Study of Routing Protocols in Mobile Ad Hoc Networks

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ABSTRACT
To support group oriented service which is said to be the primary application that are addressed by Mobile Ad hoc Networks (MANETs) in recent years, multicast routing is used. Hence there is a need to design stable and reliable multicast routing protocols for MANETs. In recent years several multicast routing protocols have been designed. Though these protocols are used for the same purpose, each protocol varies according to the design principles, working environment, functionality etc. In this paper we have made a study about some routing protocols and have given a detailed summary about those protocols. We have also compared those protocols using some features and performance metrics.

Keywords:
AQM, ORMRP, CQMP, AMRoute, AMRIS, CAMP, ROMANT, MZR, FGMP, DCMP, NSMP, SRMP, LSMRP

1. INTRODUCTION
A **mobile ad hoc network** (**MANET**), sometimes called a mobile mesh network, is a self-configuring network of mobile devices connected by wireless links. Each device in a MANET is free to move independently in any direction, and will therefore change its links to other devices frequently. Each must forward traffic unrelated to its own use, and therefore be a router.

1.1 Types of MANET
- *Vehicular Ad Hoc Networks (VANETs)* are used for communication among vehicles and between vehicles and roadside equipment.
- *Intelligent vehicular ad hoc networks (InVANETs)* are a kind of artificial intelligence that helps vehicles to behave in intelligent manners during vehicle-to-vehicle collisions, accidents, drunken driving etc.
- *Internet Based Mobile Ad hoc Networks (iMANET)* are ad hoc networks that link mobile nodes and fixed Internet-gateway nodes. In such type of networks normal ad hoc routing algorithms don't apply directly.

2. MULTICAST ROUTING PROTOCOLS
Multicasting is used to improve the efficiency of the wireless link when sending multiple copies of messages. So multicast plays an important role in MANETs. Multicast Routing Protocol is a convention or standard, which controls how nodes decide which way to route packets between computing devices in a mobile ad hoc network. These protocols are classified according to two different criteria [16].

The *first criterion* is based on the routing state and classifies routing mechanisms into two types: proactive and reactive. In *Pro-active routing protocol* routes are set up based on continuous control traffic and all routes are maintained all the time. Where as a *Re-active routing protocol d*oes not take initiative for finding routes but establishes routes "on demand" by flooding a query.

The *second criterion* classifies protocols according to the global data structure that is used to forward multicast packets. They are either tree or mesh-based.

Tree-based schemes [15] establish a single path between any two nodes in the multicast group. These schemes require minimum number of copies per packet to be sent along the branches of the tree. Hence, they are bandwidth efficient. However, as mobility increases, link failures trigger the reconfiguration of entire tree. When there are many sources, network either has to maintain a shared tree, losing path optimality or maintain multiple trees resulting in storage and control overheads. Examples of tree-based schemes include ad hoc multicast routing protocol (AMRoute [5]), ad hoc multicast routing utilizing increasing ID-numbers protocol (AMRIS [6]), and multicast ad hoc on-demand distance vector routing protocol (MAODV [14]). There are two types of *Treebased* approaches: *Source-Tree-based* and *Shared-Tree-based.* In the *Source-Tree-based* approach, each source node creates a single multicast tree spanning all the members in a group. Usually, the path between the source and each member is not the shortest. In the *Shared-Treebased* approach, only one multicast tree is created for a multicast group which includes all the source nodes. This tree is rooted at a node referred as the core node. Each source uses this tree to initiate a multicast.

Mesh-based schemes [15] establish a mesh of paths that connect the sources and destinations. They are more resilient to link failures as well as to mobility. The major disadvantage is that mesh-based schemes introduce higher redundancy of packets since multiple copies of the same packet are disseminated through the mesh, resulting in reduced packet delivery and increased control overhead under high node mobility conditions. Some examples of mesh-based protocols include on-demand multicast routing protocol (ODMRP [3]), forwarding group multicast protocol (FGMP [10]), core assisted mesh protocol (CAMP [7]), neighbor supporting ad hoc multicast routing protocol (NSMP [12]), location-based multicast protocol [2], and dynamic core-based multicast protocol (DCMP [11]).

Hybrid-based multicast routing protocols combine the advantages of both tree and mesh based approaches (robustness and efficiency).

