Multicast Routing Protocols in Mobile Ad Hoc Networks: Issues, Challenges and Applications

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Abstract:

Mobile Ad hoc Networks (MANETs) are self-configuring, de-centralized and a kind of multi hop wireless packet networks, where the mobile gadgets (also referred to as nodes) communicate with each other on wireless links. Such networks find applications where a quick deployment or dynamic reconfiguration of network is required, or there is no pre-existing network infrastructure or wired network is available. The applications include emergency search and rescue operations, military, civilian operations, law enforcement, and conferences. Multicasting is becoming important in MANETs as a lot of applications relaying on cooperation among a team. There have been a wide variety of multicast routing protocols available in the literature. This paper outlines the multicasting, various multicast routing protocols and their performance evaluation metrics..

Index Terms— ***Mobile Ad hoc Network, Multicast, Routing, Scalability, Efficiency.***

I. INTRODUCTION

Ad hoc is a Latin term which means "for this purpose". A Mobile Ad hoc Network (MANET) is an association of ad hoc mobile nodes interconnected together temporarily on wireless channels [1]. In these networks, since the communication between any two nodes of the network is done through middle nodes if they are not in the direct transmission range of each other, each node acts as a router to forward the packets as well as a host if the destination node is in the direct transmission range of that node. Hence, these networks are one kind of multi-hop wireless networks. Fig. 1 shows a case of a simple MANET with four nodes. Though the outermost nodes A and D are not within the communication range of each other, the path setup between these two nodes is completed through the intermediate nodes, either by B or C.

MANETs are of at most importance where there is no existing network infrastructure, or establishment of network is not possible, or takes time or expensive [1]. MANETs, due to their rapid and economically less demanding deployment, find a wide range of applications in several areas like Defense, emergency and disaster relief operations, research community, business, industrial and corporate environments, conventions and classrooms.

Fig. 1.
A MANET

As the nodes in these networks are mobile, change the topology of the network rapidly and arbitrarily. Furthermore, the nodes any time can get in or out of the network, making the classical routing protocols (used to discover a route that the packets should take to reach the destination node from a source node) distance-vector and link-state, used in the wired networks unsuitable for MANETs. Moreover, multicast routing - a kind of group communication, has become attractive and drawing attention of many applications in MANETs [2]. In fact, the wireless link efficiency can be improved by multicasting through the transmission of multiple copies of the data simultaneously to multiple nodes by making use of the intrinsic broadcast nature of the wireless link. Clearly, multicasting means "point-to-multipoint" or "one to many". A single destination address is used to identify each member of the multicast group. As a well known fact in a MANET, a node may leave or join the groups at any time. One node can be a member of more than one group at a time. There is no limitation of number of members and on the location in a multicast group. Moreover, a node need not necessarily be a member of a group for forwarding the data to the members in the group.

In wired networks, there are a couple of well noted multicast schemes available: "core-based tree" and "shortest path multicast tree" [3]. Former one does not guarantee the shortest path between intended nodes and since it maintains only one tree for each group it needs less storage, whereas in second scheme there is always a shortest between intended nodes. However, the case of multicasting in MANETs is different as the multicast routing protocols have to make use of scarce resources like bandwidth, time and node resources (battery life, memory capacity and processing speed) efficiently in the highly dynamic environment.

II MOTIVATION AND CONTRIBUTION

In [4] various MANET research issues are presented and classified. In literature, there exist several papers on muliticasting in MANETs. Compared to others, this paper gives an overview in an ordered way and will be useful to

those who want to get basics in the area of multicast routing in MANETs.

III MULTICAST ROUTING PROTOCOLS

Mobile nodes with limited resources, limited bandwidth and an error-prone wireless link make the design of a multicast routing protocol for MANETs a challenging one [1]. It should be robust enough to sustain for the dynamic movement of the nodes, should keep the control overhead as low as possible, should utilize node and network resources as efficient as possible, should be loop free and should not depend on any unicast routing protocol.

