ROUTING PROTOCOL IN MOBILE AD HOC NETWORK (MANET)

Muhammad Anshari*

Abstract

*Teknologi informasi masa depan sebagian besar masih tetap didominasi oleh teknologi nirkabel (*wireless*). Dan* Mobile Ad Hoc Network *(MANET) adalah pengembangan dari tradisional seluler serta komunikasi* mobile *yang sangat bergantung kepada* fixed *infrastruktur. Penelitian yang mendalam dalam MANET meliputi semua lapisan jaringan mulai dari lapisan fisik sampai kepada lapisan aplikasi, termask di dalamnya aspek sosial dan ekonomi. Makalah ini difokuskan kepada beberapa hal penting mengenai explorasi klasifikasi jaringan Ad Hoc, jenis-jenis routing protokol yang dipergunakan, proses kerjanya dan faktor-faktor yang berdampak pada desain dan kinerja.*

Keywords: wireless network, ad hoc network, routing protocol

A. Introduction

A wireless network is an emerging new technology that will allow users to access information and services electronically, regardless of their geographic position.[1] The development of wireless transmissions and the popularity of portable computing devices have

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* Department of Information Technology, Faculty of Science & Technology - State Islamic University Sunan Kalijaga Yogyakarta

[1] Padmini Misra, *Routing Protocols for Ad-Hoc Mobile Wireless Networks*, http://www.cis.ohio-state.edu/misra [2/7/2000].

made the dream of "communication anytime and anywhere". [2] Users can move around, while at the same time still remaining connected with the rest of the world. We call this mobile computing, which has received intensive attention recently.[3]

Mobile ad hoc networks have attracted considerable attention, as evidenced by the Internet Engineering Task Force (IETF) working group MANET. This has produced various Internet drafts, RFCs, and other publications.[4] Also, a conference tutorial presents a good introduction to ad hoc networks.[5] Ad hoc networks have largely been studied for military applications, but they are expected to be used commercially in the near future.

A MANET consists of a set of mobile hosts operating without the help of fixed infrastructure of centralized administration. Communication is done through wireless links among mobile hosts through their antennas. A mobile host may not be able to communicate directly with other hosts in a single hop fashion, therefore multihop scenario occurs. Thus, each mobile host in a MANET must serve as a router. For example, a scenario of MANET in a military is illustrated in Figure 1 The helicopter and thank must communicate indirectly by at least two hops.

[2] Ivan Stojmenovic, *Handbook of Wireless Networks and Mobile Computing* (n.p.: John Wiley & Sons, Inc, 2002, p. 371.

[3] A. Archarys and B. R. Badrinath, "A Framework for Delivering Multicast Messages in Networks with Mobile Hosts," *ACM/Baltzer J. of Mobile Networks and Applications, 1*, 2, 1996. P.199–219.

[4] J. Macker and M. Corson, "Mobile Ad-hoc Networking and the IETF." *ACM Mobile Computing and Communications Review, 2*(1). (1998)

[5] N. Vaidya, "Tutorial: Mobile Ad-hoc Networks: Routing, MAC and Transport Issues," in *ACM MobiCom Tutorials*, Boston, MA: ACM, 2000.

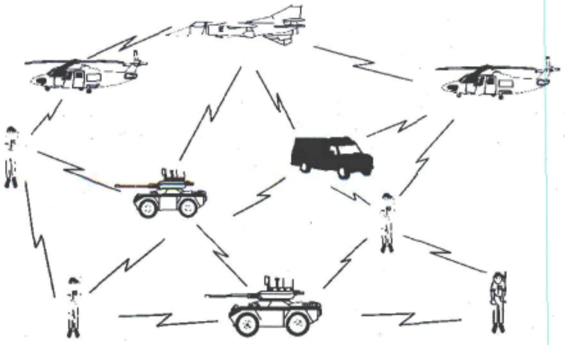

Figure1.
An example of MANET in Military

Generally, next generation of Mobile Communications can be classified in two types: Infrastructure-d network and infrastructure-less (ad hoc) networks.