2.1 Ad hoc quality of service multicast routing Protocol

In AQM [1] QoS status is announced at the initiation of a new session and updated periodically in the network. Thus, nodes are prevented from applying for membership if there is no QoS path for the session. To evaluate the efficiency, two new performance metrics, member and session satisfaction grades are introduced. Both are essential for and applicable for multicasting in order to support mobile multimedia applications in ad hoc networks

Member satisfaction grade S_{Member},

$$S_{Member} = \beta\left(1 - \frac{o}{s+\alpha f}\right)(1-\beta)\frac{r}{q} \qquad (1)$$

o -> number of overloaded nodes

s -> total number of session server

f -> total number of session forwarders

β -> member overload prevention rate

r -> number of receivers

q -> total number of join requests issued by all mobile nodes

Problem: Data accuracy is not ensured in hidden terminals

2.2 Location - Based Multicast Algorithms

Specified geographical area is called the multicast region. Set of nodes that reside within the specified multicast region is called a location-based multicast group.

Location-based multicast schemes [2] make use of location-based multicast groups and utilize location information to reduce multicast delivery overhead. Location information is provided by the global positioning system (GPS). With the availability of GPS, it is possible for a mobile host to know its physical location

Problem: Limiting the forwarding space results in fewer geocast messages

2.3 On-Demand Multicast Routing Protocol

ORMRP [3] is a mesh based and uses forwarding group concept; only a subset of nodes forwards the multicast packets via scoped flooding. It uses on-demand procedures to build routes and to maintain multicast group membership.

ODMRP is well suited for ad hoc wireless networks with mobile hosts where bandwidth is limited, topology changes frequently, and power is constrained.

Since the primary concerns of ad hoc networks are frequent topology changes and constrained bandwidth, it is critical that the protocol supplies multiple routes and yields minimal overhead. ODMRP therefore, is an attractive choice for multicasting in ad hoc wireless networks.

Problems:

- same data packet propagates through multiple paths to a destination (duplicate packets), which reduces multicast efficiency.
- control overhead also grows higher and higher with network size

2.4 Multicast Routing Protocol with Consolidated Query Packets

In CQMP, [4] an active source periodically transmits an advertising packet called QUERY to the network.

NumSources	Sender Id	Query Sequence Number	Last Hop Id			
Source Row #	Source Id	Multicast Group Id	CurrentSeq	NextSeq	HopCount	INT
...	...	...	...	...	...	...

Figure 1. Format of a QUERY packet

The QUERY is flooded at regular intervals and for two reasons:

- to update existing routes to match the current network conditions
- to enable new receivers to create a route to itself

Before transmitting the QUERY packet, the source generates *CURRENTSEQ* and *NEXTSEQ*.

If more than one QUERY from different sources is received, the source would add its information into each of them. When the INT is over, the source sets its CurrentSeq equal to its NextSeq and generates a new NextSeq. The source then creates and transmits a new QUERY.

Problem: works only with a QUERY already transmitted, does not introduce any additional transmissions.

2.5 Ad Hoc Multicast Routing Protocol

AMRoute [5] creates a bidirectional, shared tree for data distribution using only group senders and receivers as tree nodes. Unicast tunnels are used as tree links to connect neighbors on the *user-multicast tree.*

It uses five control messages for signaling purposes and one data message: JOIN_REQ, JOIN_ACK, JOIN_NAK, TREE_CREATE, TREE_CREATE_NAK, DATA_MESSAGE.

It does not require a specific unicast routing protocol. *Logical cores* are responsible for initiating and managing detection of group members and tree setup.

Problem: performance is influenced by the characteristics of unicast routing protocol being used.

2.6 Ad Hoc Multicast Routing Protocol Utilizing Increasing Id-Numbers

AMRIS [6] constructs a shared delivery tree and assigns an ID for each node. This msm-id provides each node with an indication of its "logical height" in the multicast delivery tree

Ordering between id-numbers is to direct the multicast flow and for quick connectivity repair

AMRIS consists of two main mechanisms: *Tree Initialization* and *Tree Maintenance*

- *Tree Initialization* is the mechanism by which a multicast session is created and advertised to nodes within the ad hoc network.
- *Tree Maintenance* is the mechanism whereby nodes that become "detached" from the multicast delivery tree rejoin

the tree to continue receiving multicast traffic, by executing a *Branch Reconstruction (BR)* routine

Nodes that did not join the multicast session during the initialization phase also make use of BR to join the tree

Problem: When interval between beacons is small, there is noticeably higher routing overhead.

2.7 The Core-Assisted Mesh Protocol

In CAMP [7] a shared multicast mesh is defined for each multicast group to maintain the connectivity of multicast groups even while network routers move frequently.

Within the multicast mesh of a group, packets from any source in the group are forwarded along the reverse shortest path to the source. CAMP uses cores to limit the traffic. Failure of cores does not stop packet forwarding or the process of maintaining the multicast meshes

Problem: when the underlying topology changes frequently it results in substantial control traffic since a routing tree for the purposes of multicasting packets is maintained.

