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Research on multicast routing protocols for mobile ad-hoc networks ☆

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Abstract

A mobile ad-hoc network (MANET) is composed of mobile nodes without any infrastructure. Mobile nodes self-organize to form a network over radio links. The goal of MANETs is to extend mobility into the realm of autonomous, mobile and wireless domains, where a set of nodes form the network routing infrastructure in an ad-hoc fashion. The majority of applications of MANETs are in areas where rapid deployment and dynamic reconfiguration are necessary and wired network is not available. These include military battlefields, emergency search, rescue sites, classrooms and conventions, where participants share information dynamically using their mobile devices. These applications lend themselves well to multicast operations. In addition, within a wireless medium, it is crucial to reduce the transmission overhead and power consumption. Multicasting can improve the efficiency of the wireless link when sending multiple copies of messages by exploiting the inherent broadcast property of wireless transmission. Hence, reliable multicast routing plays a significant role in MANETs. However, to offer effective and reliable multicast routing is difficult and challenging. In recent years, various multicast routing protocols have been proposed for MANETs. These protocols have distinguishing features and employ different recovery mechanisms. To provide a comprehensive understanding of these multicast routing protocols and better organize existing ideas and work to facilitate multicast routing design for MANETs, we present the taxonomy of the multicast routing protocols, their properties and design features. This paper aims to aid those MANETs researchers and application developers in selecting appropriate multicast routing protocols for their work.

Keywords: Mobile ad-hoc network (MANET); Multicast routing protocol; Taxonomy; Mobile node; Routing table

1. Introduction

Multicasting is the transmission of packets to a group of zero or more hosts identified by a single destination address [1]. Multicasting is intended for group-oriented computing, where the membership of a host group is typically dynamic that is,

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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. Also, a host does not have to be a member of a group to send packets to the members in the group. In the wired environments, there are two popular network multicast schemes: shortest path multicast tree and core-base tree. The shortest path multicast tree method guarantees the shortest path to each destination, but each source has to build a tree. Therefore, too many trees exist in the network. The core-based tree method cannot guarantee the shortest path from a source to a destination, but only one tree is required to be constructed for each group. Therefore, the number of trees is greatly reduced.

Currently, one particularly challenging environment for multicast is in MANETs [2,3]. A MANET is a self-organizing collection of wireless mobile nodes that form a temporary and dynamic wireless network established by a group of mobile nodes on a shared wireless channel without the aid of a fixed networking infrastructure or centralized administration. A communication session is achieved either through single-hop transmission if the recipient is within the transmission range of the source node, or by relaying through intermediate nodes otherwise. For this reason, MANETs are also called multi-hop packet radio networks. However, the transmission range of each low-power node is limited to each other's proximity, and out-of-range nodes are routed through intermediate nodes.

Mobile nodes in MANETs are capable of communicating with each other without any network infrastructure or any centralized administration. Mobile nodes are not bounded to any centralized control like base stations or mobile switching centers. Due to the limited transmission range of wireless network interfaces, multiple hops may be needed for one node to exchange data with another across the network. In such a network, each mobile node operates not only as a host but also as a router, forwarding packets for other mobile nodes in the network that may not be within direct wireless transmission range of each other. Each node participates in an ad-hoc routing function that allows it to discover multi-hop paths through the network to any other node.

The remainder of this report is organized as follows. We discuss related work in Section 1 and describe the motivations and contributions of the paper in Section 2. We present the leading ad-hoc multicast routing protocol which our work is mostly related to in Section 3. Several classification methods are given. The taxonomy of multicast routing protocols for MANETs, analysis and comparison of them are discussed in detail in Section 4. In Section 5, evaluation methods for multicast routing protocols are discussed. Finally, we draw summaries and discuss directions of future work about designing multicast routing protocols over MANETs in Section 6.

2. Related work

As a promising network type for future mobile application, MANETs are attracting more and more researchers [2,3]. In multicast routing protocols field, some researches on the taxonomy of multicast routing protocols over MANETs have been carried out. Tariq Omari et al. [4] classify multicast routing protocols into tree-based mesh-based, stateless, hybrid-based and flooding protocols and evaluate the performance and capacity of multicast routing protocols for MANETs. Two distinct on-demand multicast protocols, Forwarding Group Multicast Protocol (FGMP) and core-assisted mesh protocol are described in [5]. And other multicast protocols used in MANETs have also been briefly summarized. In [6], AODV ODMRP, PBM and PAST-DMPUMA are explained. In [7], Cordeiro et al. provide information about the current state-of-the-art in multicast protocols for MANETs, and compares them with respect to several performance metrics. In [7,8], authors classify these protocols into four categories based on how routes are created to the members of the group: tree-based approaches, meshed-based approaches, stateless multicast and hybrid approaches.