1. Infrastructure-d wireless networks

Infrastructure-d wireless network consists of a network with fixed and wired gateways. A mobile host communicates with a bridge in the network (called base station) within its communication radius. The mobile unit can move geographically while it is communicating. When they go out of range of one base station, they connect with new base station and starts communicating through it.[6] This is called handoff. In this approach the base stations are fixed. Sample for infrastructure-d wireless networks are Mobile Cellular Systems, Mobile IP Networks and Wireless LAN (WLAN). The current Internet services can be provided by through these Infrastructure-d wired and wireless networks. For instance, cellular net-

[6] Thampuran Santhosh R, *Routing Protocols for Ad Hoc Networks of Mobile Nodes*, http://www-aml.cs.uma--.edu/~santhosh/Papers/AdhocRouting.pdf [20/6/2005].

works connect a mobile phone to the nearest base station (BS). A BS serves a hundreds of mobile users in a given area (cell) by allocating frequencies and providing handoff support. BSs are linked (by wireline, fiberline or wireless microwave links) to base station controllers that provide switching support to several neighbouring BSs and serve thousands of users (see Figure 2). Controllers are connected to a switching centre that is capable of serving more than 100,000 users.[7] Mobile switching centre are finally connected directly to the public service telephone network (PSTN). Therefore only the first and may be the last connection are normally wireless.

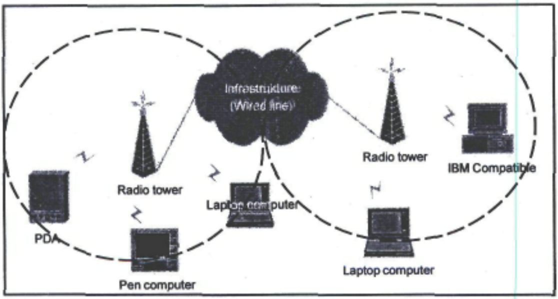

Figure 2.
Infrastructure-d Wireless Networks

2. Infrastructure-less Wireless Ad-hoc Network

Some wireless networks do not have a fixed infrastructure as a backbone. Examples are ad hoc network, sensor networks, and wireless LANs. Mobile Ad Hoc Network (MANET) is collection of two or more devices equipped with wireless communications and networking capability however without pre-existing communication infrastructure such as base station or access point.[8]

Ad Hoc wireless networks inherit the traditional problems of wireless & mobile communication, such as bandwidth optimiza-

[7] Ivan Stojmenovic, *Handbook*, p.18.

[8] Ivan Stojmenovic, *Handbook*, p. 325.

tion, power control and transmission quality enhancement. In addition, the multihop nature and the lack of fixed infrastructure generate new research problems such as configuration advertising, discovery and maintenance as well as ad hoc addressing and self-routing (see Figure 3). Devices communicate with one another within/outside the radio range to forward information packets from source of destination without the aid of centralized administrator. Each node in a wireless ad hoc network functions as both a host and a router. More interestingly, the network topology is in generic dynamic, because, the connectivity among the nodes may vary with the time due to node mobility, node departures and new node arrivals.

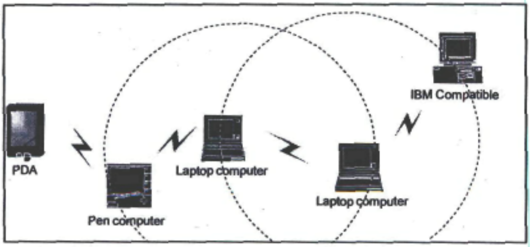

Figure 3.
Infrastructures-less Wireless Networks

The intermediate node is used to **relay** or **forward** the packet from source to destination. All the nodes are capable of movement and can be connected dynamically in an arbitrary manner.

Example ad hoc networks are heterogeneous Mobile device network such as PDA, mobile phone and mobile host network.

B. Classification of Ad-Hoc Networks

There is no standard classification of MANET; however a simple classification is to differentiate by formation and communication:

1. Singlehop

Wireless networks and mobile computing research has until recently concentrated on single-hop networks (network nodes communicating directly to a fixed infrastructure), such as cellular or satellite systems. In other word, Singlehop; nodes are in their reach area and can communicate directly.[9] Figure 4 shows the two nodes in their areas can communicate each other.

