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Mesh based and Hybrid Multicast Routing Protocols for Mobile Ad hoc Networks: Current state of the art

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Abstract: Producing multi-hop routing in Multicast routing protocols for Manets under host mobility and bandwidth constraint is critical challenge. 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, the current state of the art in development of mesh based and hybrid multicast routing protocols is discussed in detail in this paper.

I. INTRODUCTION

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.

As a promising network type in future mobile application, MANETs are increasingly attracting researchers [2], [3]. Multicast routing protocols belonging to different routing philosophies have been proposed in the literature. A proactive multicast routing protocol pre-determines the routes between any two nodes irrespective of the need for such routes. On the other hand, reactive multicast routing protocols discover routes only when required (i.e., on-demand). Some protocols consider all nodes are peers (flat network topology), while others consider a hierarchy among nodes and only nodes in the same level of the hierarchy are treated as peers. Some protocols assume each node is aware of its current location in the network and also can learn the locations of other nodes in the network. Some multicast routing protocols that are sensitive to the available battery power at the nodes and the energy to be spent in packet transfer have been also proposed in the literature. Some multicast routing protocols discover and maintain multi-paths for a given node pair. The motivation and usage for these multiple paths depends on the protocols. This paper gives the state-of-the-art review of typical multicast routing protocols for MANETs. It is impossible to say which routing protocol is better for a given condition. Hence, the motivation is to group these multicast routing protocols under different routing strategies or categories and then compare these strategies. To our surprise, we find that based on their primary routing selection principle, all of these protocols can be grouped under either application independent-based multicast routing or application dependent-based multicast routing strategies. Similarly, the results presented in this survey can be used by the research community and this can lead to a new paradigm for the comparison of multicast routing protocols [4].

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.

The rest of the paper organized as fallows. The Section II explores desired properties of the multicast routing; the taxonomy of multicast routing protocols for Manet was explored in Section III. Section IV describes the current state of the art in development of mesh based and hybrid multicast routing protocols for Manets.

II. AFFIRM PROPERTIES OF THE WELL CRAFTED MULTICAST ROUTING PROTOCOLS:

1. In order to avoid the sever cons such as packet dropping, robustness in adapting node mobility and unwarned changes in topology with limited control overhead must be the quality of multicast routing

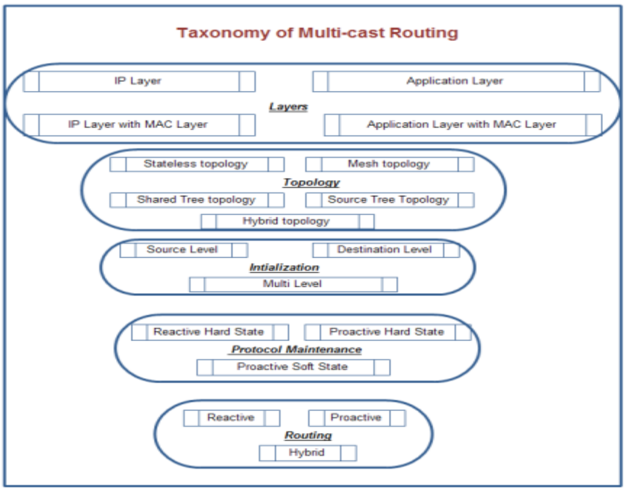
protocols. The control overhead minimization is particular in topologies with limited or low energy levels.

2. The transmission of control packets needs to be limited and related to the total number of data packets reaching their destination.
3. Energy saving techniques aimed at minimizing the total power consumption of all nodes in the multicast group (minimize the number of nodes used to establish multicast connectivity, minimize the number of overhead controls, etc.) and at maximizing the multicast life span should be considered.
4. Multicast routing protocols should be able to reserve different network resources to achieve QoS requirements such as, capacity, delay, delay jitter, and packet loss.
5. Due to ad-hoc infrastructure, wireless medium and broadcast nature manets are vulnerable to eavesdropping, interference, spoofing, and so forth. Hence it is obvious to provide security for any routing methodology that includes multicast routing also.
6. Consistency in Stability also referred as scalability need to be at its high that regardless of node count and infrastructure limits and variations.

III. TAXONOMY OF MULTICAST ROUTING PROTOCOLS:

Multicast routing protocols can be classified based on fallowing properties

- Layer: The network layer that routing protocol targeting
- Topology: The topology that used by protocol
- Routing scheme: The routing scheme selected for protocol
- Initialization: The node selected for initialization process.



