The study of multicast routing techniques for ad hoc mobile networks

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Abstract

The mobile ad-hoc network, also known as a MANET, is made up of mobile nodes and has no underlying infrastructure. Mobile nodes are responsible for their own self-organization in order to build a network using radio links. The purpose of mobile ad hoc networks (MANETs) is to expand the concept of mobility into the world of autonomous mobile and wireless domains. This is accomplished by having a collection of nodes create the network routing infrastructure in an ad hoc fashion. The vast majority of MANET applications are found in settings where rapid deployment and dynamic reconfiguration are required but there is no access to wired network infrastructure. These include emergency search and rescue areas, combat battlefields, classrooms, and conventions, all of which encourage participants to transmit information in a dynamic manner utilizing their mobile devices. These applications are ideally suited for use with multicast transmissions. In addition, it is essential to cut down on the amount of power that is consumed as well as the transmission overhead while working with a wireless medium. By taking advantage of the inherent broadcast property of wireless transmission, multicasting can improve the efficiency of the wireless link, allowing for the delivery of several copies of a message at the same time.

Keywods: MANETs, multicast routing, computing environments, Multicast Protocol

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Introduction

The delivery of packets to a group of zero or more hosts that are all identifiable by the same destination address is an example of multicasting [1]. Multicasting is designed to be used in computing environments that are geared toward collaborative work in which the membership of a host group is often fluid; that is, hosts may join or quit groups at any moment. There are no limits placed on either the physical location or the total number of participants in a host group. It's possible for a host to belong to multiple groups at the same time. Additionally, a host does not need to be a part of a group in order to send packets to the other hosts that are part of that group. There are two common types of network multicast methods used in wired environments. These are the core-base tree and the shortest path multicast tree. The shortest path multicast tree approach ensures that the path to each destination is the shortest one possible, but it requires each source to construct a tree. As a result, there are an excessive number of trees in the network. The core-based tree method is not able to ensure the shortest path from a source to a destination; nevertheless, it does only require the construction of a single tree for each of the groups. As a consequence of this, the number of trees has drastically decreased.

At the moment, one environment that presents a particularly difficult challenge for multicast is that of MANETs [2,3]. A mobile ad hoc network, also known as a MANET, is a temporary and dynamic wireless network that is formed by a group of mobile nodes on a shared wireless channel without the assistance of a fixed networking infrastructure or centralized administration. A MANET is a self-organizing collection of wireless mobile nodes that form the network. When the recipient is located within the transmission range of the source node, a communication session can be completed using a single hop of transmission. If the recipient is located further away, the session must be completed using relaying across intermediary nodes. As a result of this characteristic, MANETs are often referred to as multi-hop packet radio networks. Nevertheless, the transmission range of each low-power node is restricted to the proximity of the other nodes, and nodes that are out of range are connected to the network via intermediate nodes.

Literature Review

Researchers are becoming increasingly interested in MANETs because this sort of network holds great potential for future mobile applications [2,3]. In the field of multicast routing protocols, several studies on the taxonomy of multicast routing protocols over MANETs have been carried out. These studies focus on the classification of multicast routing protocols. In their study, Tariq Omari and colleagues [4] classified multicast routing strategies into tree-based, mesh-based, state-less, hybrid-based, and flooding protocols. They also evaluated the performance and capacity of multicast routing protocols for MANETs. In [5, two separate on-demand multicast protocols are defined.

Objectives of the Study

There are several existing surveys on multicast routing protocols over MANETs; however, 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. Despite this, there are several existing surveys on multicast routing protocols over MANETs. This paper presents a state-of-the-art review for standard multicast routing protocols together with popular classification methods for MANETs, in comparison to other survey work that has been done in the same general field.

Our primary objective is to produce a complete and up-to-date taxonomy of the field of mobile ad-hoc network multicast routing protocols so that it may be used as a useful tool. In order to achieve this objective, we will first determine the fundamental aspects of a multicast routing protocol, then separate those fundamental aspects into the necessary mechanisms, and finally classify the various multicast routing protocols according to the properties, mechanisms, and functionalities that they share. We also provide a list of feasible design choices for each classification, based on what the research communities have suggested. When compared to surveys that have been previously published, our taxonomy of multicast routing protocols over MANETs offers a number of benefits, including the following:

1. Protocols that fall into the same category are analyzed and compared side by side, and the findings are discussed. It is possible to differentiate and assess the many features, inheritance relationships, and performance aspects of these multicast routing protocols using this method.

