Proactive, Reactive and Hybrid Multicast Routing Protocols for Wireless Mesh Networks

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Abstract - **Wireless Mesh Networks comes under the category of mobile ad-hoc networks with fixed positions of nodes to communicate to the internet through a single gateway or more than one gate way. In order to provide a multi point communication within the mesh network, a multicast routing protocol is required. Multicast routing is a key technology for modern communication networks. Multicast Routing becomes a prominent technology for wireless communication networks various multicast routing protocols are developed for internet and ad-hoc communications This paper gives the overview of some of the existing proactive, reactive and hybrid multicast routing protocols over WMNs with its strengths and weaknesses. The following multicast routing protocols are selected for their performance comparison ; they are On Demand Multicast Routing Protocol(ODMRP), Multicast Ad hoc On Demand distance Vector (MAODV) Protocol, Multicast Open Shortest Path First (MOSPF), Ad hoc Multicasting Routing Protocol(AM Route) and Optimized Polymorphic Hybrid Multicast Routing Protocol(OPHMR). Among them, MOSPF and AM Route is a proactive routing protocol and OPHRM is a Hybrid routing protocol while MAODV and ODMRP are reactive multicast routing protocols.**

Index Terms: **AM Route, MAODV, MOSPF, ODMRP, OPHMR**

1. INTRODUCTION

A Wireless Mesh Network (WMN) is a wireless network where data is shared by the nodes which are connected in mesh topology. In wireless mesh network the nodes not only for just sending and receiving of data, but also serve as a relay node for other nodes and each node collaborates in propagating data on the network. The structure of WMNs is shown in Figure1.WMN is the group of mesh clients, mesh routers and gateways connected through a mesh topology. Gateway: Network Gateway is a communication which as an interface to connect nodes in the network with internet. Mesh Router: A mesh router is a device for dispatching the data packets by choosing best path in the network. Mesh Client: Mesh client is a part of hardware or software connected in a mesh topology to avail the sources of router for transmission of data packet.

In internet working, routing is the process of moving a packet of data from source to destination. A routing protocol specifies how routers communicate with each other, distributing of information that enables them to select routes between any two nodes on a computer network.

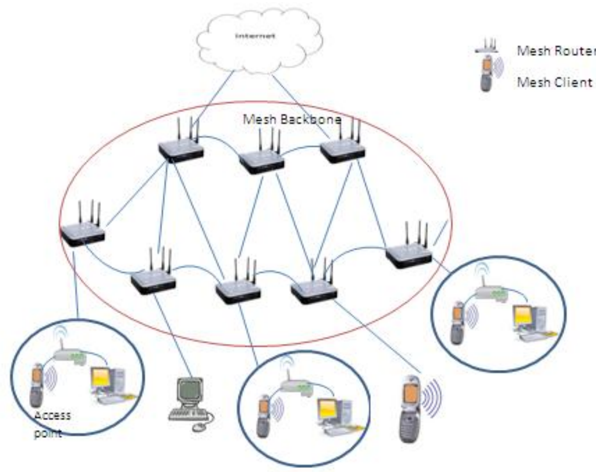

Figure 1: Architecture of Wireless Mesh Network

The network layer plays a major role in transmission of data from source to destination over multiple hops. The technologies like WLANs and WMANs use a single wireless link, and hence have no need for a network layer. In contrast, for WMNs and MANETs the source and the destination can be several wireless hops away from each other, and hence the packets have to be routed and forwarded in the wireless network itself [1]. To design such a route it needs some metrics those are:

A. Scalability/Efficiency

When the routing protocol has a high overhead and requires global information, it will be impossible to scale it with increasing number of nodes.

B. Reliability

The routing protocol should be able to reroute fast around failed nodes, broken links, and upon the failure of a gateway it should be able to redistribute the orphaned clients among neighboring gateways. For these acquisitions, fast reconfiguration and sustain of multiple gateways are essentials.

C. Mobile User connectivity

To assure consistent mobile user connectivity, the routing protocol should enable fast hand-offs.

D. Flexibility

The routing protocol should be pliable and adoptable to different network topologies.