A. Classification By Network Layers

Responsibilities of Network layers:

The IP layer is responsible for routing data between a source-destination pair (end-to-end), while the MAC layer is responsible for ensuring that the data are correctly delivered to the destination (reliability), which requires the application layer to buffer data locally until acknowledgments (ACKs) have been received.

IP Layer Multicast routing IPMR: As stated in frequently quoted IP layer Multicast routing protocols [6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28A and 29], IPMR requires cooperation of all the nodes of the network. They also require forwarders (intermediate) nodes to maintain their per group state. The network (IP) layer implements minimal functionality, "best effort" unicast datagram service, while the overlay network implements multicast functionalities such as dynamic membership maintenance, packet duplication, and multicast routing.

Overlay Multi-cast Routing OMR: OMR has been considered as basic approach by few proposals in earlier and current literature. Based on the OMR protocols [16, 45, 46, 47, 30] quoted frequently in literature, we can conclude that the OMR model can be the choice for fallowing considerations:

1) It is simple to deploy, because it does not require changes at the network layer;
2) intermediate (forwarder) nodes do not have to maintain their per group state for each multicast group (maintaining that state has always been a problem in multicasting, even on the Internet);
3) the creation of a virtual (logical) topology hides routing complications, such as link failure instances, which are left to be taken care of at the network layer; and finally
4) Overlay multicasting can deploy the capabilities of lower-layer protocols in providing flow control, congestion control, security, or reliability according to the requirements of the application.

Overlay multicasting can refer as multiple unicast routing paths, hence all multicast data packets are relayed from one group member to another in the form of a unicast packet, a large number of packet collisions and low resource utilization may result, especially where group member location density is high.

MAC layer Multicast Routing MMR: MAC layer multicasting is aimed at improving network efficiency through the implementation of positive Ack and retransmission policies for multicast data transmission. This may cause significant end-to-end latencies in multicast data delivery, especially if the source and destination are separated by a large number of hops. In addition, this method may increase the node buffer size [50]. A reliable and efficient MAC layer multicast protocol can improve the performance of multicast communication.

B. Classification By Routing Schemes

Proactive or Table Driven: As name indicates the routing information maintains at each node by one or more tables. The table update mechanism can be either event driven table update model or periodical table update model. These protocols desire table updates frequently that are relative to topology changes. The table updates occurs irrespective of whether or not information about a topology change is needed, which reflects as consuming more power, and having high capacity and considerable control overhead, especially in a highly mobile environment where topology changes frequently. On other side, this table driven approach causes minimal route acquisition latency.

Reactive or On-Demand by source: When the source node requires multicast routes to a multicast group, it initiates a route discovery process (local or global) within the network. Multicast routes and group membership are established, maintained, and updated on demand. Unlike Table-driven multicast protocols, On-Demand multicast protocols incur low control overhead, as well as saving on power and capacity. However, they may introduce route acquisition latency,

Hybrid routing scheme: When connected nodes are grouped based on the topology in hierarchical way then each hierarchy can opt to either proactive or reactive to elevate the respective drawbacks. This approach is known as Hybrid Routing Scheme. But this model needs to tolerate route acquisition latency at hierarchy level that relies on reactive approach. The delay time at node joining to a multicast group is not tolerable and can claim as drawback of this model.

C. Classification By Connection Initiation Process:

Connection Initiation by source: The source constructs a multicast mesh or tree by flooding the network with a Join Request message. Any receiver node wishing to join a multicast group replies with a Join Reply message.

Connection initiation by target: receiver node wishing to join a multicast group floods the network with a Join Request message searching for a route to a multicast group.

Connection initiation by source or target: Some multicast protocols may not fall strictly into either of these two types of approach when they do not distinguish between source and receiver for initialization of the multicast group. Initialization is achieved either by the source or by the receiver. This type can be identified as a hybrid approach.

D. Classification By Route Construction Approach:

Tree based Approaches: As in fixed (non-mobile) multicast routing, tree-based protocols build a tree over which multicast data is forwarded. Although tree based approaches are bandwidth-efficient, they do not always offer sufficient robustness and due to mobility susceptible for link failure.

