multicast Routing Classification

One of the most popular methods to classify multicast routing protocols for MANETs is based on how distribution paths among group members are

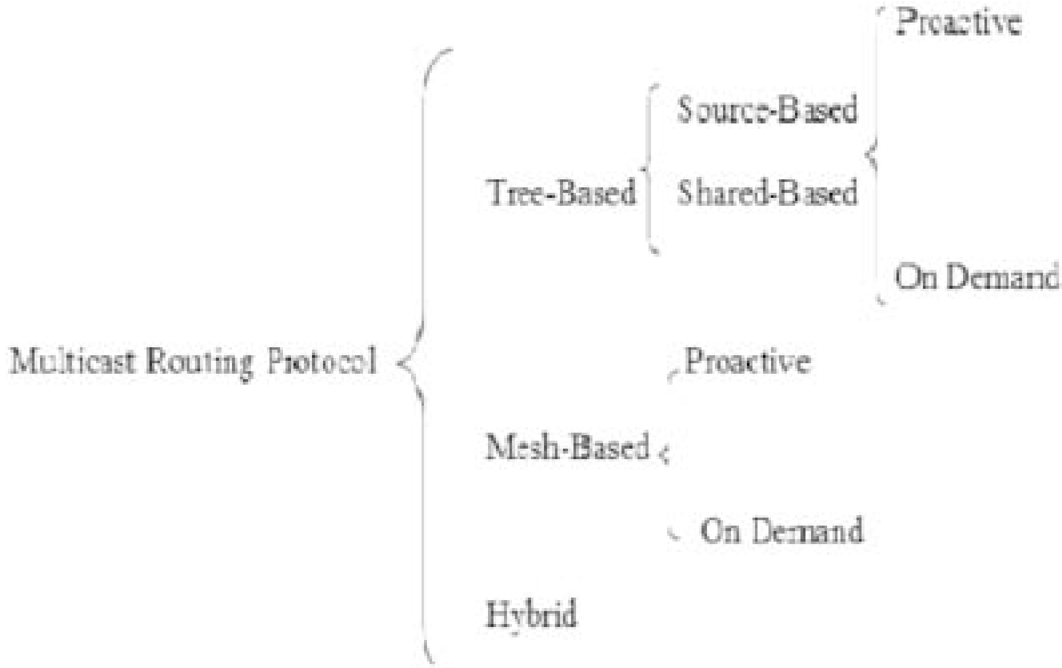

Figure I: Classification of Multicast Routing Protocols

constructed (the underlying routing structure). According to this method, existing multicast routing approaches for MANETs can be divided into tree based multicast protocols, mesh based multicast protocols and hybrid multicast protocols.

In tree-based protocols, there is only one path between a source-receiver pair. It is efficient but main drawback of these protocols is that they are not robust enough to operate in highly mobile environment. [2]

Depending on the number of trees per multicast group, tree based multicast can be further classified as source based multicast tree and group shared multicast tree. In source tree based multicast protocols, the tree is rooted at the source, whereas in shared-tree-based multicast protocols, a single tree is shared by all the sources within the multicast group and is rooted at a node referred to as the core node. The source tree based multicast perform better than the shared tree based protocol at heavy load because of efficient traffic distribution, But the latter type of protocol are more scalable. The main problem in a shared tree based multicast protocol is that it heavily depends on the core node, and hence, a single point failure at the core node affects the performance of the multicast protocol.

Some of the tree based multicast routing protocols are, bandwidth efficient multicast routing protocol (BEMRP) [3], multicast zone routing protocol (MZRP) [4], multicast core extraction distributed ad hoc routing protocol (MCEDAR) [5], differential destination based multicast protocol (DDM) [6], ad hoc multicast routing protocol utilizing increasing id numbers (AMRIS) [7], and ad hoc multicast routing protocol (AMRoute) [8].