E. QoS

In addition to support from the MAC layer, finding the optimal routes for all categories of traffic classes is a

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vital ingredient for QoS support. Load balancing, avoiding congested routes, and taking into account interferences patterns existent in a WMN are just some of the factors that directly affect the performance of WMNs. In MANETs, the traffic is assumed to be flowing between peremptory pairs of nodes while in WMNs, most of the traffic flows between the gateway and client nodes. Moreover, while the mobility of MANET nodes is usually similar, n WMNs, the nodes can be distinctly classified as either mobile or stationary. It is thus likely that for WMNs a custom routing protocol can reflective outperform general MANET protocols. Once the routes are established, data packets have to be forwarded between the clients and the gateway. The following list includes the most commonly used performance metrics:

1. Hop Count

Hop count is the number of hops between the source and the destination.

2. Expected Transmission Count (ETX)

The metric is more precise to wireless communications. It considers for data loss due to medium access contention and environmental perils, and considers the number of retransmissions needed to successfully transmit a packet over a link[3][4]..

3. Expected Transmission Time (ETT)

This metric is an enhancement of ETX as it further includes the bandwidth of the link in its computation[5]. This is of particular interest when different network technologies are used (IEEE 802.11a and IEEE 802.11b for instance[6]) in order to favor channel disparate paths

4. Energy Consumption

Node energy level can be considered as a routing metric if some nodes are energy-constrained and their involvement in the routing process can lead to path failure if they suffer from energy diminution. This problem is particularly important in MANETs and WSNs.

5. Path availability/reliability

This metric estimate the percentage of time a path is available. Node mobility effect can be captured by this metric. It is particularly important in MANETs.

The remainder of the paper is organized as follows: Section2 gives the description of various proactive, reactive and hybrid multicast routing protocols in wireless mesh networks. Section 3 gives the simulation results. Section4 gives the conclusion followed by references.

Wireless mesh networks decreases the cost of wireless communication with increase in efficiency and throughput of the wireless links between two nodes by sending multiple copies of the same message using broadcasting properties of wireless transmission. Multicasting decreases the cost, channel capacity consumption, energy utilization, data delivery ratio. Routing is the process of transmission of data packets. The goal of routing protocol is minimization of traffic overhead, identification of link failures caused by node mobility.

2. OVERVIEW OF PROTOCOLS

Multicast routing protocols of wireless mesh networks are broadly divided into three categories namely reactive, proactive and hybrid multicast routing protocols. This section explains MOSPF, AM Route from proactive protocols, ODMRP, MAODV from reactive and OPHRM from hybrid routing protocols. Section2.1 will give the description of proactive routing protocols, Section2.2 specifies the reactive routing protocols and Section2.3 describes hybrid multicast routing protocols.

2.1 PROACTIVE ROUTING PROTOCOL

Proactive routing protocols choose the available (existing) route for data transmission with all generating the route at the time of need. In proactive routing each node maintain the information table of other nodes which are in that network. Proactive routing protocols are also called as table driven protocols[6]. Proactive routing protocols works efficiently, for a small scale mesh networks with high mobility. Some of the proactive routing protocols are described in this section they are MOSPF, AM Route.

2.2 MULTICAST OPEN SHORTEST PATH FIRST (MOSPF):

MOSPF[7] means multicast open shortest path first. Open shortest path first is a unicast link state protocol uses Dijkstra's shortest path from a router to every possible destination. MOSPF (multicast open shortest path first) is a multicast proactive routing protocol which is the enhancement of OSPF. MOSPF uses a protocol called link state advertisement protocol. Each router of MOSPF maintains the list of nodes, groups using IGMP (Interior Gateway Multicast Protocol), and location of the members in a group. In MOSPF transmission of data is performed in two ways. They are: Source area and Backbone area.

Source area multicast OSPF uses intra-area shortest path tree with leaf nodes and wild-card receivers. Backbone area uses multicast-receivers of the source area calculate the shortest path from source to the multicast forwarders using reverse cast. Four different routing decision making strategies are used by MOSPF. They are flooding, Reverse path forwarding (RPF), Reverse path broadcasting (RPB), and Reverse path multicasting (RPM).

