

A Overview 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 (MNs) without any infrastructure. MNs self-organize to form a network over radio links. In this environment, multicast routing protocols are faced with the challenge of producing multi-hop routing under host mobility and bandwidth constraint. Multicast routing plays a significant role in MANETs. In recent years, various multicast routing protocols with distinguishing feature have been newly proposed. In order to provide a comprehensive understanding of these multicast routing protocols designed for MANETs and pave the way for the further research, a survey of the multicast routing protocols is discussed in detail in this paper. Qualitatively, based on their primary multicast routing selection principle, we show that all these protocols could be placed under one of two broad routing selection categories: multicast routing based on application independence and multicast routing based on application dependence.

I. 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, 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.

With the development of wireless communication technology, two basic wireless network models have been developed for the wireless communication system [1]. The fixed backbone wireless model consists of a large number of Mobile Nodes (MNs) and relatively fewer, but more powerful, fixed nodes. The communication between a fixed node and a MN within its range occurs via the wireless medium. However, this requires a fixed permanent infrastructure. Another system model, a Mobile Ad-hoc Network (MANET) [2], [3], it is a self-organizing collection of MNs that form a temporary and dynamic wireless network 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 network [4], [5]. 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.

MNs in MANETs are capable of communicating with each other without the use of a network infrastructure or any centralized administration. 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 MN operates not only as a host but also as a router, forwarding packets for other MNs in the network that may not be within direct wireless transmission range of each other. Each node participates in an ad-hoc routing protocol that allows itself to discover multi-hop paths through the network to any other node.

Although there are already a few surveys in the area and some of them are even cited by this paper itself, some of them are out of date. This paper includes new technical trends such as overlay multicast, network coding-based multicast, energy efficient multicast etc. and the classification of the multicast protocols is a novel aspect of this article. We do not follow the classification methods of either the convention internet multicast or the methods of previous work, which already presented different survey studies in the area and provide enough insight on the classification of the current research work in the field. Our primary goal is to provide a useful taxonomy of the field of multicast routing protocol, which is comprehensive and up-to-the-minute. To accomplish this goal, we identify those basic components of a multicast routing protocol, break them down into the necessary separate mechanisms, and categorize properties we feel the mechanisms need to provide in order to fulfill its function for the multicast routing protocol

II. ROUTING PROTOCOLS FOR MANETS

A. Unicast Routing Protocols

Routing is the most fundamental component in networks to support data communications. To make MANETs practical, efficient and effective unicast routing protocol is being a critical issue. Many different unicast routing protocols [4] have been developed for MANETs. They can be classified into two types of unicast routing methodologies as follows: A proactive unicast routing protocol is also called a "table driven" unicast routing protocol.

Using the proactive unicast routing protocol, nodes continuously evaluate routes to all reachable nodes and attempt to maintain consistent, up-to-date routing information. When a network topology change occurs, respective updates must be propagated throughout the network to notify the change. Most proactive unicast routing protocols proposed have inherited properties from algorithms used in wired networks. To adapt to the dynamic features of MANETs, necessary modifications have been made on traditional wired network unicast routing protocols. Using the proactive unicast routing algorithms, MNs proactively update network state and maintain a route regardless of whether the data traffic exists or not, the overhead to maintain up-to-date network topology information is high. The Optimized Link State Routing protocol (OLSR) [6] and Dynamic destination-Sequenced Distance-Vector protocol (DSDV) [7] are examples for proactive routing protocols for MANETs.

A different approach from the proactive unicast routing is the reactive unicast routing. The reactive routing protocol is also called source-initiated "on-demand" unicast routing protocol. This type of unicast routing creates routing only when desired by the source node. When a node requires a routing to a destination, it initiates a routing discovery process within the network. This process is completed once a route is found or all possible routing permutations have been examined. Active routes may be disconnected due to node mobility in MANETs. Therefore, route maintenance is an important operation of reactive routing protocols. The Dynamic Source Routing protocol (DSR) [8] and Ad-hoc On-demand Distance Vector protocol (AODV) [9] are examples for reactive routing protocols. Compared to the proactive

routing protocols, less control overhead is a distinct advantage of the reactive routing protocols. Thus, reactive routing protocols have better scalability than proactive routing protocols. However, when using reactive routing protocols, source nodes may suffer from long delays for route searching before they can forward data packets.