2. Mechanism characteristics are examined, including the route metric, the method for route discovery, the method to trigger routing update as well as the destination for those updates, and the requirement for Hello messages.

3. The properties can be used to identify which situations are applicable; for example, the support for numerous routes, the support for unidirectional link support, the capacity to do multicasting, and the kind of network structure are described.

Multicasting routing protocols

The vast majority of applications for MANETs are found in locations that require rapid deployment and dynamic reconfiguration but do not have access to a wired network. These include emergency search and rescue situations, combat battlefields, classrooms, and conventions where people share information in a dynamic manner utilizing their mobile devices. These applications lend themselves quite well to being operated in a multicast fashion. In addition, while working with a wireless media, it is even more important to cut down on the transmission overhead as well as the amount of power that is consumed. When transmitting numerous copies of a message in order to take advantage of the natural broadcast aspect of wireless transmission, multicasting is a technique that can be utilized to boost the effectiveness of the wireless link. As a result, multicasting is an essential component of MANETs [2].

Multicast routing for MANETs, in contrast to the multicast routing protocols used in wired networks, must solve a varied variety of challenges due to the characteristics of MANETs, such as low bandwidth, mobility, and low power. These characteristics include: Because MANETs have a lesser bandwidth than wired networks, the information collection process that occurs during the creation of a routing table is more expensive. The mobility of nodes, which results in topological shifts across the underlying network, also contributes to an increase in the informational volatility of the network. In addition, customers are frequently prompted to unplug mobile units due to the limited available power.

Within the realm of MAN-ETs, one of the areas that has attracted the greatest attention recently is that of multicasting routing protocols. In MANETs, multicast techniques can be broken down into one of three primary categories: [9]

1. One simple approach is to just flood the network with traffic. Each node that is in receipt of a message will propagate it to its neighboring nodes. Inundating a network has the same effect as setting off a chain reaction, which can lead to exponential development.

2. The proactive technique pre-computes routes to all of the potential destinations and then stores this information in the routing table. Routing information is frequently dispersed over the network in order to ensure that the database is always accurate and up to date.

3. The last option is to make paths to other nodes on demand whenever they are needed. A query response system, also known as reactive multicast, serves as the foundation for this approach. During the inquiry phase, a node will investigate its surrounding environment. The response phase begins as soon as the query reaches its target, at which point the path is also established.

Taxonomy of multicast routing protocols

It is vital to use proper classification methods in order to compare and analyze different multicast routing protocols. The many multicast routing protocols each have their own unique properties, and researchers and designers need classification methods to assist them comprehend these qualities and determine how they are related to one another. As a result, we will discuss the characteristics of the procedure, which will be used to categorize and evaluate the various alternatives.

These features are mostly associated with the data that is utilized for MANETs and the roles that individual nodes may play in the process of multicast routing.

Tree, mesh and hybrid multicast routing protocols

How distribution paths are generated is a popular way to characterize multicast routing techniques for MANETs. This method divides MANET multicast routing approaches into tree-based, mesh-based, and hybrid protocols. Tree-based multicast routing systems are separated into source-rooted and core-rooted schemes. In a source-rooted tree-based multicast routing system, source nodes are the trees' roots and execute building and maintenance algorithms. A source must know the multicast group's topology and receiver addresses. Dynamic networks have substantial traffic overhead with source-rooted tree-based multicast routing techniques. AM Route uses source-rooted tree multicast routing. In core-rooted tree multicast routing, cores distribute multicast data and manage membership. Some multicast routing protocols are tree-based. Multicast trees are rooted at core nodes, unlike source-rooted trees. Core nodes conduct routing and management for source-rooted multicast routing systems. Core-based multicast routing protocols for MANETs include STAMP [20] and ACMP [21].

Proactive and reactive multicast routing protocols

Another approach of classification is based on the way in which mobile nodes acquire and keep track of routing information. It is possible to categorize multicast routing protocols as either proactive or reactive using this way.

The term "table-driven" multicast routing protocol refers to a protocol that takes a proactive approach to multicast routing. Every node in a network that uses a proactive routing protocol keeps one or more tables that collectively reflect the network's overall topology. These tables can be found on every node. These tables are continuously updated in order to ensure that the routing information that is maintained from one node to another node is accurate and up to date. It is necessary for the nodes on the network to regularly share topological information with one another in order to keep the routing information up to date. This results in a rather high amount of overhead for the network. On the other hand, we will at all times be able to accommodate route requests. Protocols such as CAMP, LGT, and AMRIS are examples of typical proactive multicast routing protocols.