A. Architecture Reference Model of Multicast Routing Protocols

Fig. 2 shows the architectural framework of multicast routing protocol for a brief level understanding. Multicasting in MANETs mainly related to three layers in the OSI seven-layer model: Application (layer 7), Routing (layer 4) and Medium Access Control (MAC) (layer2) [1].

Module 1 of the layer 7 puts an appeal to join a group to module 4 of the layer 4 which uses the route cache table of module 3 and unicast route information from 8. On receiving request from module 1, the module 4 floods the packets containing route request information using module 10 of the layer 2. Module 11 of other nodes forwards these packets to their forwarding module number 7, multicast information handler module number 6 for the updating of multicast table and to the module 8. During the reply phase forwarding states are created in the multicast tables at intermediate nodes. Module 2 handles the data packets and passes them on to module 7 and takes the decision after consulting module 6 about broadcasting of data packets. Module 5 handles the route repair by getting informed by module 9 about link breaks. For a source/receiver node all the modules are in active state, for intermediate nodes all the modules of routing and MAC whereas for other nodes only the modules 10, 11, 7 and optionally 3 are active.

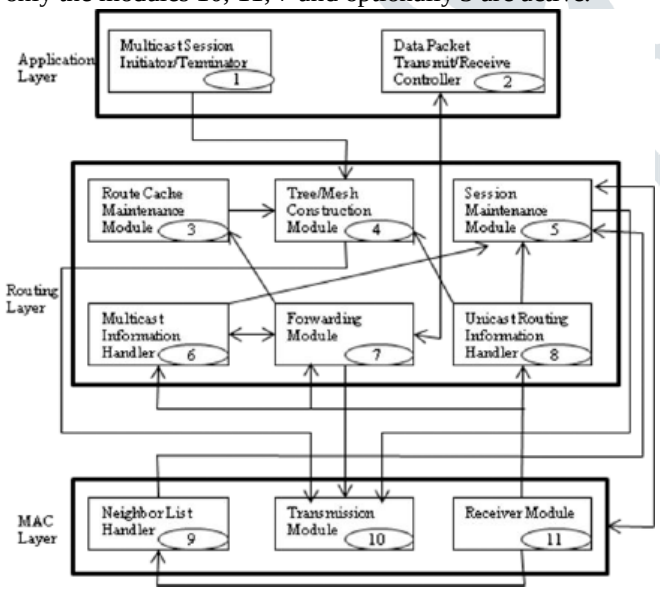

FIG. 2.
REFERENCE ARCHITECTURE MODEL OF A MANET

B. Classification of Multicast Routing Protocols

Multicast routing protocols can be broadly classified into two categories: Application Independent/generic (AI) and Application Dependent (AD) [1]. AI protocols are for conventional multicasting whereas for specific applications AD multicast routing protocols are designed. In fact, these protocols can be categorized under different dimensions:

Based on Topology of the Multicast Group: tree, mesh and hybrid [1]. Tab. I describes the characteristic features of topology based multicast routing protocols.

In source-tree, a separate tree is maintained by each source node in the multicast group, whereas in shared-tree, all the sources share a single tree and is rooted at a node referred to as the core node [1].

Based on Initialization Approach: A group can be formed by either source or destination node. If the source node initializes the formation of the multicast group, then they are called source-initiated, whereas if it is by a destination then they are called receiver-initiated [1].

Based on Topology Maintenance Mechanism: Hard-state and soft-state approaches are available in practice. In the former approach, control packets are transmitted only at the time of link breaks which results in lower control packet overhead, whereas in the latter one, periodically the control packets are transmitted to maintain up-to-date routes, leads to more control packet overhead [1]. Hard-state protocols are also called as "connection-oriented", whereas soft-state as "connection-less" [3].

Based on Routing Scheme: Proactive, reactive and hybrid [5]. The characteristic features of routing scheme based multicast routing protocols are discussed in Tab. II.