3. Motivations and contributions

Although there are several existing surveys on multicast routing protocols over MANETs, they are either not up-to-date or mostly focus on the same technical trend, such as tree, mesh and hybrid-based multicast routing protocols. Compared to other survey work in the area, this paper gives the state-of-the-art review for typical multicast routing protocols with popular classification methods for MANETs. Through the paper, we give some research examples in the area of multicast routing protocol. A number of research papers and implementations are referenced to illustrate the ideas and to provide the readers avenues for further investigations. We also draw on work and do not pretend to produce a complete taxonomy of the research area. We feel this overview will be of particular interest to those who are unfamiliar with the breadth of issues relating to multicast routing protocols design for MANETs.

Our primary goal is to provide a useful taxonomy of the field of mobile ad-hoc network multicast routing protocols, which are comprehensive and up-to-date. To accomplish this goal, we identify those basic components of a multicast routing protocol, break them down into the necessary separate mechanisms, and categorize the multicast routing protocols according to their properties, mechanisms and functionalities. For each classification, we also list possible design choices proposed by the research communities. Compared with previously published surveys, our taxonomy of multicast routing protocols over MANETs provides several advantages, including:

1. Analysis and comparison are discussed for protocols that belong to the same category. In this way, distinct features, inheriting relationships and performance characteristics of these multicast routing protocols can be distinguished and evaluated.
2. Mechanism characteristics: such as the route metric, the way for route discovery, and the way to trigger routing update and the destination for those updates, the need for Hello messages are discussed.
3. Properties can be used to determine applicable scenarios, for example, multiple routes support, unidirectional link support, multicast capability, and network structure type are discussed.
4. Presents typical protocols selected from the class of similar approaches that can reflect the state-of-the-art of research work on multicast routing protocols for MANETs. The protocols are reviewed along the typical characteristics presented.
5. Many new ideas are proposed, such as overlay multicast, network-coding-based multicast, and energy-efficient multicast. Many recent references are included.
6. Covers the major progress on this specific topic. Future work discussions serve to inspire other researchers to work on potential important and high-impact directions.

4. Multicasting routing protocols

The majority of applications for MANETs are in areas where rapid deployment and dynamic reconfiguration are necessary and the wired network is not available. These include military battlefields, emergency search and rescue sites, classrooms, and conventions where participants share information dynamically using their mobile devices. These applications lend themselves well to multicast operation. In addition, within a wireless medium, it is even more crucial to reduce the transmission overhead and power consumption. Multicasting can be used to improve the efficiency of the wireless link when sending multiple copies of messages to exploit the inherent broadcast nature of wireless transmission. So multicast plays an important role in MANETs [2].

In the wired environments, there are two popular network multicast approaches, namely, shortest path multicast tree and core-based tree [9]. The shortest path multicast tree guarantees the shortest path to each destination. But each source needs to build a tree. Usually, there exist too many trees in the network, so the overhead tends to be large. In contrast, the core-based tree constructs only one tree for each group and the number of trees is greatly reduced.

Unlike typical wired multicast routing protocols, multicast routing for MANETs must address a diverse range of issues due to the characteristics of MANETs, such as low bandwidth, mobility and low power. MANETs deliver lower bandwidth than wired networks; therefore, the information collection during the formation of a routing table is expensive. Mobility of nodes, which causes topological changes of the underlying network, also increases the volatility of network information. In addition, the limitation of power often leads users to disconnect mobile units.

Multicasting routing protocols have emerged as one of the most focused areas in the field of MANETs. There are three basic categories of multicast methods [9] in MANETs:

1. A basic method is to simply flood the network. Every node receiving a message floods it to a list of neighbors. Flooding a network acts like a chain reaction that can result in exponential growth.
2. The proactive approach pre-computes paths to all possible destinations and stores this informa-

tion in the routing table. To maintain an up-to-date database, routing information is periodically distributed through the network.