1. **Source-Tree-based approach:** In this approach each source node creates a single multicast tree spanning all the members in a group. Usually, the path between the source and each member is not the shortest.
2. **Shared-Tree based approach:** In this approach only one multicast tree is created for a multicast group which includes all the source nodes. This tree is rooted at a node referred as the core node. Each source uses this tree to initiate a multicast. Shared-Tree-based approach not considering the shortest path for routing, but it considers single point of failure, hence it maintains more routing information that leads to overhead. In addition, the traffic is aggregated on the shared tree rather than evenly distributed throughout the network, which gives it low throughput.

Mesh-based approach: In this approach source to all receivers connects under mesh topology. Here in this topology here can be multiple paths between source and any connected node that cause resilient to link failure and higher packet delivery. On other side this topology leads to capacity wastage, power inefficacy, and redundant transmission of data packets causes more overhead. Finally, the Mesh-based approach is much more suitable than the Tree based approach for MANETs. Hence it is evident that mesh based approaches are more suitable for Manets.

Hybrid approach: In order to achieve both robustness and efficiency, the Hybrid approach attempts to combine both the Mesh-based and the Tree-based approaches.

Stateless Approach: This stateless approach [14, 30, 31] is optimal to avoid the over head caused by mesh or tree construction. Since it is not scalable and stable, suits only to small multicast group networks. In this approach, instead of maintaining the routing information at every forwarding node, a source explicitly mentions the destination list in the packet header.

E. Classification By Group Maintenance Approach

MANETs suffer from frequent link breaks due to the lack of mobility of the nodes, which makes efficient group maintenance necessary.

Proactive Soft State: Proactive soft state approach maintains the multicast group by refreshing the group membership and associated routes by flooding the control packets periodically

Reactive Hard State: In this approach routes are reconfigured, by sending control packets, only when a link breaks.

Proactive Hard State: In this approach routes are reconfigured before a link breaks, and this can be achieved by using local prediction techniques based on GPS or signal strength.

The Hard-State approach is much more efficient in terms of overhead. In contrast, the Soft-State approach is much more efficient in terms of reliability (packet delivery ratio).

IV. Multicast Routing Protocols in MANETs and Current State Of the Art

Adaptive Shared-Tree Multicast (ASTM) Routing: ASTM [6] is a hybrid protocol that combines the advantages of per source and shared trees and is based on the notation of the Rendezvous Point (RP). The RP-rooted multicast forwarding tree is created by receiver members periodically sending Join Requests to the RP. The Join Request contains the forward list, which is initially set to include all senders. Sources send their multicast data to the RP, and the RP forwards the multicast data to the receivers. Internal nodes on the path between the source and the RP may not forward these packets to other nodes if the protocol is operating in the unicast sender mode. However, forwarding to other nodes known to be receivers of the source is allowed in multicast sender mode. ASTM allows sources to multicast data directly to a receiver member without being forced to travel to the RP, if the sources are nearby. This method is called adaptive multicast (adaptive per source multicast routing).

Observation: ASTM has a single point of failure, since it is based on the RP. Moreover, as mobility increases, throughput decreases, due to the inability of the routing and multicast protocol to keep up with node movements. In the case of adaptive multicast, there may be packets travelling from a source to a destination, on paths which are much longer than the shortest path between the source and the destination. This may lead to an efficiency problem.

On-Demand Multicast Routing Protocol (ODMRP): ODMRP [24] is a source-initiated multicast routing protocol. It introduces the concept of forwarding group (only a subset of nodes forwarding the multicast packets). When multicast sources have data to send but do not have routing or membership information, they flood a JOIN DATA packet. When a node receives a non duplicate JOIN DATA packet, it stores the upstream node ID and rebroadcasts the packet. When the JOIN DATA packet reaches a multicast receiver, the receiver creates a JOIN TABLE packet and broadcasts to the neighbours. When a node receives a JOIN TABLE packet, it checks whether or not the next node ID of one of the entries matches its own ID. If it does, the node realizes that it is on the path to the source and thus is part of the forwarding group. It then broadcasts its own JOIN TABLE packet built upon matched entries. The JOIN TABLE packet is thus propagated by each forwarding group member until it reaches the multicast source via the shortest path.