2.8 Efficient and Robust Multicast Routing in Mobile Ad Hoc Networks

ROMANT [8] does not require a unicast routing protocol. Any source from any multicast group can send multicast packets to another or the same multicast group, without having to know the constituency of that group.

ROMANT implements a distributed algorithm to elect one of the receivers of a group as the core of the group. Every receiver connects to the elected core along any one shortest path. All nodes on such a shortest path between any receiver and the core form the tree.

A sender sends a data packet to the group also along *any one* shortest path between the sender and the core. Nodes maintain a packet ID cache to drop duplicate data packets

Problem: Nodes may detect a partition if they consistently don't receive core announcements from the core.

2.9 Multicast Zone Routing Protocol

MZR [9] is a source-initiated, on-demand protocol. It does not depend on any underlying unicast protocol. Protocol's reaction to topological changes can be restricted to a node's neighborhood instead of propagating it throughout the network

When a node on the multicast tree receives a data packet from its upstream node, it replicates the data packet and sends a copy to each node in the downstream list

A node stops transmitting data packets to a downstream node, if the downstream node migrates and moves out of its transmission range

Problems:

- packet delivery ratio is also affected by the multicast group size
- takes a node longer to reconnect to the multicast tree if there are very few group members in the ad hoc network

2.10 Forwarding Group Multicast Protocol

FGMP [10] keeps track not of links but of groups of nodes (Forwarding Group) which participate in multicast packets forwarding.

When a forwarding node (a node in FG) receives a multicast packet, it will broadcast this packet if it is not a duplicate. If there are three senders and three receivers, three forwarding nodes take the responsibility to forward multicast packets

Multicast using forwarding group reduces channel and storage overhead, thus improving the performance and scalability

Problem: Reverse Path Forwarding causes performance degradation for medium and high mobility

2.11 Dynamic Core Based Multicast Routing Protocol

DCMP [11] expands the idea of *core based tree*, to form the mesh, but unlike the core based tree protocol, it contains more than one core.

It reduces the control overhead by dynamically classifying the sources into *Active* and *Passive* categories. The main advantage of DCMP is that its increased scalability.

Problems:

- issues such as the hidden terminal effect and the broadcast nature of the radio channel make routing more complex compared to that in wired networks
- failure of the core active source leads to failure of multiple multicast sessions

2.12 Neighbor Supporting Ad hoc Multicast Routing Protocol

NSMP [12] utilizes node locality to reduce the overhead of route failure recovery and mesh maintenance. Routes are built and maintained with basic route discovery and reply messages.

It is independent of unicast routing protocols.

There are two types of route discovery: *flooding route discovery* (control messages are broadcast by all nodes) and *local route discovery* (restricted only to a small set of mobile nodes)

NSMP prefers a path that contains existing forwarding nodes to reduce the number of forwarding nodes. This enhances route efficiency, leading to less contention and further to lower end-to-end delay. It is a robust and efficient ad hoc multicast routing protocol

Problem: period of route discovery packets is high

2.13 Source Routing Based Multicast Protocol

SRMP [13] applies source routing mechanism. A mesh is built to connect multicast group members.

To minimize the flooding scope, the Forwarding Group nodes concept is used.

Request phase invokes a route discovery process to find routes to reach the multicast group. Different routes to the multicast group are setup during the *reply phase*.

SRMP avoids the overhead of storing next hop information as well as periodical control messages, avoiding channel overhead and improving scalability.

Problem: links' break is more frequent at the cases of higher mobility.

2.14 Link Stability Based Multicast Routing Protocol

LSMRP [16] establishes a route from a source to multicast destinations in MANET. A multicast mesh is created with stable links when a source node needs to send data to receiver nodes. The scheme consists of the following phases.

1. Mesh creation through the route request (RR) and route reply (RP) packets.
2. Finding stable routes between source and destination pair of nodes by selecting stable forwarding nodes (SFNs) using link stability metric.
3. Mesh maintenance to handle link failure

Link quality [16] is a major component that decides the link stability to construct multicast routes. It is derived by the ratio of bits in error to the total number of bits received (i.e., bit error ratio (BER)).

