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A Comparative Survey and Issues in Multicast Routing Protocols for Mobile Ad-Hoc Networks

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Abstract:
A Mobile Ad-hoc Network (MANET) is composed of Mobile Nodes (MNs) without any infrastructure. Mobile Nodes self-organize to form a network over radio links. Multicasting can efficiently support data transmissions and thus is very suitable for MANETs. Implementing multicast routing protocols to MANETs leads to improve the consumption of bandwidth, reducing the cost of communication in the network and improving the efficiency. In this paper, we provide an overview of multicast routing mechanism especially in routing based on mesh and tree topology.

Key words: *MANET, Multicast Routing protocols, Mesh based protocol, Tree based protocol*

1. Introduction

A Mobile Ad-hoc-network (MANET), it is a self-organizing collection of mobile nodes that form a temporary and dynamic wireless network without a fixed Networking infrastructure. Multicast routing protocols play an important role in MANET. In MANETs environment where the bandwidth is the primary concerned, it is suitable to use multicast rather than multiple unicast. Multicasting is a technique to transmit the data packets to groups of users by single IP address as a destination. Based on the routing structure, they can broadly be classified into two categories one is tree-based protocols and another mesh-based protocols. In tree-based protocols, there exists a single path between any sender-receiver pair. Tree-based protocols have the advantage of high multicast efficiency. Mesh-based protocols provide redundant routes for maintaining connectivity to group members. The low packet delivery ratio problem caused by link failures is alleviated due to redundant routes. Mesh-based protocols are robust to node mobility.

2. Performance Criteria for Multicast Routing Protocols

The performance of a multicast routing protocol may vary dramatically with the variations of network status and traffic overhead. It is a very difficult to give a comprehensive performance comparison for a large number of multicast routing protocols. There are different ways to evaluate and compare the performances of multicast routing protocols.

- User parameters and configurations; such as average multicast degree, control overhead, packet delivery ratio, average delay, throughput, Quality of Service.
- The performance is evaluated by different simulation tools, such as NS-2, Opnet, Matlab, CASSAP, Glo-MoSim and SPW.

2.1. Classification of Multicast Routing Protocols

In general the multicast routing protocols used in mobile ad hoc networks are broadly classified into two broad categories:
Application Independent Generic Multicast Routing protocols and Application Dependent Multicast Routing Protocols. The Application Independent multicast routing protocols can be used by all kinds of applications, whereas the Application-Dependent Multicast Routing Protocol is designed for certain specific applications such as nuclear reactor control, missile control and so on. The Application Independent multicast routing protocols are again classified with respect to three major factors: topology, multicast session initialization, and route maintenance mechanism.

- Tree-based multicast routing protocol: In the tree-based multicasting, structure can be highly unstable in multicast ad-hoc routing protocols, as it needs frequent re-configuration in dynamic networks
- Mesh-based multicast protocol: Mesh-based multicast routing protocols are more than one path may exist between a source receiver pair
- Hybrid multicast routing protocol: hybrid multicast routing protocol like AMRoute.

2.2. Proactive Multicast Routing Protocols

Conventional routing protocols such as Ad-hoc Multicast Routing (AMRoute), Core-Assisted Mesh Protocol (CAMP) and Ad-hoc Multicast Routing Protocol Utilizing Increasing id-numbers (AMRIS) are proactive multicast routing protocols. Periodic broadcast of network topology updates are needed to compute the shortest path from the source to every destination, which consumes a lot of bandwidth.

2.3. Reactive Multicast Routing Protocols

Traditional routing protocols such as On Demand Multicast Routing Protocol (ODMRP) and Multicast Ad-hoc on-demand Distance Vector (MAODV) are Reactive multicast routing protocols. Reactive routing that means discovers the route when needed. Reactive routing protocols are well suited for a large-scale, narrow-band MANET with moderate or low mobility.