Bandwidth-Efficient Multicast Routing Protocol (BEMRP)

It tries to find the nearest forwarding nodes, rather than the shortest path between source and receiver. Hence, it reduces the number of data packet transmissions. To maintain the multicast tree, it uses the hard state approach in which control packets are transmitted (to maintain the routes) only when a link breaks, resulting in lower control overhead, but at the cost of a low packet delivery ration. In BEMRP, the receiver initiates the multicast tree construction. When a receiver wants to join the group, it initiates flooding of Join control packets the existing members of the multicast tree, on receiving these packets, respond with Reply packets. When many such Reply packet reach the requesting node, it chooses one of them and sends a Reserve packet on the path taken by the chosen Reply packet.

Multicast Operation of the Ad-hoc On-Demand Distance Vector Routing Protocol (MAODV)

MAODV [9] is a shared-tree-based protocol that is an extension of AODV [10] to support multicast routing. With the unicast route information of AODV, MAODV constructs the shared tree more efficiently and has low control overhead. In MAODV, the group leader is the first node joining the group and announces its existence by Group Hello message flooding. An interested node P sends a join message toward the group leader. Any tree node of the group sends a reply message back to P. P only answers an MACT message to the reply message with minimum hop count to the originator. Then a new branch to the shared tree is set up.

Ad Hoc Multicast Routing Protocol Utilizing Increasing Id-numbers (AMRIS)

AMRIS [12] is an on-demand shared-tree-based protocol which dynamically assigns every node in a multicast session an id- number. The multicast tree is rooted at a special node called Sid and the id- numbers of surrounding nodes increase in numerical value as they radiate from the Sid. These id-numbers help nodes know which neighbours are closer to the Sid and this reduces the cost to repair link failures.

Sid initially floods a NEW-SESSION message associated with its id -number through the network. Each node receiving the NEW- SESSION message generates its own id- number by computing a value that is larger than and not consecutive to the received one. Then the node places its own id-number and routing metrics before rebroadcasting the message. Each node sends a periodic beacon for exchanging information (like its own id- number) with its neighbours. When a new node P wants to join the session, it sends a join message to one of its potential parent nodes (i.e., those neighbouring nodes having smaller id-numbers) Q. If Q is a tree node, it replies a message to P; otherwise, Q forwards this join message to one of its own potential parent nodes. This process is repeated until a tree node is found (see Figure. 2). If no reply message returns to P, a localized broadcast is used.

Adaptive Demand-Driven Multicast Routing (ADMR)

ADMR [13] is an on-demand sender-tree-based protocol which adapts its behaviour based on the application data sending pattern. It does not require periodic floods of control packets, periodic neighbour sensing, or periodic routing table exchanges. The application layer behaviour allows efficient detection of link breaks and expiration of routing state. ADMR temporarily switches to the flooding of each data packet if high mobility is detected.

A multicast tree is created when a group sender originates a multicast packet for the first time. Interested nodes reply to the sender's packet to join the group. Each multicast packet includes inter -packet time which is the average packet arrival time from the sender's application layer. The inter-packet time lets tree nodes predict when the next multicast packet will arrive and hence no periodic control messages are required for tree maintenance. If the application layer does not originate new packets as expected, the routing layer of the sender will issue special keep-alive packets to maintain the multicast tree. The sender occasionally uses network floods of data packets for finding new members.

The Differential Destination Multicast Protocol (DDM)

DDM [14] is a sender-tree-based protocol that is designed for small group. DDM has no multicast routing structure. It encodes the addresses of group members in each packet header and transmits the packets using the underlying unicast routing protocol. If a node P is interested in a multicast session, it unicast a join message to the sender of the session. The sender adds P into its member list (ML) and unicasts an ACK message back to P. DDM has two operation modes: stateless mode and soft-state mode. In stateless mode, the sender includes a list of all receivers' addresses in each multicast packet. According to the address list and the unicast routing table, each node receiving the packet determines the next hop for forwarding the packet to some receivers, and will partition the address list to distinct parts for each chosen next hop.