Observation: The main disadvantage of ODMRP is high control overhead while maintaining current forwarder groups and all network request package flooding. This problem can be overcome using preemptive route maintenance, as suggested by Xiong et al. [36]. Another disadvantage is that the same data packet propagates through multiple paths to a destination (duplicate packets), which reduces multicast efficiency. In addition, ODMRP has a scalability problem. Finally, the sources must be part of the group's multicast mesh, even when they are not interested in receiving multicast packets.

Adaptive Core Multicast Routing Protocol (ACMRP): ACMRP [9] is an on-demand core based multicast routing protocol. A multicast mesh is shared by the sources of a group. A designated node, called a core, while not well known, adapts to the current network topology and group membership status. A multicast mesh is created and maintained by the periodic flooding of a Join Request packet which is performed by the adaptive core. When a node receives a fresh JREQ, it inserts the packet into its jreq cache and updates the route to the core. Then, it changes the "upstream node address" field in the packet to its own address and retransmits the packet. Group members (including multicast receivers as well as sources) send a Join Reply (JREP) packet to their upstream node on receipt of a non duplicate JREQ packet. Upon receiving the JREP, the upstream node stores the group address, which will be used to forward multicast packets destined for the group in the future. This node is called a forwarding node. It inserts a (group address, source address) pair into the forwarding group table. Then, it sends a JREP to its own upstream node. Eventually, the JREP reaches the core. The backward propagations of JREPs construct multicast routes between group members and the core. Consequently, a multicast mesh is established. The adaptive core mechanism of ACMRP automatically handles any link failure, node failure, or network partition.

Observation: The enhanced adaptivity of ACMRP minimizes core dependency, thereby improving performance and robustness and making ACMRP operate well in dynamically changing networks. An ACMRP scales well to large numbers of group members and is suitable even in a heavily loaded ad hoc network. One disadvantage of this protocol is that the paths between the sources and the receivers are not optimal. Also, the selection of the core is critical. The position of the core node is very important. It should be placed with the minimum hop counts of routes toward group members and guarantee that it has enough residual power for support until the next core is elected.

Dynamic Core-Based Multicast Routing Protocol (DCMP): DCMP [15] is an extension to ODMRP [24] and attempts to reduce the number of senders flooding JREQ packets by selecting certain senders as cores. This reduces the control overhead and therefore improves the efficiency of the ODMRP multicast protocol. DCMP constructs a mesh similar to that in ODMRP. It reduces the number of sources flooding the JREQ by having three types of sources: active, passive, and core active. Only active sources and core active sources flood the JREQ. Packets initiated at passive sources are sent to the core active node (as a proxy for passive sources), which forwards them to the mesh. The number of passive sources a single core active source can serve must be limited for robust operation. The distance (number of hops) between a passive source and its core active node must also be limited to ensure that the packet delivery ratio is not reduced.

***Observation*:** DCMP does not entirely alleviate the drawback of ODMRP, which is multiple control packet floods per group, but it is still much more scalable than ODMRP. It also has a high delivery ratio compared to ODMRP. However, in the case of failure of the core active source, multiple multicast sessions will fail.

Multicast for Ad Hoc Networks with Swarm Intelligence (MANSI): MANSI [7] applies swarm intelligence mechanisms to the problem of multicast routing in MANETs. Swarm intelligence refers to complex behaviors that arise from very simple individual behaviors and interactions, which are often observed in nature, especially among social insects such as ants and honey bees. Although each individual (an ant, e.g.,) has little intelligence and simply follows basic rules using local information obtained fromthe environment, global optimization objectives emerge when ants work collectively as a group. Similarly, MANSI utilizes small control packets which deposit information at the nodes they visit. This information is used later by other control packets. MANSI adopts a core-based approach to establish multicast connectivity among members through a designated node (core). The core is the first node that initiates the multicast session. It announces its existence to the others by flooding the network with a CORE ANNOUNCE packet. Each member node then relies on this announcement to reactively establish initial connectivity by sending a JREQ back to the core via the reverse path. Nodes receiving a JREQ addressed to themselves become forwarding nodes of the group and are responsible for accepting and rebroadcasting non duplicated data packets, regardless of from which node the packets were received. To maintain connectivity and allow new members to join, the core floods CORE ANNOUNCE periodically, as long as there are more data to be sent. As a result, these forwarding nodes form a mesh structure that connects the group members, while the core serves as a focal point for forwarding set creation and maintenance.