B. Multicast Routing Protocols

Applications of MANETs are in areas where rapid deployment and dynamic reconfiguration are necessary, but the 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 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 property of wireless transmission. So multicasting plays an important role in MANETs.

In the wired environment, there are two popular network multicast approaches, namely, the shortest path multicast tree and core-based tree. 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, such as, low bandwidth, mobility and low power. MANETs deliver lower bandwidth than wired networks. Therefore, the information collection is expensive during the formation of a Routing Table (RT). 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.

Recently, many multicast routing protocols have been newly proposed. The Ad-hoc Multicast Routing protocol utilizing increasing ID numbers (AMRIS) [10] builds a shared-tree to deliver multicast data. Each node in the multicast session is assigned an ID number and it adapts to connectivity changes by utilizing the ID numbers. The Multicast Ad-hoc On-Demand Vector (MAODV) [11] stems from the use of a destination sequence number of each multicast entry. The sequence number is generated by the multicast group-head to prevent loops and to discard stale routes. The Ad-hoc Multicast Routing (AMRoute) [12] is also a shared-tree protocol which allows dynamic core migration based on group membership and network configuration. The Lightweight Adaptive Multicast (LAM) algorithm [13] is a group shared-tree protocol that does not require timer-based messaging. Similar to the On-Demand Multicast Routing Protocol (ODMRP) [14], the Core Assisted Mesh Protocol (CAMP) [15] uses a mesh. However, a conventional routing infrastructure based on enhanced distance vector algorithm or link state algorithm is required for CAMP to operate. Core nodes are used to limit the traffic required when a node joins a multicast group. The Location Guided Tree (LGT) [16] is a small group multicast scheme based on packet encapsulation. It builds an overlay multicast packet distribution tree on top of the underlying unicast routing protocol. The Differential

Destination Multicast (DDM) [17] can be viewed as flooding with "limited scope," wherein the flooding is contained within selected Forwarding Group (FG) nodes.

III.CHARACTERISTICS OF MULTICAST ROUTING PROTOCOLS

Characteristics of multicast routing protocols are very important for researchers and designers to help to understand a multicast routing protocol and find its relationship with others. These characteristics mainly are related to the information, which is exploited for MANETs, when this information is acquired, and the roles which nodes may take in the multicast routing process.

A. Evaluation Principles for Multicast Routing Protocols

Most of the multicast routing protocols assume physically flat network architecture with MNs having homogeneous capability in terms of network resources and computing power. In practice, however, this assumption often may not hold true since there exist various types of MNs with different role, capacity and mobility pattern. In architecture-based multicast routing protocols, MANETs have physically hierarchical architecture, where different types of MNs form an ad-hoc network hierarchy. For example, the Hierarchical QoS Multicast Routing Protocol (HQMRP) [18] builds a

multicast structure at each level of the hierarchy for efficient and scalable multicast message delivery. And the Self- Organizing Map (SOM) [19] 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 MNs when needed [20]. 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 locations of the forwarding node's neighbours and the destination node.

B.Performance Criteria for Multicast Routing Protocols

Although numerous multicast routing protocols have been proposed for MANETs, there is no a "one-for-all" scheme

that works well in scenarios with different network sizes, traffic overloads and node mobility patterns. Moreover, those protocols are based on different design philosophies to meet specific requirements of different application domains. Thus, the performance of a multicast routing protocol may vary dramatically with the variations of network status and traffic overhead. It is a very difficult make to give a comprehensive performance comparison for a large number of multicast routing protocols. There are three different ways to evaluate and compare the performances of multicast routing protocols as follows:

1)User parameters and configurations; such as average multicast degree, control overhead, average delay, throughput and multicast service cost;

2)Different updating methods; Multicast routing updating can be done in one of three ways: 1) Store and update: store the information in a RT and update it by listening to routing messages; 2) Delete all and refresh: discard all old routes (timeout) and start over again; 3) Unicast protocol support: use the services of a separate unicast routing protocol for routing updating;

3)The performance is evaluated by different simulation tools, such as NS-2, Opnet, Matlab, CASSAP, Glo-MoSim and SPW.