A. Flooding:

It simply broadcasts packets. The drawback of flooding is, it generates loops in the system.

B.Reverse path forwarding (RPF):

It is a mechanism which is for avoiding loops in the system. In RPF[8] router forwards single copy of the packet instead of sending all copies of packets by travelling of the forwarded packet through the shortest path from source to the router. RPF eliminate the loop in the system by checking route of the packet travelled from source to router of the packet travelled from source to router. The copy of the packet is through shortest path verified at routing table then it chooses that path for forwarding other copies of data. In that packet not travelled through shortest path then the packet leaves the router and come back again like this RPF eliminate the loops in the system.

C. Reverse Path Broadcasting (RPB):

RPF gives the guarantee of receiving of a multicast packet by each network without certain of loops, but does not give a guarantee of receiving only on copy by each network. The better solution to this problem is overcome by RPB. In RPB it selects a router as a parent router for each network which maintains the information of shortest path from parent router to the source. To avoid the loop, router (parent router) sends the packet to the source through that shortest path specified by parent router. RPB gives the guarantee of receiving one and only one copy of the packet by the destination.

D. Reverse path multicasting (RPM):

To improve the efficiency of network, multicast packet sends to the network having active members for that particular group. To do this it uses pruning and grafting.

2.2.1 AD HOC MULTICASTING ROUTING PROTOCOL (AM ROUTE)

Wireless mesh networks has two basic categories of routing protocols, namely Mesh based routing protocol and Tree based routing protocol.AM Route is a proactive tree based multicast routing protocol.AM Route[9] has to phases in its structure: Mesh creation phase and Tree Creation phase.

Mesh creation phase: in mesh creation phase a new member from a new group is selected as a core member by themselves using a simple core resolution mechanism. Each core member floods JOIN-REQ message for identification of the members belongs to other group. When a member of one group receives the JOIN-REQ packet from the core member of the same group belongs to different mesh then that member sends JOIN-ACK packet to the core member. If the node receives the JOIN-REQ from the core member belongs to the same mesh and same group the member sends a JOIN-NACK to the core member. In case, the node wants to disconnect from the group then also that node can send the same packet (JOIN-NACK) and separates from the group. When the core receives the JOIN-ACK from the other members then that core establishes the connection between from core member and the members belongs to other group using a bidirectional tunnel for data transmission. The member of the group maintains the details of the core member. If a member of the group receives the TREE-CREATE message from a new core member, it resets the core which is having highest IP value compared to the old core and new core member.

Tree creation phase: The tree creation phase is for generating shared tree .To generate such a tree core continuously transmits TREE-CREATE through unicast tunnel in the mesh. After getting of non-duplicate TREE-CREATE message, then node forward that message to all other links except incoming link. If the core receives duplicate TREE-CREATE message it discard the message and send TREE-CREATE-NACK to the incoming link. If a member sends a TREE-CREATE-NACK means, that node has connection in mesh. If that node sends TREE-CREATE-ACK it means, that node is free, has no connection, and willing to join in the tree structure. If any node want to discontinue (break) form from the link then it send TREE-CREATE-NACK message.

An efficient and robust shared tree will be created by AM Route, and also keeps the multicast delivery tree as static in all conditions like changes in the network topology. When network node mobility is more AM Route will faces some of the problems like Loop formation, creation of a non-optional tree, and need higher overhead for selecting and assigning new core.

2.3 REACTIVE ROUTING PROTOCOL

In reactive routing protocol choose the demand when the indication must be delivered to an unknown destination. In this protocol the routes are calculated when a node needs to send data to an unknown destination. So, route discovery is developed only when needed. This protocol saves the unused routes. Some of the reactive routing protocols are described in this section they are MAODV and ODMRP.

2.3.1 MULTICAST OPERATION OF AD HOC ON DEMAND DISTANCE VECTOR (MAODV):

MAODV means Multicast operation of Ad hoc On-demand Distance Vector. Operation of Ad hoc On-demand Distance Vector (AODV) is a unicast routing protocol. Whereas MAODV is a Multicast reactive routing protocol. This is enhancement of AODV. Each node of MAODV maintain three routing tables .On that first table is Routing Table it is used for if the node is multicast tree member then the data send multicast group to other destination. Second table is Multicast Route Table used for listing the next hops for the tree structure of each multicast group. Third table is Request Table for Optimization purpose.