2.4. Hybrid Multicast Routing Protocols

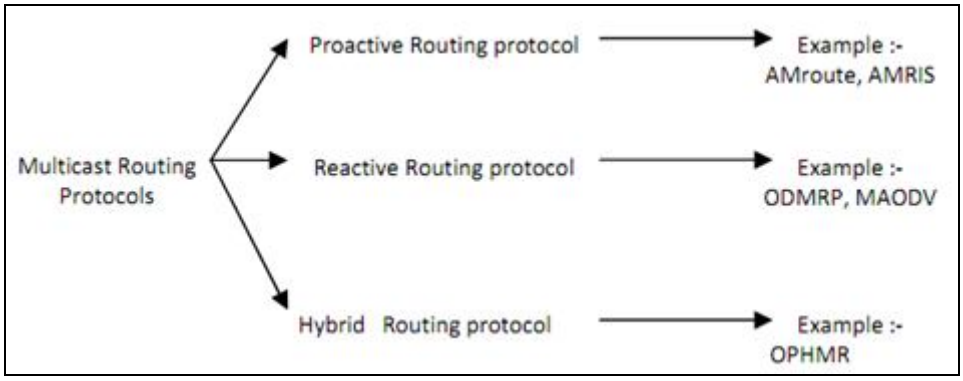
Traditional routing protocol such as Optimized Polymorphic Hybrid Multicast Routing Protocol (OPHMR) is the Hybrid multicast routing protocol. Hybrid routing protocol attempts to discover balance between the two such as proactive for neighbourhood, reactive for far away.

2.5. Topology-Based Multicast Routing Protocols

One of the most popular methods to distinguish MANETs multicast protocols is based on how distribution paths among group members are constructed. In terms of this method, existing multicast routing protocols for MANETs can be divided into tree-based, mesh-based and hybrid-based multicast routing protocol. Tree-based multicast routing protocols can be further divided into source-rooted and core-rooted schemes according to the roots of the multicast trees. In a source-rooted tree-based multicast routing protocol, source nodes are roots of multicast trees and execute algorithm for distribution tree construction and maintenance. This requires that a source must know the topology information and addresses of all its receivers in the multicast group. Therefore, the source-rooted tree protocols suffer from control traffic overhead when used for dynamic networks. AMRoute is an example for the source-rooted tree multicast routing protocol for MANETs. In a core-rooted tree multicast routing protocol, cores are nodes with special functions such as multicast data distribution and membership management. Some core-rooted multicast routing protocols utilize tree structures also, but unlike source-rooted tree-based multicast routing, multicast trees are rooted at core nodes. For different source-rooted multicast routing protocols, core nodes may perform various routing and management functions. The Shared Tree Ad-hoc Multicast Protocol (STAMP) and the Adaptive Corebased Multicast Routing Protocol (ACMP) are core-based multicast routing protocols proposed for MANETs. The tree-based protocols establish a single path between any two nodes in the multicast group. These protocols require a minimum number of copies per packet to be sent along the branches of the tree. Therefore, they are bandwidth efficient. If there is only one source, only a minimal number of nodes are involved in the routing. Hence, tree-based approaches could also be relatively power efficient. However, as mobility increases, link failures trigger the reconfiguration of the entire tree. Either has to maintain a shared tree, losing path optimality, or maintain multiple trees resulting in storage and control overhead when there are many sources.

In a mesh-based multicast routing protocol, packets are distributed along mesh structures that are a set of interconnected nodes. Routing discovery and mesh building are accomplished in two ways: by using broadcasting to discover routes or by using core or central points for mesh building. The meshed based protocols have high robustness in comparison with the tree-based protocols in the high mobility environment as they provide redundant paths from source to destinations while forwarding data packets. To maintain the mesh topology however, it requires more control messages than the treebased approach since multiple copies of the same packet are disseminated through the mesh, resulting in power inefficiency, network load and control overhead. The Mesh-based Multicast Routing Protocol with Consolidated Query Packets (CQMP) the Enhanced On-Demand Multicast Routing Protocol (E-ODMRP) and the Bandwidth Optimized and Delay Sensitive (BODS) are mesh-based multicast routing protocols proposed for MANETs.

Hybrid-based multicast routing protocols combine with the advantages of both tree and meshed-based approaches. Hence hybrid protocols address both efficiency and robustness.



2.6. Mesh-based Multicast Routing Protocols

Mesh based protocol is highly stable in mobile ad hoc network .There may exist more than one path between source and receiver. There are many mesh based multicast routing protocols exist in MANET. Examples of mesh based protocols are on demand multicast routing protocol (ODMRP).