In order to reduce the packet size, DDM can operate in soft-state mode. Each node in soft-state mode records the set of receivers for which it has been the forwarder. Each multicast packet only describes the change of the address list since the last forwarding by a special DDM block in the packet header. For instance, if R4 moves to another place and loses connection to R3, the DDM block in the packet header describes that R4 is removed. Then B knows that it only has to forward the packet to R3.

Multicast Core-Extraction Distributed Ad Hoc Routing (MCEDAR)

MCEDAR is a multicast extension to the CEDAR architecture which provides the robustness of mesh structures and the efficiency of tree structures. MCEDAR uses a mesh as the underlying infrastructure, but the data forwarding occurs only on a sender-rooted tree. MCEDAR is particularly suitable for situations where multiple groups coexist in a MANET.

At first, MCEDAR partitions the network into disjoint clusters. Each node exchanges a special beacon with its one hop neighbors to decide that it becomes a dominator or chooses a neighbor as its dominator. A dominator and those neighbors that have chosen it as a dominator form a cluster. A dominator then becomes a core node and issues a message to nearby core nodes for building virtual links between them. All the core nodes form a core graph.

When a node intends to join a group, it delegates its dominating core node P to join the appropriate mgraph instead of itself. An mgraph is a subgraph of the core graph and is composed of those core nodes belonging to the same group. P joins the mgraph by broadcasting a join message which contains a joinID. Only those members with smaller joinIDs reply an ACK message to P (see Figure. 6). Other nodes receiving the join message forward it to their nearby core nodes. An intermediate node Q only accepts at most R ACK messages where R is a robustness factor. Q then puts the nodes from which it receives the ACK message into its parent set and the nodes to which it forwards the ACK message into its child set.

When a node has less than R/2 parents, it periodically issues new join messages to get more parents. When a data packet arrives at an mgraph member, the member only forwards the packet to those nearby member core nodes that it knows.

Mesh-based protocols may have more than one path between a source-receiver pair thereby provide redundant routes for maintaining connectivity to group members. Because of the availability of multiple paths between the source and receiver mesh based protocols are more robust compared to tree based.[2]

On-Demand Multicast Routing Protocol (ODMRP)

ODMRP provides richer connectivity among group members and builds a mesh for providing a high data delivery ratio even at high mobility. It introduces a "forwarding group" concept to construct the mesh and a mobility prediction scheme to refresh the mesh only necessarily.

The first sender floods a join message with data payload piggybacked. The join message is periodically flooded to the entire network to refresh the membership information and update the multicast paths. An interested node will respond to the join message. Note that the multicast paths built by this sender are shared with other senders. In other words, the forwarding node will forward the multicast packets from not only this sender but other senders in the same group (see Figure. 7).

Due to the high overhead incurred by flooding of join messages, a mobility prediction scheme is proposed to find the most stable path between a sender-receiver pair. The purpose is to flood join messages only when the paths indeed have to be refreshed. A formula based on the information provided by GPS (Global Positioning System) is used to predict the link expiration time between two connected nodes. A receiver sends the reply message back to the sender via the path having the maximum link expiration time.

A Dynamic Core Based Multicast Routing Protocol (DCMP)

DCMP aims at mitigating the high control overhead problem in ODMRP. DCMP dynamically classifies the senders into different categories and only a portion of senders need issue control messages. In DCMP, senders are classified into three categories: active senders, core senders, and passive senders. Active senders flood join messages at regular intervals. Core senders are those active senders which also act as the core node for one or more passive senders. A passive sender does not flood join messages, but depends on a nearby core sender to forward its data packets. The mesh is created and refreshed by the join messages issued by active senders and core senders.

All senders are initially active senders. When a sender S has packets to send, it floods a join message. Upon receiving this message, an active sender P delegates S to be its core node if P is close to S and has smaller ID than S. Afterwards, the multicast packets sent by S will be forwarded to P first and P relays them through the mesh.