In MAODV[10] connect to multiple group members, as an On-demand routing protocol discovers the routes based on a Route Request (RREQ) message and Route Reply (RREP) message cycle.so.it is a hard state protocol. Finally, a member node of a multicast group wants to terminate its group member ship it must ask for AODV. In MAODV each group identified by a unique multicast address and maintained by using tree structure, several routers and group members.

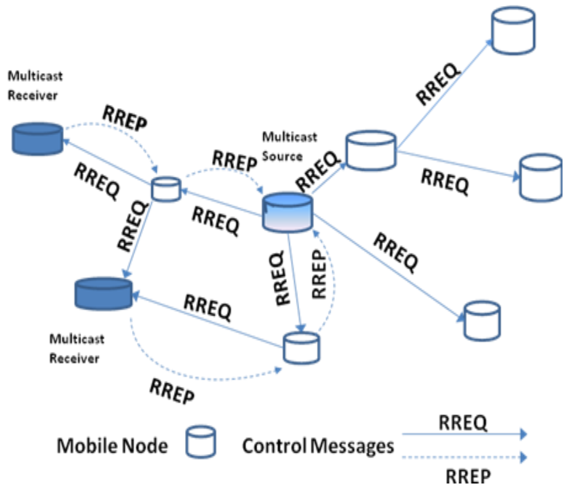

Figure 2: MAODV Routing Protocol

MAODV having the first member of the multicast group becomes the leader of the group. Leader takes the responsibility to maintain group sequence number and this number propagate to the entire group through Group HELLO (GRPH) message. Multicast Activation (MACT) is a node which acts as a next hop. Group member use the GRPH message to update their request table and distance to leader. Once the group is setup, group leader is ready to accept join message (RREQ) from others. When a source node sent to RREQ for multicast group, source node expected to receive multiple replies. One of the replies (RREP) caused a branch to connect the existing tree in order to avoid loops. If it is not a multicast tree, it just updates its multicast route table when necessary. In this group tree may have a break due to node mobility. At that time MAODV tries to repair the broken link, in this cost of breakage link is very expansive because of it requires nodes listen to any neighbor's transmission. If the node in downstream of the break point is responsible for repairing and broken link, either it broad cast RREQ and gets RREP, thus the link is fixed. This technique also avoids formation of the loop by preventing nodes on the same side of the break from responding to the RREQ. It is used to broadcast an expanding rings search, they are allowing for a local repair and check the RREQ. When a downstream node on the multicast tree receives the MACT message and determines this packet arrived from its upstream mode, it increases the hop count value in the MACT packet and updates its distance to the group leader. This procedure continues till reaching to the leaf nodes. MAODV authenticate poor performance in terms of packet delivery ratio, throughput and end to end delay where breakage of link is frequent.

2.3.2 ON-DEMAND MULTICAST ROUTING PROTOCOL (ODMRP):

ODMRP is a mesh based approach and uses a forwarding group concept.

ODMRP means On-Demand Multicast Routing Protocol for multi-hop wireless networking. It is used for a mesh of nodes for each multicast group. Nodes are added to the mesh through a route selection and simulation protocol. A soft state way is appropriated in ODMRP to maintain group membership. Therefore, no explicit control message is prescribed to leave the group. It applies "On-demand" routing approach to avoid channel overhead.

ODMRP routing structure consists of a *request phase and reply phase*. To design the forwarding mesh for multicast group, it handles two types of control packets: J-Query and J-Reply. When a node has the information to send, but no route to the acceptor, a *J-Query* message is broad casted to the unified network. When a *J-Query* packet reaches to the multicast receiver, it creates a *J-Reply*, It checks if the next node address of one of the entries matches its own address.