2.7. ODMRP: On-Demand Multicast Routing Protocol

ODMRP provides 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. 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.

2.8. Advantages

It proposes an effective "forwarding group". The offering of shortest paths reduces data delivery. The mobility prediction scheme lowers control overhead at mobility.

2.9. Disadvantages

It suffers from excessive flooding when there is a large number of senders. The duplicate transmissions waste bandwidth at low mobility.

2.10. Tree-based Multicast Routing Protocols

The tree based routing protocol are highly unstable in the mobile ad hoc network as it need frequent re-configuration in the dynamic network, mobility of nodes There is only a single path between multicast source and receiver. There are various tree based protocols like multicast extension of ad hoc on demand distance vector (MAODV)

2.11. MAODV: Multicast Operation of the Ad-hoc On-Demand Distance Vector Routing Protocol

A multicast group usually has several senders and thus it costs high for each sender to build its own tree. Some protocols select a single sender to build a multicast tree that is shared with other senders. This kind of tree construction is called a shared tree-based one and the selected sender is called the group leader (or core node). Other senders first transmit data packets to the group leader and the group leader then relays the packets downward the shared tree to all receivers. The kind of initialization of tree construction by one or more senders is called a sender initiated scheme. The receiver intiated scheme requires receivers to initiate the tree construction, and it is often used for the shared-tree structure. Due to node mobility, the routing structure requires reconfiguration. If a broken link is repaired by periodic flood packets issued by a sender (or the group leader), this kind of protocol is called a soft-state one. Periodic flood packets also help new members join the group. If a link failure is repaired by a node on the link, this kind of protocol is called a hard-state one. Since no periodic flood packets are issued in hard-state protocols, new members usually join the group by using expanded ring searches (i.e., iteratively expand the flood range). A group member usually leaves the group by sending a message to inform its parent of its departure. In addition to link failures, node mobility may cause partition of the routing structure. Partition must be merged for successfully delivering data packets to all group members. Sender-tree-based protocols incur higher control overhead than shared-tree-based ones because each sender builds its own tree. Shared-tree-based protocols have two main drawbacks: single point of failure of the group leader and sub-optimal multicast paths. Moreover, the group leader may locate in a bad position which further decreases multicast efficiency and increases packet latency.

3. Typical Multicast Routing Protocols

3.1. The Shared Tree Ad-hoc Multicast Protocol (STAMP)
The Shared Tree Ad-hoc Multicast Protocol (STAMP) is a reactive core-rooted multicast routing protocol for MANETs, which is independent from the underlying unicast routing protocol in order to achieve efficient and adaptive multicast communications firstly inside each cluster and secondly among the clusters. In STAMP, a source of a multicast group does not need to join the multicast delivery structure to send a datagram to the group. Multicast datagram is sent on the shortest paths between the sources and the core. As soon as a data packet reaches a tree member, it is forwarded on the tree. Finally, a distributed mechanism is used to elect the core node among the receiver nodes of a specific multicast group. Therefore, unlike CAMP operation, core nodes are not pre-assigned. STAMP combines the advantages of both mesh based and tree-based protocols and achieves high delivery ratio even under heavy mobility and heavy traffic.

3.2. *Enhanced On Demand Multicast Routing Protocol (EODMRP)*

4. Issues in Multicasting

4.1. Resource Management
Resource management is a major issue that must considered in efficient multicasting. During the deployment of the operational network, the bandwidth provided to each of the node of the network may be different, but according to the application to which the nodes are provisioned they may or may not need much bandwidth sufficiency. In order to help from the nodes from a particular outage, the work load between the channels of nodes should be reduced by controlling its input traffic. The fair flow value can be found out by evaluating some bound values which achieves maximum or minimum flow between the nodes. The algorithm based on the max/min bound value performs wee and good compared to other algorithms based on analytical bound value.