Evaluating capacity, architecture and location for multicast routing protocols

The majority of multicast routing methods are based on the assumption that the network design is physically flat, with mobile nodes that have similar capabilities in terms of their access to network resources and their processing capacity. However, this assumption may not always hold true in practice due to the fact that there are many different kinds of mobile nodes, each with a unique set of responsibilities, competences, and mobility patterns. MANETs use an architecture-based multicast routing protocol, which results in the formation of physically hierarchical topologies.

Quality of service

MANETs are also classified by multicast routing metrics. Most multicast routing protocols minimize network data traffic or packet hops. Some protocols may be unsatisfactory or unfeasible when Quality of Service (QoS) is considered due to lack of resources, excessive calculation overhead, lack of global network state knowledge, or excessive message processing overhead. LGT, AMRIS, and CAMP are designed without QoS. QoS multicast routing entails finding a route from a source to a destination and satisfying end-to-end QoS requirements. MANETs make QoS difficult to guarantee since the wireless band- width is shared among adjacent nodes and the network topology varies as nodes move. This involves node collaboration to construct routes and secure QoS resources. With MANETs' many applications, QoS measures including bandwidth, delay, packet loss rate, and cost should be employed for multicast routing protocols. QoS multicasting routing protocols must send data across multi-hop pathways despite node migrations and topology changes. QoS-based multicast routing protocols for MANETs include MCEDAR [32].

Energy efficiency

As a result of the fact that MANETs are composed of a collection of nodes that mutually decide to form an ad hoc and transient network in the absence of any form of centralized administration or infrastructure, as well as the fact that nodes are typically powered by batteries that have a limited supply of energy, the operation of each node is terminated when the battery runs out. As a result, due to the energy restrictions that are placed on the network's nodes, the development of energy-efficient multicast routing protocols is an important issue for MANETs. This will maximize the lifetime of the network's nodes, which will in turn maximize the lifetime of the network itself [33,34]. Minimal Weight Incremental Arborescence (MWIA) [35], RB-MIDP, and D-MIDP [36] are a few examples of multicast routing protocols that are efficient in terms of energy consumption.

Network coding

Numerous areas of networking are subject to change as a result of the introduction of the idea of coding at the packet level, often known as network coding [37]. When creating multicast routing protocols, one of the challenges that must be met is to maximize the multicast throughput between a source node and a group of receivers when the network in question has capacity limits on the links. The use of network coding has the most significant benefits when applied to multicast situations. By enabling a network node, like a router, to encode its received data before forwarding it, network coding enables better resource utilization and achieves the max-flow, which is the theoretical upper bound of network resource utilization.

Reliable multicast routing protocols

Every link in an ad-hoc network is a wireless one, and every node in the network can move freely. Because of these traits, it is simple to lose data, and multicasting is both inefficient and unstable. When it comes to MANETs, developing a reliable multicast routing protocol becomes a highly tough research problem. The implementation of dependable multicasting is contingent on the following three choices: (1) who is responsible for the detection of problems; (2) how error messages are communicated; and (3) how missing packets are made up for.

Overlay multicast routing protocols

For the majority of protocols, in order to forward data packets, both group members and non-members on a tree or mesh network are required to preserve the multicast states. Therefore, multicast protocols need to be able to detect and fix broken links, which may have occurred as a result of migrations made not only by group members but also by individuals who are not members of the group. As a direct consequence of this, a great number of control messages are sent out to restore damaged links.

Single and multiple source multicast routing protocols

Because many kinds of services or applications might be simultaneously delivered by the networks, a multicast group may have more than one source. Each single source multicast routing protocol results in a significant amount of overhead and, as a result, wastes a substantial amount of network resources in systems that support multiple sources of multicasting. Clustering is a technique that is used in multiple source multicast routing protocols. With this technique, a large network can be divided into several sub-networks, and only a few cluster heads need to be responsible for maintaining local information.