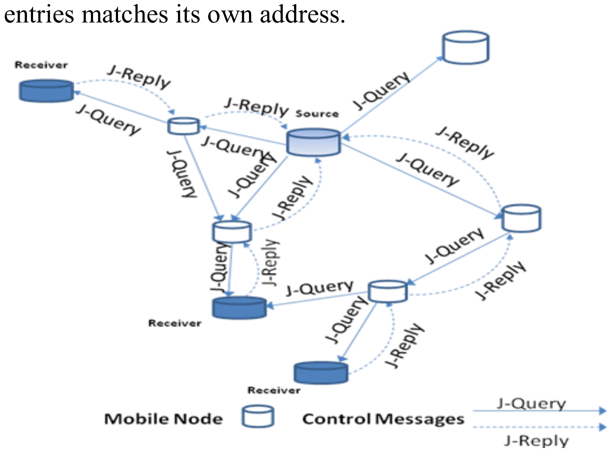

Figure: 3 ODMRP Routing Protocol

If the address is matched, the node is on the path to the source and it becomes a part of the forwarding group (FG) by setting FG flag. It then broadcasts its own J-Reply, which contains matched entries. The next hop IP address can be attained from the message cache. This process construct (or update) the routes from sources to receivers and builds the forwarding group. Membership information and route information is upgraded by recurrently (certain interval times) sending *J-Query* packet. Nodes only forward data packet if they belong to the forwarding group or if they are multicast group members.

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 Nguyen et al[12]. 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 source must be part of the group's multicast mesh, even when they are not interested in receiving multicast packets.

2.4 HYBRID ROUTING PROTOCOL:

In Routing algorithm [13] the third classification is hybrid routing protocol. For more accurate metrics hybrid routing protocols use distance vectors. To find best paths to the destination networks, it uses routing information maintained by the routers, when there is any changes in the topology the router update its routing table. It allows rapid convergence but for rapid convergence it requires less processing power & memory when compared to link state routing.

2.4.1 OPTIMIZED POLYMORPHIC HYBRID MULTICAST ROUTING (OPHMR)

OPHMR[14] is a polymorphic protocol i.e., both proactive and reactive. It is depending upon the underlying context. It attempts to combine three design dimensions one is hybridization - the capability and behavior of mobile node (MNs) either proactively or reactively, depending on the conditions , another is adaptability – the capability of the protocol is to improve the performance of the network by adapting the behavior of network in all situations(e.g. mobility and vicinity density levels)and power efficiency. The protocol is mainly based on ODMRP that is used to drive its reactive behavior of OPHMR is based on four different modes of operation and based on power residue, may be fixed or may depend upon the initial battery power of MNs, mobility level and /or vicinity density level. The four Modes of operations are:

1. Proactive Mode1 (PM1): If a Mobile node is in PM1, it frequently upgrade s information by sending out an upgrade packet with zone Radius R set as the time-to-level (TTL) and the upgrade interval is set to a tunable parameter value i.
2. Proactive Mode2 (PM2): The PM2 mobile node behavior is similar to the node in PM1,but the upgrade interval is set to $2\times i$ (less in proactive state)
3. Proactive Ready Mode (PRM): A node is in both PM1 and PM2; it frequently sends out upgrade packets and discards any received upgrade packets.
4. Reactive Mode (RM): When a node in RM, it does not send out update packets and rejects any received upgrade packets.

The reactive behavior of ODMRP[15] and the proactive behavior of the MZRP (Multicast Zone Routing Protocol[16]) Protocol is used to built OPHMR[17] .

In a route, each Mobile node attempts to determine the destination node according to its own strategy (proactive or reactive). The mobile node tries to find the next forwarding nodes based on own routing own routing tables, which are established by proactive stations, or by using reactive stations.

This feature insures that any hysterical action is avoided. Each mobile node determines its modes of operation based on the threshold values.

When a node needs to join a multicast group wants to sends data to that group, it begins the route discovery procedure. It sends out a JREQ message and waits for replies, when it is in reactive mode. It first looks in its neighborhood table to see whether or not there are nodes that belong to the destination multicast group, when the node is in proactive mode or proactive ready mode (PRM). It unicasts JREQ messages to all these nodes and waits for replies. Otherwise, the node will broadcast a JREQ message. When a node receives a message and check whether it is a member of the multicast group, it sends a reply to the source node of that message and updates its multicast routing table to record the route. The node checks its own behavior, when it is not a send a reply to the mobile node. It just floods the JREQ message and records it in the route cache, when it is in reactive mode. If the node is in reactive mode, it just propagates the JREQ message and upgrades it in the route cache. When the node is in Proactive mode or in proactive ready mode (PRM), it looks in its neighborhood tunnel to find the destination of multicast group member. It unicast the JREQ message to all of them, when there members in its zone. Otherwise, it just propagates the message. Node updates its multicast routing table, when the source node receives a reply.