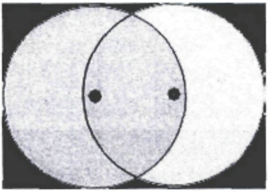

Figure 4.
Singlehop node communications

2. Multihop

Some nodes are far and cannot communicate directly. Therefore, the traffic of these communication end-points has to be forwarded by other intermediate nodes.[10] In the picture below the communication path of far nodes is depicted by black lines. In figure 5 shows that how the communication can take place when one node wish to communicate to the other end which far, then the node must go through intermediate node in order to reach intended destination.

[9] Iskra Popova, *Routing in Ad Hoc Networks*, 9th CEENet Workshop on Network Technology NATO ANW, 9th CEENet Workshop Budapest, 2004

[10] Ibid

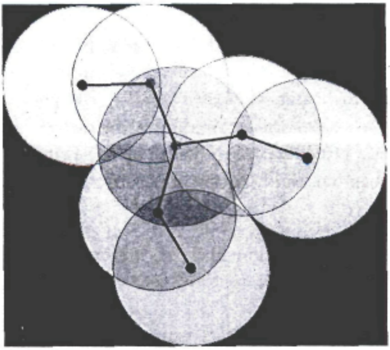

Figure 5.
Multihop Nodes Communication

C. Features of MANET

The nodes in MANETs are mobile; therefore the network topology changes continuously in the worst case. This property of MANET demands that the applied solutions and approaches have to deal with a very different environment than their counterparts in fixed networks. Additionally, in MANETs there are no nodes which are always reachable, i.e. you can't find a server which offers important services. A special variant of a MANET is the 3M-Network which stays for **Mobile, Multi-hop** and **Multimedia**.

In general MANET has special restrictions which should be considered by the design of solutions for this kind of networks.

1. Dynamic Topology

Due to the node mobility the topology of mobile multi-hop ad-hoc networks change continuously. The communication is typically multi-hop, which aggravates the communication quality further, thus several radio links exist in an end-to-end path.

The fact that the end-to-end path consists of several radio links may impact the performance of protocols and application which are in upper layers.

2. Bandwidth

The available bandwidth in Ad Hoc Networks is compared to fixed networks very small. The used air interface has higher bit error rates which aggravates the expected link quality.[11]

Current technologies suitable for the realization of MANET are IEEE 802.11(b,a) with bandwidth up to 54Mbps and Bluetooth providing bandwidth of 1Mbps.

3. Energy

The energy question plays an important role in MANET. This important resource has to be used very efficiently.

4. Security

The nodes and the information in MANET are exposed to the same threats like in other networks. Additionally to these classical threats, in MANET there are special threats, e.g. denial of service attacks against the energy resource can be performed by using of any of the services a node is offering.

D. Routing Protocols

The process of information exchange from one host to the other host in a network is called routing. It is an important aspect; an effective routing mechanism is required to establish a smooth transmission across the network. Because the topology of the network is always changing, the issue of routing packets between any pair of nodes becomes a challenging task in mobile ad-hoc networks.[12]

Due to the dynamic nature of a mobile ad-hoc network, it suffers with frequent topology changes. The network topology may change rapidly and unpredictably and the connectivity among the terminals may vary with time. The mobile nodes in the network dynamically establish routing among themselves as they move about; moreover a user in the mobile ad-hoc network may not only oper-

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[11] http://www.adhoc-nets.de, *Mobile Ad-Hoc Networks (MANET)*, August 2004.

[12] Bakht Humayun, "Wireless Infrastructure: A Focus on the Challenges of Mobile Ad-hoc N. .works," *Computing Unplugged Magazine*, 2003-200.

ate within the ad-hoc network, but may require access to a public fixed network. Mobile ad-hoc networks therefore should be able to adapt the traffic and propagation conditions as well as the mobility patterns of the mobile network nodes.

Routing protocols for a MANET can be classified as proactive (table-driven), reactive (on-demand) and recently a hybrid of proactive and reactive approaches, called the zone routing protocol (ZRP),[13] depending on how they react to topology changes.[14] Most of the existing protocols for mobile ad hoc networks are not univocally proactive or reactive, as some of the protocols have a hybrid proactive and reactive design or simply present elements of both approaches.