3. The final method is to create paths to other nodes on demand. The idea is based on a query response mechanism or reactive multicast. In the query phase, a node explores the environment. Once the query reaches the destination the response phase starts and establishes the path.

Recently, many multicast routing protocols have been newly proposed to perform multicasting in MANETs. These include ad-hoc multicast routing protocol utilizing increasing Id numbers (AMRIS) [10], multicast ad-hoc on-demand vector (MAODV) [11], core assisted mesh protocol (CAMP) [12], lightweight adaptive multicast (LAM) [13], location guided tree (LGT) [14], on-demand multicast routing protocol (ODMRP) [15], forwarding group multicast protocol (FGMP) [16], ad-hoc multicast routing (AMRoute) [17], multicast core extraction distributed ad-hoc routing (MCEDAR) [18] and differential destination multicast (DDM) [19]. Most of these multicast routing protocols are primarily based on flavors of distance-vector or link-state routing plus additional functionalities to assist the routing operations in particular ways. The goals of all these protocols include minimizing control overhead, minimizing processing overhead, maximizing multi-hop routing capability, maintaining dynamic topology and preventing loops in the networks etc.

However, many multicast routing protocols do not perform well in MANETs because in a highly dynamic environment, nodes move arbitrarily, thus network topology changes frequently and unpredictably. Moreover, bandwidth and battery power are limited. These constraints in combination with the dynamic network topology make multicasting routing protocol designing for MANETs extremely challenging.

5. Taxonomy of multicast routing protocols

To compare and analyze multicast routing protocols, appropriate classification methods are important. Classification methods help researchers and designers to understand the distinct characteristics of different multicast routing protocols and find out the internal relationship among them. Therefore, we present protocol characteristics which are used to group and compare different approaches. These characteristics are mainly related to the information which is exploited for MANETs and the roles which nodes may take in the multicast routing process.

5.1. Tree, mesh and hybrid multicast routing protocols

One of the most popular methods to classify multicast routing protocols for MANETs is based on how distribution paths among group members are constructed. 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. 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 algorithms for distribution tree construction and maintenance. This requires a source to be aware of the topology information and addresses of all its receivers in the multicast group. Therefore, source-rooted tree-based multicast routing protocols suffer from high traffic overhead when used for dynamic networks. AMRoute is an example for source-rooted tree multicast routing protocol.

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. But unlike source-rooted tree-based multicast routing, multicast trees are only rooted at core nodes. For different source-rooted multicast routing protocols, core nodes may perform various routing and management functions. Shared Tree Ad-hoc Multicast Protocol (STAMP) [20] and Adaptive Core-based Multicast Routing protocol (ACMP) [21] are core-based multicast routing protocols proposed for MANETs.

Tree-based protocols provide high data forwarding efficiency at the expense of low robustness. Their advantage is their simplicity. Their disadvantage is that until the tree is reconstructed after movement of a node, packets possibly have to be dropped.

In a mesh-based multicast routing protocol, packets are distributed along mesh structures that are a set of interconnected nodes. Route 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.

Mesh-based protocols perform better in high mobility situation as they provide redundant paths from source to destinations while forwarding data packets. However, mesh-based approaches sacrifice multicast efficiency in comparison to tree-based approach. Mesh-based Multicast Routing Protocol with Consolidated Query Packets (CQMP) [22], Enhanced On-Demand Multicast Routing Protocol (E-ODMRP) [23] and Bandwidth Optimized and Delay Sensitive (BODS) [24] are the mesh-based multicast routing protocols proposed for MANETs.

Hybrid-based multicast routing protocols combine the advantages of both tree and mesh-based approaches. Hence, hybrid protocols address both efficiency and robustness. Using this scheme, it is possible to get multiple routing paths, and duplicate messages can reach a receiver through different paths. However, they may create non-optimal trees with nodes mobility. Efficient Hybrid Multicast Routing Protocol (EHMRP) [25] is an instance for hybrid-based multicast routing protocol.

5.2. Proactive and reactive multicast routing protocols

Another classification method is based on how routing information is acquired and maintained by mobile nodes. Using this method, multicast routing protocols can be divided into proactive routing and reactive routing.