For particular measured error, if S is the average of standard deviations of many bit error trials and a is the accuracy of received bits, then BER between nodes i and j (denoted as BER_{ij}) is given by Eq. (2)

$$BER_{ij} = \frac{S^2}{a^2} \quad (2)$$

As link quality q_{ij} between two neighboring nodes i and j is inversely proportional to BER, a better approximation of link quality with proportionality constant K is given by Eq. (3)

$$q_{ij} = K \times \frac{1}{BER_{ij}} \quad (3)$$

Stability factor is the value computed for a link to a neighbor based on the power level, distance and link quality. Stability factor Sij of a link between nodes i and j is defined by Eq. (4)

$$S_{ij} = \frac{Pw_{ij} \times q_{ij}}{d_{ij}} \quad (4)$$

where Pw_{ij} and d_{ij} are the signal strength and the distance between nodes i and j respectively. q is link quality.

Then the neighbor node that has the highest stability factor is selected as the forwarding node by the sender.

2.15 Hydra

Hydra [17], a sender initiated multicast routing protocol creates a multicast mesh formed by a mixture of source- specific and shared sub-trees (or sub-meshes) using as few control packets as receiver-initiated schemes. The key ideas behind Hydra are:

1. Electing a sender as the core in non-destructive manner
2. Restricting the dissemination of control packets to those regions of the network where other dynamically designated sender has previously discovered receivers
3. Forwarding Multicast Data Packets

If a source has data to send to a multicast group, it first determines whether it has received a Join Query (JQ) message from the core of that group. If that source node has, it adopts the core specified in the JQ it has received and transmits a non Core Join Query (JQnC) message advertising the same core for the group. Otherwise, it considers itself the core of the group and starts transmitting JQ s periodically to its neighbors.

3. PERFORMANCE EVALUATION CRITERIA

There are several criteria for evaluating the performance of Multicast Routing Protocols in MANET. Some are given here. Increased packet delivery ratio and reduced packet delay improves network throughput and reduced overheads reduce bandwidth consumed and efficient usage of various resources for route discovery and maintenance.

1. *Packet delivery ratio (PDR):* It is defined as the sum of number of packets received at all the multicast receivers to the product of number of packets sent at source and number of multicast receivers.
2. *Control overhead:* It is the total number of control packets (request, reply, and acknowledgment packets) needed to establish a stable route from source to the multicast receivers.
3. *End-to-End Delay:* This represents the average time a data packet takes to travel from the transmitter to the receiver. It is a metric which can be used to evaluate the timeliness of the protocol.
4. *Throughput:* It is the total number of control packets received with in a particular time.

4. COMPARISON

Table 1. Comparison of Multicast Routing Protocols in MANET

Protocol	Layer of Operation	Routing Scheme	Multicast Topology	Unicast Routing Protocol Dependent	Initialization Method	Control Overhead
AQM	Application, Session and Network	Proactive	Tree based	No	Source initiated	Low
LBM	Application	Proactive	Mesh based	Yes	Source	Low

					initiated	
ODMRP	Network	Reactive	Mesh based	No	Source initiated	Low
CQMP	Network	Proactive	Mesh based	Yes	Hybrid	High
AMRoute	Application	Proactive	Hybrid	Yes	Hybrid	High
AMRIS	Network	Reactive	Tree based	No	Source initiated	Low
CAMP	Network	Proactive	Mesh based	Yes	Hybrid	High
ROMANT	Network	Proactive	Tree based	No	Source initiated	Low
MZR	Network	Hybrid	Tree based	Yes	Source initiated	Low
FGMP	Network	Reactive	Mesh based	Yes	Receiver initiated	Low
DCMP	Network	Reactive	Mesh based	No	Source initiated	Low
NSMP	Network	Reactive	Mesh based	No	Source initiated	Low
SRMP	Network	Reactive	Mesh based	Yes	Receiver initiated	Low
LSMRP	Network	Reactive	Mesh based	No	Source initiated	Low
Hydra	Network	Reactive	Mesh based	No	Source initiated	Low

5. CONCLUSION

This study clearly gives the principles of the some multicast routing protocols about how they work. We have proposed that the protocols are classified according to two different criteria: routing state and global data structure. Tree-based protocols provide high data forwarding efficiency at the expense of low robustness. In Mobile Ad hoc Networks, topology changes very frequently. In such cases mesh-based protocols seem to outperform tree-based protocols. Hybrid-based multicast routing protocols combine the advantages of both tree and mesh based approaches. The multicast routing protocols also uses query control mechanisms which is used to exploit the structure of the routing zone to provide enhanced detection and prevention of overlapping queries. These techniques can be applied to single or multiple channel ad hoc networks to minimize both the delay and traffic of routing protocols. In general usefulness of different protocols depends on their application environments. Accurate studies are required to establish, with various networking environments and topologies. Still the researches on the use of multicast routing protocols are insufficient. Issues such as QoS and security should also be addressed in the future.

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