1. Proactive Protocols

The proactive approach is similar to the connectionless approach of traditional datagram networks, which is based on a constant update of the routing information.[15] Maintaining consistent and up-to-date routes between each source–destination pair requires the propagation of a large amount of routing information, whether needed or not. As a onsequence, in proactive protocols, a route between any source–destination pair is always available, but such protocols cannot perform properly when the mobility rate in the network is high or when there are a large number of nodes in the network. In fact, the control overhead, in terms of both traffic and power consumption, is a serious limitation in mobile ad hoc networks, in which the bandwidth and power are scarce resources.[16] The proactive approaches are more similar in design to traditional IP routing protocols; thus, they are more likely to retain the behavior features of presently used routing protocols. Existing transport protocols and applications are more likely to operate as designed

[13] Z. J. Haas and M. R. Pearlman, "The Zone Routing Protocol (ZRP) for Ad-hoc Networks," *Internet draft*, Aug. 1998.

[14] E. M. Royer and C.-K. Toh, "A Review of Current Routing Protocols for Ad hoc Mobile Wireless Networks," *IEEE Personal Communications*, Apr., 46–55, 1999.

[15] Ibid.

[16] Ibid

using proactive routing approaches than on-demand routing approaches.[17]

OLSR is proactive protocols; a proactive approach to MANET routing seeks to maintain a constantly updated topology understanding. The whole network should, in theory, be known to all nodes. This results in a constant overhead of routing traffic, but no initial delay in communication.

It is a table-driven pro-active protocol. It uses the link-state scheme in an optimized way to diffuse topology information.[18] In a classic link-state algorithm, link-state information is flooded throughout the network. OLSR uses this approach as well, but since the protocol runs in wireless multi-hop scenarios the message flooding in OLSR is optimized to preserve bandwidth. The optimization is based on a technique called *MultiPoint Relaying.*

Being a table-driven protocol, OLSR operation mainly consists of updating and maintaining information in a variety of tables. The data in these tables is based on received control traffic, and control traffic is generated based on information retrieved from these tables. The route calculation itself is also driven by the tables.

OLSR defines three basic types of control messages:

HELLO - *HELLO* messages are transmitted to all neighbours. These messages are used for neighbour sensing and MPR calculation.

TC - *Topology Control* messages are the link state signalling done by OLSR. This messaging is optimized in several ways using MPRs.

MID - *Multiple Interface Declaration* messages are transmitted by nodes running OLSR on more than one interface. These messages list all IP addresses used by a node.

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[17] J. P. Macker, V. D. Park, and M. S. Corson, "Mobile and Wireless Internet Services: Putting the Pieces Together," *IEEE Communication Magazine,* June, 2001.

[18] Tonnesen Andreas, *Implementing and extending the Optimized Link State Routing Protocol*, University of Oslo Department of Informatics 1st August 2004, p.19.

DSDV is based on the traditional distance vector routing mechanism, also called Bellham-Ford routing algorithm,[19] with some modifications to avoid routing loops. The main operation of the distance vector scheme is as follows. Every router collects routing information from all its neighbours, and then computes the shortest paths to all nodes in the network. After generating new routing table, the router broadcasts this table to all its neighbours. This will trigger other neighbours to recompute their routing tables, until information is steady.

DSDV is featured with freedom from loops and differentiation from stale routes from new ones by sequence numbers. Each mobile host maintains a sequence number by increasing it each time the host sends an update message to its neighbours. A route will be replaced only when the destination sequence number is less than the new one, or the two routes have the same sequence number but one has a lower metric.

2. Reactive Protocols

A reactive routing protocol only tries to maintain routes when necessary. In general, a routing protocol for MANET needs to address three issues: route discovery, data forwarding and route maintenance.[20] When a source node wants to deliver data to a destination node, it has to find a route first. Then data packets can be delivered. The topology of the MANET may change. This may deteriorate or even disconnect an existing route while data packets are being transmitted. Better routes may also be formed. This is referred to as route maintenance. In the following, we review several protocols according to these issues.

AODV is a reactive protocol; reactive protocols seek to set up routes on-demand. If a node wants to initiate communication with a node to which it has no route, the routing protocol will try to establish such a route.

In AODV, like all reactive protocols, is that topology information is only transmitted by nodes on-demand. When a node want

[19] G. Malkin, "RIP Version 2 Carrying Additional Information," *RFC, 1723*, 1994.