IV. SURVEY OF TYPICAL MULTICAST ROUTING PROTOCOL

Because many multicast routing protocols have been proposed for MANETs, it is impossible to cover all of them in this review. In this section, the multicast routing protocols are discussed in detail and distinct features, inheriting relationships and performance characteristics of these routing protocols can be evaluated. There are some selection criteria for the multicast routing protocols in the paper as follows:

- 1)Protocols which are just popular and reflect the state-of the-art of research work on multicast routing protocols.
 - 2)Protocols which cover the major progress on this specific topic and inspire other researchers on which potential directions they should work.
 - 3)Protocols which present new ideas, new technical trends and are currently in practical use.
 - 4)Protocols which are simple and easy to understand through sufficiently introducing the fundamental concepts and background of multicast.
 - 5)Protocols which are published in top international conferences or journals.
 - 6)Protocols which are abbreviated and easy to be remembered for the researchers in this filed.
- A. The Shared Tree Ad-hoc Multicast Protocol (STAMP)

The Shared Tree Ad-hoc Multicast Protocol (STAMP) [24] 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.

B. The Adaptive Core-Based Multicast Protocol (ACMP)

The Adaptive Core-based Multicast routing Protocol (ACMP) [25] is an on-demand, source-oriented group-shared tree multicast routing protocol. ACMP is trying to find trade-off between routing overhead and data transmission efficiency. It uses a tree structure to connect all group members on demand. A core is the first source of a multicast session for group members to join the multicast group. If no core exists in the network, it is not necessary to construct and maintain tree and all receivers would remain silent. ACMP selects the core to give the indication of multicast data so that a multicast structure can be constructed and maintained only when there are requirements. Core also limits the control traffic for group members to join the multicast group.

C. The Mesh-Based Multicast Routing Protocol with Consolidated Query packets (CQMP)

The Mesh-based multicast routing Protocol with Consolidated Query packets (CQMP) [26] is a reactive mesh-based multicast routing protocol with an idea of “query packet consolidation” to address this scalability problem. It retains all of the advantages of the ODMRP, such as high packet delivery ratio under high mobility, high throughput. Moreover, the protocol significantly reduces control overhead, one of the main weaknesses of ODMRP, under the presence of multiple sources. This feature is a crucial contributing factor to the scalability of multicast routing for MANETs.

D. The Enhanced On Demand Multicast Routing Protocol (EODMRP)

The Enhanced On-Demand Multicast Routing Protocol (EODMRP) [27] is an enhancement of ODMRP, which is a reactive mesh-based multicast routing protocol. It is an enhanced version of ODMRP with adaptive refresh. Adaptation is driven by receivers’ reports. The second enhancement is the “unified” local recovery and receiver joining scheme. As the time between refresh episodes can be quite long, a new node or a momentarily detached node might lose some data while waiting for the routing to it to be refreshed and reconstructed. Upon joining or upon detection of broken route, a node performs an expanding ring search to proactively attach itself to forwarding mesh or to requests a global route refresh from the source. Compared to ODMRP, a slightly lower packet delivery ratio might be expected in EODMRP in light load since the new scheme uses packet loss as indicator of a broken link. The major advantage is reduced overhead, which translates into a better delivery rate at high loads, yet keeping the same packet delivery ratio as the original ODMRP.