Performance criteria

Multiple multicast routing protocols have been proposed for MANETs, each of which takes a somewhat different approach to the construction of the network in order to satisfy the requirements of a particular application domain. There are three distinct approaches of assessing and contrasting the performance of multicast routing protocols for MANETs, which are as follows:

1. The first one is determined by the user's configurations and settings, such as the average multicast degree, the control overhead, the average delay, the throughput, and the cost of the multicast service [45].

2. The second method is to examine various strategies for updating multicast routing information. One of these three methods can be used to do a multicast routing update: (a) Store the information and then update it by listening to routing messages: store the information in a routing table and then update it by doing so.

Conclusions

We can state that a MANET is made up of dynamic collections of low power nodes that have rapidly changing topologies that involve several hops and are typically made up of relatively low bandwidth wireless links. Because of these limits, multicasting in MANETs is a difficult task. In general, the answers to these difficulties include avoiding worldwide flooding and advertising, building routes on demand, and dynamically maintaining memberships, amongst other potential solutions. A wide variety of applications that are characterized by a high level of collaboration, which is common for many MANETs, can be efficiently supported by multicasting in an effective manner. Specific goals and criteria are used as a driving force in the design of multicast routing protocols for MANETs. These goals and requirements are based on respective assumptions about the qualities of the network or the application area. Each protocol has a set of benefits and drawbacks that are unique to itself. While some people develop multicast trees to cut down on end-to-end latency, others build mesh to make sure the system is reliable. Certain protocols are responsible for the creation of overlay networks and the implementation of unicast routing to forward packets. Energy-aware multicast protocols optimize either the total amount of energy consumption or the lifetime of the system that the multicast tree is running on.

Future work

Research in the field of multicasting over MANETs is not even close to being exhaustive, as was indicated earlier. A significant portion of the work that has been done up to this point has focused on the development of routing protocols that are intended to facilitate communication that is both effective and efficient between nodes that are members of a multicast group. When all of these concerns are taken into consideration, developing a multicast routing system is a very challenging task. Nevertheless, there are still a great many subjects that warrant additional investigation:

1. Scalability: This problem is not just associated with the use of multicast in MANETs but also with the ad-hoc protocol itself. A multicast routing technique can be made to scale despite the presence of certain MANET-imposed restrictions.

2. The configuration of the address: It's possible that a different way of treating things will be necessary in ad-hoc settings. It is imperative that extra precautions be made to prevent other groups from reusing a multicast address that is being utilized by a group at the same time. The process of synchronizing multicast addresses in a MANET is made extremely challenging by the migration of nodes and the splitting of the network.

3. Support for services using multicast: The multicast protocol outlines the requirements for entering and exiting groups, and participants in multicast should have the freedom to enter or exit groups at their discretion. On the other hand, service providers can be persuaded to accept multicast protocols if they are shown sufficient evidence.

4. Security: How can the network protect itself from nodes that are hostile or have been compromised? Because wireless communication is broadcast, security provisioning is made more difficult by this characteristic of the medium. Further investigation is required to determine how to prevent an intruder from entering an active multicast session or how to prevent a node from receiving packets from other sessions. Both of these scenarios involve multicasting.

5. Traffic control: Both source-based and core-based techniques direct traffic to a single node for concentration. The fact that the source has control over the membership of the group in stateless multicasting makes the multicasting protocols used in MANETs susceptible to attack. When it comes to MANETs, the question of how to effectively distribute traffic from a central node to the other member nodes needs to be researched further.

6. QoS: A assurance that the network will meet a set of the user's preset service performance limitations with regard to end-to-end delay, jitter, and available bandwidth is what Quality of Service (QoS) stands for. This guarantee is supplied by the network. Therefore, multicast routing protocols need to be practical in order for a MANET to support the successful operation of a wide variety of limited multicast applications. However, because MANETs include dynamic topologies, distributed administration, and multi-hop connections, it is a significant problem from a technical standpoint to define an all-encompassing framework for quality of service (QoS) support.

7. The exercise of power: When it comes to routing and multicasting, one of the most important considerations for power-constrained wireless networks is to preserve as much power as possible while yet attaining satisfactory throughput performance.

8**. Multiple sources**. The majority of the multicast routing protocols that are currently in use in ad hoc networks were created with single source multicasting in mind. However, due to the fact that the networks can simultaneously deliver many different kinds of services and applications, a multicast group might have more than one source. In a setting that supports many sources of multicast data, the use of single-source multicast routing protocols results in a significant amount of unnecessary overhead and the waste of significant amounts of network resources.

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