[20] Ivan Stojmenovic, *Handbook of Wireless Networks*, p. 373.

to transmit traffic to a host which it has no route, it will generate a *route request* (RREQ) message that will be flooded in a limited way to other nodes. This causes control traffic overhead to be dynamic and it will result in an initial delay when initiating such communication. A route is considered found when the RREQ message reaches either the destination itself, or an intermediate node with a valid route entry for the destination. For a route exists between two endpoints, AODV remains passive. When the route becomes invalid or lost, AODV will again issue a request.[21]

The *counting to infinity* problem in AODV from the classical distance vector algorithm by using sequence numbers for every route. The counting to infinity problem is the situation where nodes update each other in a loop. Consider nodes A, B, C and D making up a MANET as illustrated in figure 6. A is not updated on the fact that its route to D through C is broken. This means that A has a registered route, with a metric of 2, to D. C has registered that the link to D is down, so once node B is updated on the link breakage between C and D, it will calculate the shortest path to D to be via A using a metric of 3. C receives information that B can reach D in 3 hops and updates its metric to 4 hops. A then registers an update in hop-count for its route to D via C and updates the metric to 5. And so they continue to increment the metric in a loop.[22]

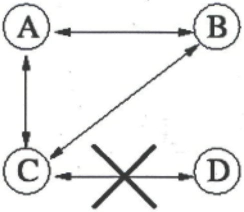

Figure 6.
A scenario that can lead to the ``counting to infinity" problem.

[21] Tonnesen Andreas, *Implementing and extending the Optimized Link State Routing Protocol*, University of Oslo Department of Informatics 1st August 2004, p.18.

[22] Andreas, *MANET Routing Protocols*, http://www.olsr.org/docs/report_html/node3.html [29/07/2004]

The way this is avoided in AODV, for the example described, is by B noticing that as route to D is old based on a sequence number. B will then discard the route and C will be the node with the most recent routing information by which B will update its routing table.

3. Hybrid - Zone Routing Protocol (ZRP)

Hybrid protocols seek to combine the proactive and reactive approaches. Achieving the right balance between reactive and proactive operation in a hybrid approach may require some a priori knowledge of the networking environment or additional mechanisms to adaptively control the mode of operation.[23] An example of such a protocol is the *Zone Routing Protocol* (ZRP).[24] ZRP divides the topology into zones and seek to utilize different routing protocols within and between the zones based on the weaknesses and strengths of these protocols. ZRP is totally modular, meaning that any routing protocol can be used within and between zones. The size of the zones is defined by a parameter *r* describing the radius in hops. Figure 7 illustrates a ZRP scenario with r set to 1. Intra-zone routing is done by a proactive protocol since these protocols keep an up to date view of the zone topology, which results in no initial delay when communicating with nodes within the zone. Inter-zone routing is done by a reactive protocol. This eliminates the need for nodes to keep a proactive fresh state of the entire network.

ZRP defines a technique called the *Bordercast Resolution Protocol* (BRP) to control traffic between zones. If a node has no route to a destination provided by the proactive inter-zone routing, BRP is used to spread the reactive route request.

[23] J. P. Macker, V. D. Park, and M. S. Corson, "Mobile and Wireless Internet Services: Putting the Pieces Together," *IEEE Communication Magazine,* June, 2001.

[24] Z. J. Haas and M. R. Pearlman, "The Zone Routing Protocol (ZRP) for Ad-hoc Networks," *Internet* draft, Aug. 1998.

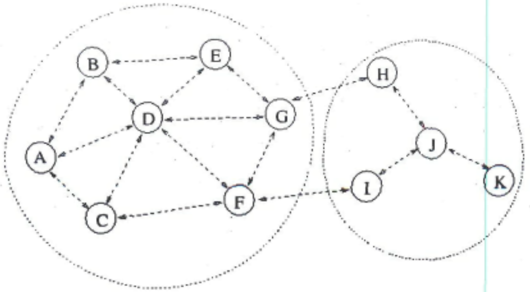

Figure 7 A ZRP scenario showing the zones of node A and node J using a r value of 2. Within the zones a pro-active routing protocol is used while a re-active protocol is used between zones.