Adaptive Core Multicast Routing Protocol (ACMRP)

ACMRP presents an adaptive core mechanism in which the core node adapts to the network and group status. In general mesh-based protocols, the mesh provides too rich connectivity and results in high delivery cost. Hence, ACMRP forces only one core node to take responsibility of the mesh creation and maintenance in a group. The adaptive core mechanism also handles any core failure caused by link failures, node failures, or network partitions.

A new core node of a group emerges when the first sender has multicast packets to send. The core node floods join messages and each node stores this message into its local cache. Interested members reply a JREP message to the core node. Forwarding nodes are those nodes who have received a JREP message. If a sender only desires to send packets (it's not interested in packets from other senders), it sends an EJREP message back to the core node. Those nodes receiving this EJREP message only forward data packets from this sender. If a new sender wishes to send a packet but has not connected to the mesh, it encapsulates the packet toward the core node. The first forwarding node strips the encapsulated packet and sends the original packet through the mesh.

ACMRP proposes a novel mechanism to re-elect a new core node which is located nearby all members regularly. The core node periodically floods a query message with TTL set to acquire the group membership information and lifetime of its neighboring nodes. The core node will select the node that has the minimum total hop count of routes toward group members among neighboring nodes as the new core node.

Multicast Protocol for Ad Hoc Networks with Swarm Intelligence (MANSI)

MANSI relies on only one core node to build and maintain the mesh and applies swarm intelligence to tackle metrics like load balancing and energy conservation. Swarm intelligence refers to complex behaviors that arise from very simple individual behaviors and interactions. Although each individual has little intelligence and simply follows basic rules using local information obtained from the environment, globally optimized behaviors emerge when they work collectively as a group. MANSI utilizes this characteristic to lower the total cost in the multicast session.

The sender that first starts sending data takes the role of the core node and informs all nodes in the network of its existence. Reply messages transmitted by interested nodes construct the mesh. Each forwarding node is associated with a height which is identical to the highest ID of the members that use it to connect to the core node. After the mesh creation, MANSI adopts the swarm intelligence metaphor to allow nodes to learn better connections that yield lower forwarding cost. Each member P except the core node periodically deploys a small packet, called FORWARD ANT, which opportunistically explores better paths toward the core.

A FORWARD ANT stops and turns into a BACKWARD ANT when it encounters a forwarding node whose height is higher than the ID of P. A BACKWARD ANT will travel back to P via the reverse path. When the BACKWARD ANT arrives at each intermediate node, it estimates the cost of having the current node to join the forwarding set via the forwarding node it previously found. The estimated cost, as well as a pheromone amount, is updated on the node's local data structure. The pheromone amounts are then used by subsequent FORWARD ANTs that arrive at this node to make a decision which node they will travel to next.

MANSI also incorporates a mobility-adaptive mechanism. Each node keeps track of the normalized link failure frequency (nlff) which reflects the dynamic condition of the surrounding area. If the nlff exceeds the threshold, the node will add another entry for the second best next hop into its join messages. Then the additional path to the core node increases the reliability of MANSI.

Neighbor Supporting Ad Hoc Multicast Routing Protocol (NSMP)

NSMP utilizes the node locality concept to lower the overhead of mesh maintenance. For initial path establishment or network partition repair, NSMP occasionally floods control messages through the network. For routine path maintenance, NSMP uses local path recovery which is restricted only to mesh nodes and neighbor nodes for a group.

The initial mesh creation is the same with that in MANSI. Those nodes (except mesh nodes) that detect reply messages become neighbor nodes, and neighbor nodes do not forward multicast packets. After the mesh creation phase (see Figure. 11), all senders transmit LOCAL_REQ messages to maintain the mesh at regular interval. Only mesh nodes and neighbor nodes forward the LOCAL_REQ messages. In order to balance the routing efficiency and path robustness, a receiver receiving several LOCAL_REQ messages replies a message to the sender via the path with largest weighted path length.

Since only mesh nodes and neighbor nodes accept LOCAL_REQ messages, the network partition may not be repaired. Hence, a group leader is elected among senders and floods request messages through the network periodically. Network partition can be recovered by the flooding of request messages. When a node P wishes to join a group as a receiver, it waits for a LOCAL_REQ message. If no LOCAL_REQ message is received, P locally broadcasts a MEM_REQ message.