4.1.1. Load Balancing
Load balancing is a dandier issue in multicast networks since the packets are send through a group of routers to a group of receivers. The unbalanced load present in the network can cause several types of clogging like, gateway and channel overloading. Gateway overloading occurs mainly because of the data aggregation that occurs at the gateway and channel overloading due to the increased number of packets in the channels and the data overhead. The center overloading occurs mainly due to the static nature of networks, presence of nodes on the shortest path of the network, and the multihop relaying mechanism. These are the major cistrons that are to be considered in designing of an effective multicast protocol since load balancing plays a crucial role on improving the network utilization and the performance; it also helps to avoid the hotspots that are present in the network.

4.2. Control Overhead
Control overhead is a basic criterion on which highly reliable networks are made up and operated. The optimization of control overhead during the design phase of a network gives high throughput and performance for the network. Controlling of overhead is a matter of concern in multicast networks. For the minimal overhead on demand routing protocols such as ODMRP can be best fit since they provide creation of mesh networks based on the need of the nodes that wants to join the group and thus the overhead can be balanced to a great extend.

4.3. Reliability
In some applications like real time and military applications its not permitted to lose any data packets and it must all data packet sng to receives completely from the destinations, so multicast routing protocol should guaranty this characteristic.

4.4. Quality of services
The guarantee of QoS in MANETs is very difficult comparing to other networks type because its available bandwidth is shared among nodes and the network structure will be changed as nodes moving away from network. Multicast routing protocol should be provided by mechanism to control and management the total traffic that mechanism to control and management the total traffic that can flow in the network and achieve a globally efficient in resource utilization.

- Comparison of Multicast Protocols

5. Comparison Based Upon Characteristics of Multicast Routing Protocols
AODV and CAMP are the only two protocols that are using core nodes as the use of core nodes introduces robustness problems when the core node is not available. Moreover these two are the only ones which are using the concept of centralized nodes. In terms of unicast routing protocol, all protocols except CAMP provide their own mechanism.

6. Conclusion

In this paper, we have reviewed a broad range of multicast routing protocols designed for MANETs. We classify all multicast routing protocols into two categories: tree-based protocols and mesh-based protocols. For each protocol, we summarize the properties, describe the operation, and list the strengths and weaknesses. We focus only on general multicast routing protocols for ad hoc networks in this paper. There are other multicast routing protocols that aim at providing reliability, QoS guarantees, security, and so on. We plan to investigate these protocols and make our survey more complete in our future work. In many cases, it is difficult to compare these protocols with each other directly since each protocol has a different goal with different assumptions and employs mechanisms to achieve the goal. According to the study, these protocols have different strengths and drawbacks. A multicast protocol can hardly satisfy all requirements. In other words, one routing protocol cannot be a solution for all energy efficient and security issues that are faced in MANETs, but rather each protocol is designed to provide the maximum possible requirements, according to certain required scenarios.

7. Future work

We believe that research on the use of multicast in mobile ad hoc networks is still in its infancy. Open issues include QoS guarantee, reliable multicast, security provisioning, power efficiency, congestion control, scalability, and efficient membership updates. It is difficult to design a multicast routing protocol that takes all these issues into consideration, that is, a one-size-fits-all design. One possible solution would be to develop an adaptive approach to routing, and this may be the best way forward. Possible topics for future research on multicast routing protocols include the following.

- **Interoperability:** Most of the existing multicast routing protocols for mobile ad hoc networks were not designed to interoperate with other networks such as wired networks, wireless mesh networks, WiMAX, and so forth. However, it is difficult to design a multicast routing protocol that performs efficiently in a mobile ad hoc network while still being able to interoperate with other networks. In order to offer seamless interoperation, novel mechanisms must be developed to achieve the best performance.
- **Mobility:** The continuous and random mobility of nodes in mobile ad hoc networks can easily make the information derived fromthe network topology stale. As a result, group membership information, such as leaving or joining a multicast group, may induce frequent updates on the protocol states. Moreover, the transmission of data packets can be obstructed during the update process. Thus, group membership approaches should efficiently cope with membership changes in order to minimize their impact on the overall performance of the protocol.
- **Congestion control:** Adjacent nodes in mobile ad hoc networks compete with each other to access the wireless medium and transmit their packet. Thus, the network can be easily congested. Congestion, especially in dense networks, introduces long endto- end delay and buffer overflows and decreases reliability. Instead of leaving the MAC layer to deal with congestion control, multicast protocols should deploy additional novel mechanisms to overcome this congestion.

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