A proactive multicast routing protocol is called "table-driven" multicast routing protocol. In a network utilizing a proactive routing protocol, every node maintains one or more tables representing the entire topology of the network. These tables are updated regularly in order to maintain up-to-date routing information from each node to every other node. To maintain up-to-date routing information, topology information needs to be exchanged between the nodes on a regular basis, leading to relatively high overhead on the network. On the other hand, routes will always be available on request. There are some typical proactive multicast routing protocols, such as CAMP, LGT and AMRIS.

A reactive multicast routing protocol is also called "on-demand" multicast routing protocol. Reactive protocols seek to set up routes on-demand. If a node wants to initiate communication with a node to which it has no route, the routing protocol will try to establish such a route. Reactive multicast routing protocols have better scalability than proactive multicast routing protocols. However, when using reactive multicast routing protocols, source nodes may suffer from long delays for route searching before they can forward data packets. ACMP and CQMP are examples for reactive routing protocols for MANETs.

5.3. Evaluating capacity, architecture and location for multicast routing protocols

Most of the multicast routing protocols assume a physically flat network architecture with mobile nodes having homogeneous capability in terms of network resources and computing power. In practice however, this assumption may not often hold since there exist various types of mobile nodes with different roles, capacities and mobility patterns. In an architecture-based multicast routing protocol, MANETs have physically hierarchical architectures, which are formed by different types of mobile nodes. For example, Hierarchical QoS Multicast Routing Protocol (HQMRP) [26] for MANETs builds a multicast structure at each level of the hierarchy for efficient and scalable multicast message delivery. Self-Organizing Map (SOM) [27] is also a typical hierarchical architecture, which provides a way for automatically organizing the hierarchical architecture. In location-based multicast routing protocols, the availability of a Global Positioning System (GPS), Bluetooth or other locations systems easily gets geographical information of mobile nodes when needed [28]. Each node determines its own location through the use of GPS or some other type of positioning service. A location service is used by the sender of a packet to determine the location of the destination. The routing decision at each forwarding node is then based on the location information of its neighbors and the destination nodes [29]. Location-based Geocasting and Forwarding (LGF) [30], LGT and Scalable Position-Based Multicast (SPBM) [31] protocol are typical location-based multicast routing protocols for MANETs.

5.4. Quality of service

Another protocol classification is based on metrics used for multicast routing construction as criteria for MANETs. Most of conventional multicast routing protocols are designed for minimizing data traffic in the network or minimizing the average hops for delivery a packet. When Quality of Service (QoS) is considered, some protocols may be unsatisfactory or impractical due to the lack of resources, the excessive computation overhead, and the lack of knowledge about the global network state or the excessive message processing overhead. However, some multicast routing protocols, such as LGT, AMRIS and CAMP are designed without explicitly considering QoS. QoS multicast routing not only requires finding a route from a source to a destination, but satisfying the end-to-end QoS requirement, often given in terms of bandwidth or delay. QoS is more difficult to guarantee in MANETs than in other types of networks, because the wireless bandwidth is shared among adjacent nodes and the network topology changes as the nodes move. This requires extensive collaboration between the nodes, both to establish the routes and to secure the resources necessary to provide the QoS. With the extensive applications of MANETs in many domains, the appropriate QoS metrics should be used, such as bandwidth, delay, packet loss rate and cost for multicast routing protocols. Therefore, QoS multicasting routing protocols face the challenge of delivering data to destinations through multi-hop routes in the presence of node movements and topology changes. Multicast Core Extraction Distributed Ad-hoc Routing (MCEDAR) [32] is an example for QoS-based multicast routing protocols for MANETs.

5.5. Energy efficiency

Because MANETs are a set of nodes that agree upon forming a spontaneous, temporary network with the lack of any centralized administration, any form of infrastructure and nodes are typically powered by batteries with a limited energy supply, each node ceases its function when the battery exhausts. Therefore, given the energy constraints placed on the network's nodes, designing energy-efficient multicast routing protocols is an important issue for MANETs, maximizing the lifetime of its nodes and thus of the network itself [33,34]. Minimum Weight Incremental Arborescence (MWIA) [35], RB-MIDP and D-MIDP [36] are examples for energy-efficient multicast routing.