The Core-Assisted Mesh Protocol (CAMP)

CAMP is a receiver-initiated protocol. It assumes that an underlying unicast routing protocol provides correct distances to known destinations. CAMP establishes a mesh composed of shortest paths from senders to receivers. One or multiple core nodes can be defined for each mesh, and core nodes need not be part of the mesh, and nodes can join a group even if all associated core nodes are unreachable.

It is assumed that each node can reach at least one core node of the multicast group which it wants to join. If a joining node P has any neighbor that is a mesh node, then P simply tells its neighbors that it is a new member of the group. Otherwise, P selects its next hop to the nearest core node as the relay of the join message. Any mesh node receiving the join message transmits an ACK message back to P. Then P connects to the mesh. If none of the core nodes of the group is reachable, P broadcasts the join message using an expanded ring search.

For ensuring the shortest paths, each node periodically looks up its routing table to check whether the neighbor that relays the packet is on the shortest path to the sender. The number of packets coming from the reverse path for a sender indicates whether the node is on the shortest path. A special message will be issued to search a mesh node and the shortest path can be re-established. At last, to ensure that two or more meshes eventually merge, all active core nodes periodically send messages to each other and force nodes along the path that are not members to join the mesh.

III. Present Status of Multicast Routing Protocols

Multicasting is a mechanism in which a source can send the same communication to multiple destinations. In multicast routing a multicast tree is to be found out to a group of destination nodes along which the information will be disseminated to different nodes in parallel. Multicast routing is more efficient as compared to unicast because in this data is forwarded to many intended destination in one go rather than sending individually. At the same time it is not as expensive as broadcasting in which the data is flooded to all the nodes in the network. It is extremely suitable for a bandwidth constrained network like MANET.

Table I: Comparison of Multicast Routing Protocols

Multicast Protocols	Multicast Topology	Initiali-zation	Independent On Routing Protocol	Dependency On Specific Routing Protocol	Maintenance Approach	Loop Free	Flooding of Control Packets	Periodic Control Messaging
ABAM	Source-Tree	Source	Yes	No	Hard State	Yes	Yes	No
BEMRP	Source-Tree	Receiver	Yes	No	Hard State	Yes	Yes	No
DDM	Source-Tree	Receiver	No	No	Soft State	Yes	Yes	Yes
MCEDAR	Source-Tree Mesh	Source or Receiver	No	Yes (CEDAR)	Hard State	Yes	Yes	No
MZRP	Source-Tree	Source	Yes	No	Hard State	Yes	Yes	Yes
WBM	Source-Tree	Receiver	Yes	No	Hard State	Yes	Yes	No
PLBM	Source-Tree	Receiver	Yes	No	Hard State	Yes	No	Yes
MAODV	Source-Tree	Receiver	Yes	No	Hard State	Yes	Yes	Yes
ADAPTIVE SHARED	Combination of Shared And Source tree	Receiver	Yes	No	Soft State	Yes	Yes	Yes
AMRIS	Shared-Tree	Source	Yes	No	Hard State	Yes	Yes	Yes
AMROUTE	Shared Tree Mesh	Source or Receiver	No	No	Hard State	No	Yes	Yes
ODMRP	Mesh	Source	Yes	No	Soft State	Yes	Yes	Yes
DCMP	Mesh	Source	Yes	No	Soft State	Yes	Yes	Yes
FGMP	Mesh	Receiver	Yes	No	Soft State	Yes	Yes	Yes
CAMP	Mesh	Source or Receiver	No	No	Hard State	Yes	No	No
NSMP	Mesh	Source	Yes	No	Soft State	Yes	Yes	Yes

Traditional multicast routing protocols for wireless network cannot be implemented as it is in mobile ad-hoc network which poses new problems and challenges for the design of an efficient algorithm for MANET.