Observation: MANSI adopts the concept of swarm intelligence to reduce the number of nodes used to establish multicast connectivity. However, the path between the multicast member and forwarding set to the designated core is not always the shortest. MANSI employs a mesh-based approach to increase redundancy by allowing packets to be forwarded over more than one path, thereby raising the chances of successful delivery. In MANSI, group connectivity can be made more efficient by having some members share common paths to the core with other members in order to further reduce the total cost of forwarding data packets. Since a node's cost is abstract and may be defined to represent different metrics, MANSI can be applied to many variations of multicast routing problems for ad hoc networks, such as load balancing, secure routing, and energy conservation.

Forward Group Multicast Protocol (FGMP): FGMP [16] is a multicast routing protocol that creates a multicast mesh on demand, and is based on the forwarding group concept. FGMP keeps track not of links but of groups of nodes which participate in multicast packet forwarding.

Observation: FGMP limits flooding within the selected FG nodes, thereby reducing channel and storage overhead. In a high mobility environment, frequent FG changes can adversely affect the protocol's performance. FGMP provides a feasible solution only in small networks and when the number of senders is greater than the number of receivers. It is more efficient to utilize FGMP-SA when the number of sources is smaller than the number of destinations in the multicast group. However, when the number of sources is greater than the number of destinations, FGMP-RA is more efficient than FGMP-SA.

CAMP: Core-Assisted Mesh Protocol: CAMP [13] extends the notion of core based trees CBT [37] introduced for Internet multicasting into multicast meshes, which have much richer connectivity than trees. A shared multicast mesh is defined for each multicast group to maintain the connectivity of multicast groups, even during the frequent movement of network routers. CAMP establishes and maintains a multicast mesh, which is a subset of the network topology, which provides multiple paths between a source-receiver pair and ensures that the shortest paths from receivers to sources (called reverse shortest paths) are part of a group's mesh. One or multiple cores are defined per multicast group to assist in join operations; therefore, CAMP eliminates the need for flooding. CAMP uses a receiver-initiated approach for receivers to join a multicast group. A node sends a JREQ toward a core if none of its neighbors is a member of the group; otherwise, it simply announces its membership using either reliable or persistent updates. If cores are not reachable from a node that needs to join a group, the node broadcasts its JREQ using an ERS, which eventually reaches some group member. In addition, CAMP supports an alternate way for nodes to join a multicast group by employing simplex mode.

Observation: CAMP needs an underlying proactive unicast routing protocol (the Bellman-Ford routing scheme) to maintain routing information about the cores, in which case considerable overhead may be incurred in a large network. Link failures have a small effect in CAMP, so, when a link fails, breaking the reverse shortest path to a source, the node affected by the break may not have to do anything, because the new reverse shortest path may very well be part of the mesh already. Moreover, multicast data packets keep flowing along the mesh through the remaining paths to all destinations. However, if any branch of a multicast tree fails, the tree must reconnect all components of the tree for packet forwarding to continue to all destinations.

Source Routing-Based Multicast Protocol (SRMP): SRMP [27] is an on-demand multicast routing protocol. It constructs a mesh topology to connect each multicast group member, thereby providing a richer connectivity among members of a multicast group or groups. To establish a mesh for each multicast group, SRMP uses the concept of FG nodes. SRMP applies the source routing mechanism defined in the Dynamic Source Routing (DSR) [38] protocol to avoid channel overhead and to improve scalability. Also, SRMP addresses the concept of connectivity quality. Moreover, it addresses two important issues in solving the multicast routing problem: the path availability concept and higher battery life paths.

Observation: SRMP selects the most stable paths among multicast group members. This maximizes the lifetime of the routes, offers more reliability and robustness, and results in the consumption of less power. In addition, it discovers routes and detects link failures on demand, thereby minimizing channel and storage overhead (improving the scalability of the protocol), as well as saving bandwidth and network resources. The value of the four metrics used in selecting the paths may not be globally constant, however. They probably vary with different network load conditions. So, the four metrics must be made to be adaptive to the network load conditions.

Neighbor-Supporting Multicast Protocol (NSMP): NSMP [22] is a source-initiated multicast routing protocol, and is an extension to ODMRP[24]. A mesh is created by a source, which floods a request throughout the network. Intermediate nodes cache the upstream node information contained in the request and forward the packet after updating this field. When any receiver node receives the route discovery packets, it sends replies to its upstream nodes. Intermediate nodes receiving these replies make an entry in their routing tables and forward the replies upstream toward the source. In the case where the receiver receives multiple route discovery packets, it uses a relative weight metric (which depends on the number of forwarding and non forwarding nodes on the path from the source to the receiver) for selecting one of the multiple routes. A path with the lowest value of relative weight is chosen.