5.6. Network coding

The advent of the notion of coding at the packet level, commonly called network coding, changes many aspects of networking [37]. Given a network with capacity constraints on links, one problem of designing multicast routing protocols is to maximum the multicast throughput between a source node and a set of receivers. The main advantage of using network coding can be seen in multicast scenarios. Network coding enables better resource utilization and achieves the max-flow which is the theoretical upper bound of network resource utilization, by allowing a network node, such as a router to encode its received data before forwarding it. Each node implementing the network coding function, receives information from all the input links, encodes it and sends the encoded information to all output links. The coded-network lends itself, for multicast connections, to a cost optimization which not only outperforms traditional routing tree-based approaches, but also lends itself to a distributed implementation and to a dynamic implementation when changing conditions, such as mobility, arise [37]. In [38], the authors shows that under a simplified layered model of MANETs, the minimum energy multicast problem in MANETs is solvable as a linear program, assuming network coding.

5.7. Reliable multicast routing protocols

In ad-hoc environments, every link is wireless and every node is mobile. Those features make data loss easy as well as multicasting inefficient and unreliable. Reliable multicast routing protocol becomes a very challenging research problem for MANETs. The design of reliable multicasting depends on the following three decisions: (1) by whom errors are detected; (2) how error messages are signaled and (3) how missing packets are retransmitted.

In the sender-initiated approach, the sender is responsible for the error detection. Error messages are signaled using ACK signals sent from each receiver. A missing piece of data at a receiver is detected if the sender does not receive an ACK from the receiver. In this case, the need to retransmit a missing packet is handled by retransmitting the missing data from the source through a unicast. When several receivers have missing packets, the sender may decide to re-multicast the missing packets to all receivers in the multicast group. In the receiver-initiated approach, each receiver is responsible for error detection. Instead of acknowledging each multicast packet, each receiver sends a NACK once it detects a missing packet. If multicast packets are time-stamped using a sequence number, a missing packet can be detected by a gap between sequence numbers of the receiving packets. When the sender-initiated approach is applied, only the sender is responsible for retransmitting the missing packet, and the corresponding retransmitting method is called an sender-oriented. Note that when the sender receives ACK signals from all the receivers, the corresponding packet can be removed from the history. There are three ways to retransmit the missing packet when the receiver-initiated approach is used: (1) sender-oriented, (2) neighborhood-oriented, and (3) fixed-neighborhood-oriented.

Examples of reliable multicast routing protocols include EraMobile [39], Busy Elimination Multiple Access (BEMA) [40] and Reliable Multicast protocol for wireless mobile multi-hop ad-hoc networks (ReMHoc) [41].

5.8. Overlay multicast routing protocols

In most protocols, both group members and non-members on a tree/mesh link must maintain the multicast states to forward data packets. Thus, multicast protocols must detect and restore link failure, which can be a result of migrations by non-group members as well as group members. As a result, many control messages are issued to repair broken links. To provide data forwarding without involvement of non-group members and to constrain the protocol states on group members, overlay multicast protocols for MANETs enhance the packet delivery ratio by reducing the number of reconfigurations caused by non-group members' unexpected migration in a tree or mesh structure. The advantages of overlay multicast come at the cost of low efficiency of packet delivery and long delay. However, when constructing the virtual infrastructure, it is very hard to prevent different unicast tunnels from sharing physical links, which results in redundant traffic on the physical links. Overlay multicast based on heterogeneous forwarding (OMHF) [42] is an example for overlay multicast routing protocols for MANETs.

5.9. Single and multiple source multicast routing protocols

A multicast group may contain multiple sources due to different kinds of services or applications simultaneously provided by the networks. Each single source multicast routing protocol induces a lot of overhead and thus wastes tremendous network resources in multi-source multicast environments. In multiple source multicast routing protocols, using the clustering technique, a large network can be divided into several sub-networks with only a few cluster heads needing to maintain local information, thus preventing flooding of useless packets and avoiding wasting bandwidth. To achieve efficient multicasting in a multi-source multicast environment, the clustering technique is employed to design an efficient multicast routing protocol for multi-source multicasting. Cluster and multicast path maintenance is expected to adapt dynamic network topology [43].

Multiple source routing is essential for load balancing and offering quality of service. Other benefits of multiple source routing include: the reduction of computing time that routers' CPUs require, high resilience to path breaks, high call acceptance ratio (in voice applications) and better security. Special attention should be given to transport layer protocols as duplicate acknowledgments could occur, which might lead to excessive power consumption and congestion [44].