E. The Bandwidth Optimized and Delay Sensitive protocol (BODS)

The Bandwidth Optimized and Delay Sensitive (BODS) [28] is a source-rooted mesh multicast routing protocol in a distributed manner. It constructs a multicast delivery structure based on nearest participant heuristic, which is more optimal Bandwidth optimal multicast delivery structure in terms of bandwidth consumption without sacrificing delay performance. The effectiveness of this algorithm is verified by integrating BODS into ODMRP protocol. BODS can achieve similar or better packet delivery ratio with a reduction of data overhead and improve the delay performance of the network especially under high traffic load. This is particularly important for bandwidth-avid and delay-sensitive applications such as multimedia streaming in a bandwidth-limited MANETs. Moreover, being a multicast path setup protocol, BODS is a general protocol that can be integrated into any existing mesh based multicast routing protocols.

F. The Efficient Hybrid Multicast Routing Protocol (EHMRP)

The Efficient Hybrid Multicast Routing Protocol (EHMRP) [29] is a hybrid multicast routing protocol to be suitable for high mobility applications and improve the scalability of the ODMRP. It separates out data forwarding path from join query forwarding path. EHMRP incorporates low overhead local clustering technique to classify all nodes into core and normal categories. When multicast routes to stination nodes are unavailable, join-query messages are sent to all nodes in the network and data packets are forwarded by the core nodes to the destination nodes using DDM, which is a stateless multicast approach where multicast tree information is appended with each data packet header. EHMRP does not require any underlying unicast protocol.

G. The Robust Multicasting in Ad-Hoc Network Using Tree (ROMANT)

The Robust Multicasting in Ad-hoc Network using Tree (ROMANT) [39] is a reactive tree-based multicast routing protocol. Instead of using a new kind of control packet, the existing control packet, the group hello is used to avoid the problem in fixing broken links faced by MAODV. ROMANT fixes the performance problems faced by MAODV (high control overhead and low packet delivery ratio in situations of high mobility, high traffic load and a large number of members). Moreover, ROMANT does not introduce new problems. The process of merging of partitions in ROMANT is much simpler than that of MAODV. ROMANT eliminates the drawbacks of MAODV and avoids any dependency on unicast routing protocols without incurring any extra overhead. It also provides equal or better packet delivery ratio than ODMRP at only a fraction of the total overhead incurred by ODMRP.

H. The Optimized Polymorphic Hybrid Multicast Routing Protocol (OPHMR)

The Optimized Polymorphic Hybrid Multicast Routing protocol (OPHMR) [41] is a proactive, polymorphic energy efficient and hybrid multicast routing protocol. It attempts to benefit from the high efficiency of proactive behaviour and the limited network traffic overhead of the reactive behaviour, while being power, mobility, and vicinity-density aware. The protocol is based on the principle of adaptability and multi-behavioural modes of operations. It is able to change behaviour in different situations in order to improve certain metrics like maximizing battery life, reducing communication delays, improving deliverability, etc. OPHMR defines four different behavioural modes of operation, two power level thresholds, one mobility level threshold and one vicinity density thresholds. Under the four different modes, the lifetime of its corresponding entry is also different. Power threshold determines the node's behaviour in order to extend its battery life. Speed threshold is required to maintain better connectivity and awareness of the topology changes. Density threshold is considered when the mobility speed is high.

I. The Mobile Agents Aided Multicast Routing Protocol (MAMR)

The Mobile Agents aided Multicast Routing protocol (MAMR) [42] is a reactive QoS-based hybrid multicast routing protocol where intelligent MAs can be used with any on demand multicast routing protocol. MAMR can integrate with other existing multicast routing protocols, such as MAODV and ODMRP in order to overcome the limitation that most of multicast routing protocols try to discover the outgoing on demand by flooding route request messages. In MAMR, MAs are simple packets, which move over the network and provide the current topology information and other QoS values such as link delay, congestion etc, which helps nodes for taking efficient routing decisions as they visit different nodes. The

information carried by the MAs helps to find a route for a given destination, when no route exists in the multicast table to

the destination. By this way, the protocol overcomes the additional delay which would have been required, in finding a new route to the destination and also reduces the control traffic generated. And the availability of this route formation at nodes will avoid routing protocols in doing broadcast route discovery and hence reduces end-to-end latency of the network. Although this method requires extra cost for processing MAs, the benefits would be gained in terms of better end-to-end latency and packet delivery ratio.