***Observation*:** NSMP is aimed at reducing the flood of control packets to a subset of the entire network. It utilizes node locality to reduce control overhead while maintaining a high delivery ratio. NSMP favors paths with a larger number of existing forwarding nodes to reduce the total number of multicast packets transmitted. It is preferable to make the relative weight metric adaptive to variations in the network load conditions.

On-Demand Global Hosts for Ad Hoc Multicast (OGHAM): OGHAM [23] constructs a two-tier architecture by selecting backbone hosts (BHs) on demand for multicast services. Each multicast member must be attached to a BH. Hosts with a minimal number of hops to the other hosts, rather than those with a maximal number of neighbors, will be adopted as BHs in order to obtain shorter multicast routes. BHs are responsible for determining multicast routes, forwarding data packets, handling dynamic group membership (the nodes can dynamically join or leave the group), and updating multicast routes due to host movement.

***Observation*:** OGHAM minimizes transmission time and lost packets because BHs minimize the total number of hops to all hosts (receivers). In OGHAM, once the infrastructure for a particular multicast group has been constructed, the selected BHs are globally available for the other ad hoc multicast groups. Therefore, it is not necessary for follow up multicast groups to flood again in order to construct additional infrastructures. Hence, as the group size or the group number increases, the ratio of control packets declines (very scalable).

Agent-Based Multicast Routing Scheme (ABMRS): ABMRS [40] employs a set of static and mobile agents in order to find the multicast routes, and to create the backbone for reliable multicasting, as a result of which the packet delivery ratio is improved. The steps of the ABMRS are the following: reliable node identification, reliable node interconnection, reliable backbone construction, multicast group creation, and network and multicast group management. The Route Manager Agent (RMA) at each node computes the Reliability Factor (RF, which depends on various parameters such as power ratio, bandwidth ratio, memory ratio, and mobility ratio) and advertises to each of its neighbors. The Network Initiation Agent (NIA) at each node receives the advertised packet and determines who has the highest RF. The node with the highest RF will announce itself as a reliable node and inform its RMA.

Observation: ABMRS computes multicast routes in a distributed manner, which provides good scalability. ABMRS is more reliable, that is, it has a higher packet delivery ratio, than MAODV [19]. This is because ABMRS constructs the multicast tree based on reliable nodes. However, ABMRS incurs a significant control overhead compared to MAODV, especially when mobility and the multicast group size are increased. The reason for this is that more agents are generated to find a route to reliable nodes. ABMRS assumes the availability of agent platform at all mobile nodes. However, in the case of agent platform unavailability, traditional message exchange mechanisms can be used for agent communication. As a result, more control overhead will be incurred. In addition, ABMRS is based on Dijkstra’s algorithm for computing the routes between the reliable nodes, and, therefore, it needs to know the network topology in advance. As a result, it has a scalability issue, and a significant overhead will be incurred as well.

Optimized Polymorphic Hybrid Multicast Routing Protocol (OPHMR): OPHMR [41] is built using the reactive behavior of ODMRP [24] and the proactive behavior of the MZRP [21] protocol. In addition, the Multipoint Relay-(MPR-) based mechanism of the OLSR [42] protocol is used to perform an optimization forwarding mechanism. OPHMR attempts to combine the three desired routing characteristics, namely, hybridization (the ability of mobile nodes (MNs) to behave either proactively or reactively, depending on the conditions), adaptability (the ability of the protocol to adapt its behavior for the best performance when mobility and vicinity density levels are changed), and power efficiency. To enable hybridization and adaptability, that is, polymorphism, OPHMR introduces different threshold values, namely, power, mobility, and vicinity density. OPHMR is empowered with various operational modes which are either proactive or reactive, based on an MN’s power residue, mobility level, and/or vicinity density level. In a route, each MN tries to determine the destination node according to its own strategy (proactive or reactive). Thus, the MNs try to find the next forwarding nodes by using their own routing tables, which are established in the background for proactive stations, or by using broadcasting for reactive stations. This feature ensures that any hysterical behavior is avoided.