6. Performance criteria

Many multicast routing protocols are proposed for MANETs based on different design points of view to meet specific requirements from different application domains. There are tree different ways to evaluate and compare the performance of multicast routing protocols for MANETs:

1. The first one is based on user parameters and configurations, such as the average multicast degree, the control overhead, the average delay, the throughput and the multicast service cost [45].
2. The second way is comparing different multicast routing updating methods. Multicast routing update can be done in one of three ways: (a) Store and update: store the information in a routing table and update it by listening to routing messages. (b) Delete all and refresh: discard all old routes (timeout) and start over and (c) Unicast protocol support: use the services of a separate unicast routing protocol for route updating. In another method, the performance of multicast routing protocols is evaluated with different simulation tools, such as NS-2, Opnet, Matlab, CASSAP and SPW [46,47].
3. With the popularity of MANETs and considering the dynamic network features of MANETs, integrated criteria for evaluating performance of MANETs multicast routing protocols should be

proposed to meet the different mobile application requirements in different environments and different design targets [48–50].

7. Summary and future work

7.1. Summary

In summary, a MANET consists of dynamic collections of low power nodes with quickly changing multi-hop topologies that usually composed of relatively low bandwidth wireless link. These constraints make multicasting in MANETs challenging. General solutions to solve these problems are to avoid global flooding and advertising, construction of routes on demand, and dynamically maintain memberships, etc. Multicasting can efficiently support a wide variety of applications that are characterized by a close degree of collaboration, typical for many MANETs. The design of the multicast routing protocols for MANETs are driven by specific goals and requirements based on respective assumptions about the network properties or application area. All protocols have their own advantages and disadvantages. Some constructs multicast trees to reduce end-to-end latency while others build mesh to ensure robustness. Some protocols create overlay networks and use unicast routing to forward packets. Energy-aware multicast protocols optimize either total energy consumption or system lifetime of the multicast tree.

7.2. Future work

As mentioned earlier, research in the area of multicast over MANETs is far from exhaustive. Much of the effort so far has been on devising routing protocols to support effective and efficient communication between nodes that are part of a multicast group. It is really difficult to design a multicast routing protocol considering all the above mentioned issues. Still, there are still many topics that deserve further investigation:

1. *Scalability*. This issue is not only related to multicast in MANETs but also with the ad-hoc itself. A multicast routing protocol is scalable with respect to some constraints posed by MANETs.
2. *Address configuration*. In ad-hoc environments, a different addressing approach may be required. Special care must be taken so that other groups do not reuse a multicast address used by a group at the same time. Node movement and network partitioning makes this task of synchronizing multicast addresses in a MANET really difficult.
3. *Multicast service support*. The multicast protocol defines conditions for joining/leaving groups, multicast participants should be able to join or leave groups at will. On the other hand, service providers can be convinced to support multicast protocols.
4. *Security*. How can the network secure itself from malicious or compromised nodes? Due to the broadcast nature of the wireless medium security provisioning becomes more difficult. Further research is needed to investigate how to stop an intruder from joining an ongoing multicast session or stop a node from receiving packets from other sessions.
5. *Traffic control*. Both source and core-based approaches concentrate traffic on a single node. In stateless multicast group membership is controlled by the source, which leads to the vulnerability of multicast protocols for MANETs. Still need to be investigated is how to efficiently distribute traffic from a central node to other member nodes for MANETs.
6. *QoS*. QoS defines a guarantee given by the network to satisfy a set of predetermined service performance constraints for the user in terms of end-to-end delay, jitter, and available bandwidth. Therefore, multicast routing protocols must be feasible for all kinds of constrained multicast applications to run well in a MANET. However, it is a significant technical challenge to define a comprehensive framework for QoS support, due to dynamic topology, distributed management and multi-hop connections for MANETs.
7. *Power control*. For power-constrained wireless networks, a crucial issue in routing and multicasting is to conserve as much power as possible while still achieving good throughput performance.
8. *Multiple sources*. Most of the existing multicast routing protocols in ad-hoc networks are designed for single source multicasting. However, a multicast group may contain multiple sources due to different kinds of services or applications simultaneously provided by the networks. Each single source multicast routing protocol induces

a lot of overhead and thus wastes tremendous network resources in a multi-source multicast environment.

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