J. The Multicast Power Greedy Clustering protocol (MPGC)

The Multicast Power Greedy Clustering protocol (MPGC) [43] is an adaptive power-aware and on-demand multicasting protocol with the mesh scheme. It first forms the hierarchical cluster structures with greedy power control where each node can adjust flexibly its transmission power to fit individual geographical location. MPGC uses greedy heuristic clustering, power aware multicasting and clustering maintenance that try to be energy efficient and prolong the network lifetime. MPGC assumes that each node has multiple power levels for transmission and any cluster-head among the super-nodes can connect directly at least one of the other cluster-heads for guarantee of strong connection. The greedy heuristic clustering tries to partition a large scale ad-hoc network into clusters. Simultaneously, it adjusts all nodes' power level for the purpose of power conservation. The selected cluster-heads comprise the super-nodes topology which MPGC can execute on. Importantly, the cluster structure could be disturbed due to the mobility of nodes.

K. The Probability for Refining Energy Efficiency of Multicast Tree Protocol (P-REMiT)

The Probability for Refining Energy-efficiency of Multicast Tree (P-REMiT) [44] is a tree-based multicast routing protocol for building an energy efficient multicast routing. It uses the probability method to balance the total energy consumption and system lifetime of multicast tree. P-REMiT assumes that nodes with omni-directional antennas are stationary, and each node knows the distance between itself and its neighboring nodes. P-REMiT includes three major steps as follows: (1) Building an initial multicast tree; all nodes run the distributed algorithm to build a multicast tree. (2) Refining the multicast tree; the phase is organized in rounds. Each round is led by the multicast source nodes. Source nodes terminate P-REMiT when there is no change in the last round. (3) Eliminating all non-members redundant transmissions by pruning the multicast tree.

L. The Power-Aware Multicast Routing Protocol (PMRP)

The power-aware multicast routing protocol (PMRP) [45] is a tree-based minimum energy multicast routing protocol with mobility prediction. In order to select a subset of paths that provide increased stability and reliability of routes in routing discovery, each node receives the RREQ packet and uses the power-aware metric to get in advance the power consumption of transmitted data packets. If the node has enough remaining power to transmit data packets, it uses the GPS to get the location information (i.e. position, velocity and direction) of the MNs and utilizes this information to calculate the Link Expiration Time (LET) between two connected MNs. During routing discovery, each destination node selects the routing path with the smallest LET and uses this smallest link expiration time as the Route Expiration Time (RET). The destinations nodes collect several feasible routes and then select the path with the longest RET as the primary routing path. Then the source node uses these routes between the source node and each destination node to create a multicast tree. In the multicast tree, the source node will be the root node and the destination nodes will be the leaf nodes.

V. CONCLUSION

In summary, multicasting can efficiently support a wide variety of applications that are characterized by a close degree of collaboration, typical for any MANETs. And the design of the multicast routing protocols are driven by specific goals and requirements based on respective assumptions about the network properties or application areas. In this paper, we

present a comprehensive survey of the multicast routing protocols for MANETs. The purpose of this paper is to survey the multicast routing protocols and study their primary routing selection principles. We discuss the characteristics, routing metrics and routing philosophies of each of these protocols selected from the class of similar approaches, which can reflect the state-of-the-art research work on multicast routing protocols. The classifications of the primary routing selection principles can simplify the task of a network designer in deciding the multicast routing strategies to be adopted at a given condition. Then, we believe our survey will be very useful to the research community and also serve as a great introductory material for someone embarking on MANETs.

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Ravi et al., International Journal of Advanced Research in Computer Science and Software Engineering 3(9), September - 2013, pp. 856-862

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