Observation: OPHMR is, in the long run, able to extend battery life and enhance the survivability of the mobile ad hoc nodes. As a result, it decreases the end-to-end delay and increases the packet delivery ratio, in comparison with other protocols, such as ODMRP [24], while keeping the control packet overhead at an acceptable rate. OPHMR follows the proactive Hard-State approach to maintain the multicast topology. Hence, the packet delivery ratio decreases as the mobility of the nodes increases.

Ad Hoc Multicasting Routing Protocol (AMRoute): AMRoute [43] creates a multicast shared-tree over mesh. It creates a bidirectional shared multicast tree using unicast tunnels to provide connections between multicast group members. Each group has at least one logical core that is responsible for group members and tree maintenance. Initially, each group member declares itself as a core for its own group of size 1. Each core periodically floods JREQs (using an ERS) to discover other disjoint mesh segments for the group.

Observation: AMRoute creates an efficient and robust shared tree for each group. It helps keep the multicast delivery tree unchanged with changes of network topology, as long as paths between tree members and core nodes exist via mesh links. When mobility is present, AMRoute suffers from loop formation, create trees that are not optimal, and requires higher overhead to assign a new core. Also, AMRoute suffers from a single point of failure of the core node.

Progressively Adapted Sub-Tree in Dynamic Mesh (PASTDM): PASTDM [46] is an overlay multicast routing protocol that creates a virtual mesh spanning all the members of a multicast group. It employs standard unicast routing and forwarding to fulfill multicast functionality. A multicast session begins with the construction of a virtual mesh, on top of the physical links, spanning all group members. Each member node starts a neighbor discovery process using the ERS technique [35]. For this purpose, Group REQ messages are periodically exchanged among all the member nodes.

Observation: PASTDM constructs a virtual mesh topology, which has the advantage of scaling very well, since this topology can hide the real network topology, regardless of the network dimension. In addition, it uses unicast routing to carry the packets. Moreover, PASTDM alleviates the redundancy in data delivery in the existence of the change of the underlying topology. However, the link cost calculation may be incorrect, since PASTDM does not explicitly consider node mobility prediction in the computation of the adaptive cost. In addition, the overlay is constructed and maintained even if no source has multicast data to transmit. Exchanging link state information with neighbors and the difficulty of preventing different unicast tunnels from sharing the same physical links may affect the efficiency of the protocol. Simulations [46] show that PASTDM is more efficient than AMRoute.

CONCLUSION:

In this article we provide descriptions of several mesh based and hybrid multicast routing schemes proposed for ad hoc mobile networks. We also provide a classification of multicast routing schemes according to network layer, topology used, initiation strategy and maintenance strategy. Finally we concluded that it is not clear that any particular algorithm or class of algorithm is the best for all scenarios, each protocol has definite advantages and disadvantages, and is well suited for certain situations. The field of ad hoc mobile networks is rapidly growing and changing, and while there are still many challenges that need to be met.

Protocol	***Routing Scheme***	***Initialization Approach***	***Topology***	***Maintenance Approach***
ASTM	Proactive	Receiver initiated	Hybrid	Hard State Reactive
AMRoute	Proactive	Hybrid	Hybrid	Hard State Reactive
MANSI	Reactive	Receiver initiated	Mesh	Soft State Proactive
CAMP	Proactive	Hybrid	Mesh	Hard State Reactive
OPHMR	Hybrid	Source initiated	Mesh	Hard State Reactive
NSMP	Reactive	Source initiated	Mesh	Soft State Proactive
FGMP	Reactive	Receiver initiated	Mesh	Soft State Proactive
DCMP	Reactive	Source initiated	Mesh	Soft State Proactive
ODMRP	Reactive	Source initiated	Mesh	Soft State Proactive
PAST-DM	Proactive	Hybrid	Hybrid	Soft State Proactive
OGHAM	Reactive	Source initiated	Hybrid	Hard State Reactive
ACMRP	Reactive	Source initiated	Mesh	Soft State Proactive
SRMP	Reactive	Receiver initiated	Mesh	Hard State Reactive
PUMA	Reactive	Receiver initiated	Mesh	Soft State Proactive
ABMRS	Reactive	Hybrid	Mesh	Hard State Reactive

Table 1: Tabular representation of the mesh based and hybrid multicast routing protocols and their properties

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