Mobile Ad Hoc network mainly showed the following aspects:

Dynamic network topology structure: In mobile Ad Hoc network, the node has a arbitrary mobility, the network topology structure may change at any time, and this change mode and speed are difficult to predict.

Limited bandwidth transmission: Mobile Ad Hoc network applies wireless transmission technology as its communication means, it has a lower capacity relative to the wireless channel. Furthermore, affected by multiple factors of noise jamming, signal interference and etc, the actually available effective bandwidth for mobile terminals will be much smaller than the maximum bandwidth value in theory.

The limitation of mobile terminal: although the user terminals in mobile Ad Hoc network have characteristics of smart and portable, they use the fugitive energy like battery as their power and with a CPU of lower performance and smaller memory, especially each of the host computers doubles the router, hence, there are quite high requirements on routing protocols.

Distributed control: there is no central control point in mobile Ad Hoc network, all the user terminals are equal, and the network routing protocols always apply the distributed control mode, so it has stronger robustness and survivability than center-structured network.

Multihop communication: as the restriction of wireless transceiver on signal transmission range, the mobile Ad Hoc network is required to support multihop communication, which also brings problems of hidden terminals, exposed terminals, equity and etc.

Security: as the application of wireless signal channel, wired power, distributed control and etc, it is vulnerable to be threatened by security, such as eavesdropping, spoofing, service rejecting and etc attacking means.

Till date so many multicast routing protocols have been proposed and they have their own advantages and disadvantages to adapt to different environments. Therefore the hope for a standard multicast routing protocol which will be suitable for all network scenarios is highly unrealistic.

At the same time, it is very difficult to confirm multicast routing algorithms or protocols adapted to specific application fields for mobile Ad Hoc network, because the application of Ad Hoc network requires a combination and integration of the fixed network with the mobile environment. So there still needs a deeper research of multicast application in the mobile Ad Hoc network environment.

IV. Comparison Of Multicast Routing Protocols

The design goal of any multicast routing protocol to transmit information to all intended nodes in an optimum way and incur minimum redundancy in the process.

All the protocols try to deal with many problems like nodes mobility, looping, routing imperfections, whether on demand construction, routing update, the control over packet transmission methods (net-wide flooding broadcast or broadcast subjected to member nodes) etc.

In all tree based multicast routing protocols a unique path is obtained between any pair of nodes which saves the bandwidth required for initializing muticast tree as compared to bandwidth requirement of any other structure. The disadvantage of these protocols is the survivability of communication system in case of link/node failure. For example if any nodes moves out of transmission range dividing tree into two or more sub-tree which makes the communication difficult among all the nodes in the tree. In addition the overhead involved in maintaining the multicast tree is relatively larger as compared to other protocols.

Resource requirement for mesh based multicast routing protocols is much larger as compared to tree based protocols. It also suffers from routing loop problems and special measures are taken to avoid such problems which incur extra overhead on the overall communication system.

The biggest advantage of such protocols are their robustness, if one link fails it will not affect the entire communication system. Therefore such protocols are suitable for harsh environments where topology of the network is changing very rapidly.

Hybrid routing protocol is a combination of both the tree and mesh and is suitable for an environment with moderate mobility. It is as efficient as tree based protocols and at the same time it survives the frequent breaks in the network due to high mobility of nodes.

A comparison of all multicast routing protocols discussed above has been summarized in Table1 at the end.

V. Conclusion

Mobile Ad hoc network faces variety of challenges like Dynamic network topology structure, Limited bandwidth transmission, The limitation of mobile terminal, Distributed control, Multihop communication and Security therefore routing is more difficult in such challenging environment as compare to other networks.

Multicast routing is a mode of communication in which data is sent to group of users by using single address. On one hand, the users of mobile Ad Hoc Network need to form collaborative working groups and on the other hand, this is also an important means of fully using the broadcast performances of wireless communication and effectively using the limited wireless channel resources.

This paper summarizes and comparatively analyzes the routing mechanisms of various existing multicast routing protocols according to the characteristics of mobile Ad Hoc network.

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