4. Quality of Service (QoS) Routing

The specification and management of quality of service (QoS) is important to support multimedia applications (such as video and audio transmissions). QoS defines nonfunctional characteristics of a system that affect the perceived quality of the result. In multimedia, this might include picture quality, image quality, delay, and speed of response. From a technological point of view, QoS characteristics may include timeliness (e.g., delay or response time), bandwidth (e.g., bandwidth required or available), and reliability (e.g., normal operation time between failures or down time from failure to restarting normal operation).[25]

It is difficult to provide QoS in a MANET due to its broadcast and dynamic nature. First, unlike wired networks, a wireless link's bandwidth may be affected by the transmission activity of its adjacent links. Second, unlike cellular networks, which only need to guarantee quality for one hop, in MANET we must guarantee the quality for multiple hops in a path. Third, mobile hosts may

[25] C. Qiao, H. Wu, and O. Tonguz, "iCAR: An Integrated Cellular and Ad-hoc Relay System," in *IEEE International Conference on Computer Communications and Networks*, 2000.

join, leave, and rejoin at any time and at any location; existing links may disappear and new links may be formed as mobile hosts move. Recently, the QoS transmission problem in a MANET was addressed in several works.[26] We review some of these works from several aspects in the following subsections.

5. Route Delay and Bandwidth

To investigate the delay and bandwidth of a route in MANET, an implementation conducted by S.-L.Wu et.al, result is reported in Route maintenance in *a wireless mobile ad hoc network*, *Telecommunication Systems* [27], based on a next-hop routing protocol on top of the Linux operating system. The platform used consisted of a number of notebooks of a variety of speeds, each equipped with a Lucent WaveLAN wireless card conformed to the IEEE 802.11 MAC protocol operating at the 2.4 GHz band. The transmission rate of these network cards is claimed to be 2 Mbit/sec. With this platform, the authors observed the effect of hop count on the delay to discover a route. The mobile hosts were placed in a linear manner such that each host could hear only one or two of its neighbors. The first experiment used the ping command at a certain host to contact another host, observe the delay, and discover a new route. This experiment was done in an environment in which all mobile hosts had no up-to-date entries in their route caches. The result is shown in Figure 8. As can be seen, the delay is quite small. The time needed to find a route will increase linearly with respect to the hop count, which is reasonable.

[26] Y.-K. Ho and R.-S. Liu, "On-demand QoS-based Routing Protocol for Ad hoc Mobile Wireless Networks," in *IEEE Symposium on Computers and Communications ISCC '00*, 2000.

[27] S.-L. Wu, S.-Y. Ni, Y.-C. Tseng, and J.-P. Sheu, Route maintenance in a wireless mobile ad hoc network, *Telecommunication Systems, 18*, 1/3, 61–84, 2001.

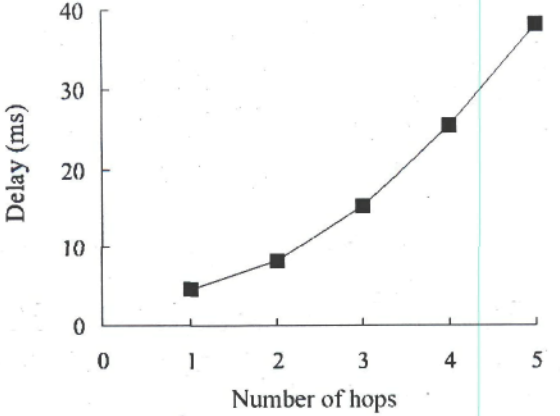

Figure 8
The delay to discover a new route versus route length in a MANET by Ping Command

E. Conclusion

In this paper we have introduced mobile ad hoc networks. Such wireless network architectures can be utilized when the construction of base stations is to costly. Routing protocols for mobile ad hoc networks are different than protocols for conventional networks, due to increased mobility and rapid topology change. Different international organizations and universities have proposed many protocols, but no single protocol can handle all the real world network scenarios. The simulations prove the fact that no single protocol can successfully address all the networking problems in ad hoc networks. Variant of distance vector routing algorithm like AODV do perform good in most of simulations but the jitter performance and the control over head do not match the performance of link state routing algorithm like OLSR. It is also evident that the routing layer alone cannot tackle all the problems, and support form link layer is required.

A hybrid approach, which incorporates both reactive and proactive route acquisition process, can give better results as compared to existing routing protocols.

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