The strengths of OPHMR is, in the long run it has the capability 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, 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.

3. SIMULATION RESULTS

The performance comparison of multicast routing protocols, ODMRP, MAODV, MOSPF AMRoute, and OPHMR are compared on various scenarios like throughput, end-to-end delay, and packet delivery ratio with number of nodes. This experiment is performed by changing the multicast group size.

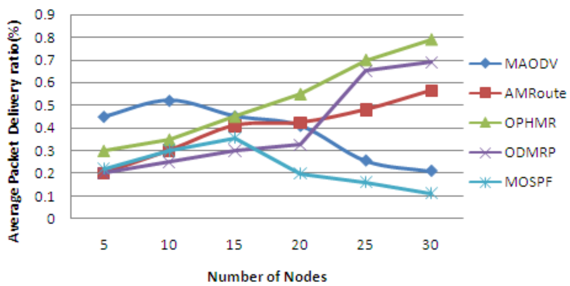

Figure 4:Average Packet Delivery Ratio of MRP by varying group size

Figure4. Shows the packet delivery ratio of all multicast routing protocols compared by varying the multicast group size. By increasing the traffic load the OPHMR gives the better packet delivery ratio and MOSPF gives the less packet delivery ratio compared to other protocols. So compared to other multicast routing protocols OPHMR is better.

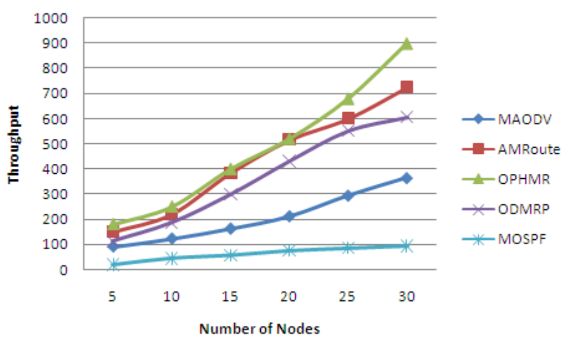

Figure 5: Throughput of MRP by varying group size

Figure5. Shows the through put of all multicast routing protocols are compared by changing the number nodes. By increasing the traffic load the OPHMR gives the better through put and MOSPF gives the less through put compared to other protocols. So compared to other multicast routing protocols OPHMR is better.

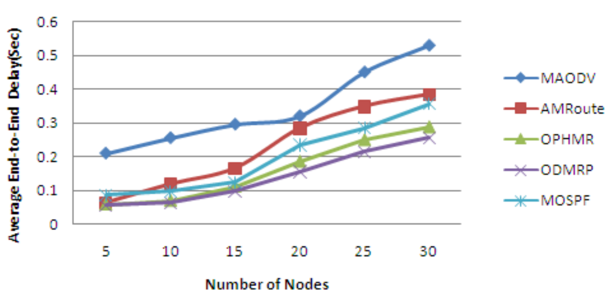

Figure 6: Average End-to-End Delay of MRP by varying group size.

Figure 6. Shows the end-to-end delay of all multicast routing protocols are compared by changing the number nodes. By increasing the traffic load the MAODV gives the high end-to-end delay and ODMRP gives the less end-to-end delay compared to other protocols. So compared to other multicast routing protocols ODMRP is better.

4. CONCLUSION

Wireless Mesh Network is the group of mesh clients, mesh routers and gateways connected through a mesh topology. Wireless Networks faces a major problem with routing. So, routing becomes interesting and attractive area of research. This paper gives the description of reactive, proactive, and hybrid multicast routing protocols in wireless mesh networks and its strengths and weaknesses. This will become more useful to researchers to enhance the existing Protocols, to avoid the problem in the existing protocols.

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