Based on Routing Structure: When homogeneous nodes (having equal capability in terms of storage capacity, computing power etc.) form a MANET flat multicast routing protocols are used, whereas when mobile nodes of different capacities form a MANET hierarchical multicast routing protocols are used [3].

Table I. Topology based

Tree	Mesh	Hybrid
For any given source and destination nodes there is only one path available	More than one path is available between any given source and destination nodes	Combines best features of Tree and Mesh
Efficient in data transmission	Robust to topology changes	
Non robust	Large overhead	
Further divided into two types: "source-tree-based" and "shared-tree-based"		

Table II. Routing scheme based multicast routing protocols

Proactive	Reactive	Hybrid
Familiar as table-driven	Familiar as on-demand	Takes best features of Proactive and Reactive
Topology of the group is maintained in the form of routing tables at each node	Basically route finding process starts on demand	
Routing tables are updated periodically	Pre-existing routes can be used	
Large overhead and requires excess bandwidth	Better scalability but long route estiablishing delays	

IV PERFORMANCE EVALUATION METRICS

The performance of multicast routing protocols(Table III) is typically evaluated based on two metrics: Qualitative and Quantitative.

Qualitative metrics include

- Topology of the multicast group
- Routing structure
- Routing scheme
- Sleep mode support
- Loop free routing
- Routing metric
- Node participation in the routing process
- Power consumption

The quantitative metrics include [1], [6]

Multicast Efficiency: A multicast protocol should make a minimum number of transmissions to deliver a data packet to all the group members.

Robustness: The multicast routing protocol must be able to recover and reconfigure quickly from potential mobility-induced link breaks thus making it suitable for use in highly dynamic environments.

Control Overhead: The scarce bandwidth availability in ad hoc wireless networks demands minimal control overhead for the multicast session

Group Reliability: Group Reliability refers to the process of accepting multicast session members and maintaining the connectivity among them until the session expires. This process of group management needs to be performed with minimal exchange of control messages.

Scalability: The multicast routing protocol should be able to scale for a network with a large number of nodes

Security: Authentication of session members and prevention of non-members from gaining unauthorized information play a major role in military communications.

The performance varies based on the parameters like mobility model (like random-waypoint, bouncing ball), multicast group size, traffic type (like CBR, VBR), number of multicast groups, number of packets, packet size, density of nodes, field range, node's transmission power-range, node's bandwidth [6].

Multicast Proto-cols	Multicast Topology	Initia-lization	Independent of 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 over 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	Shared-tree	Receiver	Yes	No	Hard state	Yes	Yes	Yes
Adaptive Shared	Combination of Shared- and Source-trees	Receiver	Yes	No	Soft state	Yes	Yes	Yes
AMRIS	Shared-tree	Source	Yes	No	Hard state	Yes	Yes	Yes
AMRoute	Shared-tree over 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

Table III. Classification of multicast routing protocols

CONCLUSION

Multicasting is used when the same message or the same stream of data must be forwarded to multiple destinations. Multicasting is an efficient data transmission method to support group-oriented communications in one-to-many or many-to-many applications such as audio/video conferencing, collaborative works, and so on. In MANETs, the most challenging issue in multicast routing is to

effectively handle the frequent and unpredictable topology changes caused by host mobility, link breakage and host failure. This paper provided a survey of most recent multicast routing protocols for MANETs. This study showed that each multicast routing protocol may improve network performance

in terms of delay, throughput, reliability or lifetime. Due to severe constraints of mobile wireless ad hoc networks such as host mobility, limited resources and very unreliable communication channel, single protocol or a set of protocols that can improve all these performance parameters is extremely hard to find. Selection of a multicast routing protocol is as much dependent on the nature of application, and different applications have diverse requirements. Stability against the host mobility, energy efficiency, low overhead, reliability, and scalability are several requirements for which the multicast routing protocols are designed. This survey enables the researchers to identify the strengths and weaknesses of different multicast routing protocols and helps them to choose the best one for a particular application.

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