Mobile Ad Hoc Network Routing Protocols: A Comparative Study

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ABSTRACT

An Ad hoc network is a collection of wireless mobile hosts forming a temporary network without the aid of any centralized administration or infrastructure. Such networks have no fixed topology due to the high degree of node mobility. Hence, efficient and reliable routing is one of the key challenges in mobile ad hoc networks. Many routing algorithms have been proposed and developed for accomplishing this task. Therefore, it is difficult to determine which protocol performs best under a number of different scenarios. Hence, this paper presents review and a comparison of the typical representatives of routing protocols designed for MANETs.

KEYWORDS

Mobile Ad Hoc Networks, Routing protocols, DSDV, DSR, AODV, review

1. INTRODUCTION

Wireless communication is an emerging and upcoming technology that will allow users to access information and services electronically, irrespective of their geographic location. There are solutions to these demands, one being wireless local area network (based on IEEE 802.11 standard). However, there is increasing demand for connectivity in situations/places where there is no base station / infrastructure available. This is where ad hoc network came into existence. Wireless networks can be classified into infrastructure networks and infrastructure less networks or mobile ad hoc networks (MANETs).

MANETs are autonomously self-organized and self-configuring networks without infrastructure support. In such networks, since node mobility is very high the network may experiences frequent and unpredictable topology changes. Mobility and the absence of any fixed infrastructure make MANETs very attractive for time-critical applications. Ad hoc network applications include students using laptop to participate in an interactive lecture, business associates sharing information during a conference and search & rescue operations.

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Recently, Mobile Ad Hoc networks became a hot research topic among researchers due to their flexibility and independence of network infrastructures such as base stations. The infrastructure less and the dynamic nature of these networks demand new set of networking strategies to be implemented in order to provide efficient end-to-end communication. MANETs can be deployed quickly at a very low cost and can be easily managed. In the future, there is no doubt that we will have more and more ad-hoc networks, in which routing is one of the critical issue.

Need of a routing algorithm arises whenever a packet needs to be transmitted to a node via number of different nodes. Several routing protocols exist for wired networks, which can be classified as using either the *distance vector* or the *link-state* algorithm. These algorithms were designed for use in wired networks where topology changes are infrequent. They are also computation intensive, making them difficult to use with limited resources. Due to these problems, new routing algorithms are designed keeping in mind the characteristics of MANETs. An ad-hoc routing protocol must be able to decide the best path between the nodes having unidirectional links, minimize the routing overhead to enable proper routing, minimize the time required to converge after the topology changes and maximize the bandwidth utilization. Therefore, developing support for routing is one of the key research areas in MANETs.

Until now, many researchers performed valuable research with reference to routing in MANETs. This article is the first to present a qualitative comparison between the three typical representatives of routing protocols designed for MANETs- DSDV [5], DSR [2] & AODV [6]. The rest of the article is organized as follows. Section II discusses the related work with a focus on comparative study of the routing protocols. Section III presents the classification of existing routing protocols. Working of some of these protocols is described in Section IV, with a glimpse of their advantages and limitations. Section V presents a comparative study of these protocols. Lastly, section VI concludes the article.

2. RELATED WORK

A number of routing protocols have been proposed and implemented for MANETs in order to enhance the bandwidth utilization, minimum energy consumption, higher throughputs, less overheads per packet, and others. Different routing protocols have used different metrics to determine an optimal path between the sender and the recipient. All these protocols have their own advantages and disadvantages.

Any MANET routing protocol exhibits two types of properties:

- Qualititaive such as loop freedom, security, demand based routing, distributed operation, multi-path routing etc.
- Quantitative such as throughput, delay, route discovery time, packets delivery ratio, jitter etc.

Obviously, most of the routing protocols are both qualitatively and quantitatively enabled. A lot of simulation studies were carried out in paper [3], [16] to analyze the quantitative properties of routing protocols.

A number of comparative studies/ review papers on various MANET routing protocols have been proposed, which highlights some of the quantitative analysis or comparison between different types of protocols[1], [7]. Our efforts is to provide a qualitative comparison of the three most popular routing protocols designed for MANETs- DSDV [5], DSR [2] & AODV [6].

The emphasis in this paper is concentrated on the study, survey and comparison of most popular routing protocols DSDV, AODV & DSR, as these are best suited for ad-hoc networks. Our work is to methodically investigate the characteristics of proactive and on-demand routing approaches by studying some of the protocols. The next section describes the classification of routing protocols.

3. CLASSIFICATION OF ROUTING PROTOCOLS

The inadequate and limited resources in MANETs have made designing of an efficient and reliable routing strategy a very challenging task. An intelligent routing algorithm is required to efficiently use these limited resources while at the same time being adaptable to the changing network conditions such as network size, traffic density, nodes mobility, network topology and broken routes.

Numerous routing protocols have been proposed and developed for ad hoc networks. Such protocols must deal with the limited resources available with these networks, which include high power consumption, low bandwidth and high mobility. Existing routing protocols can be classified in many ways, but most of these are done depending on routing strategy and network structure [7]. According to the routing strategy, routing protocols can be categorized as Table-driven, On-demand driven and Hybrid (see Fig. 1), while depending on the network structure they are classified as flat routing, hierarchical routing and geographic position assisted routing.

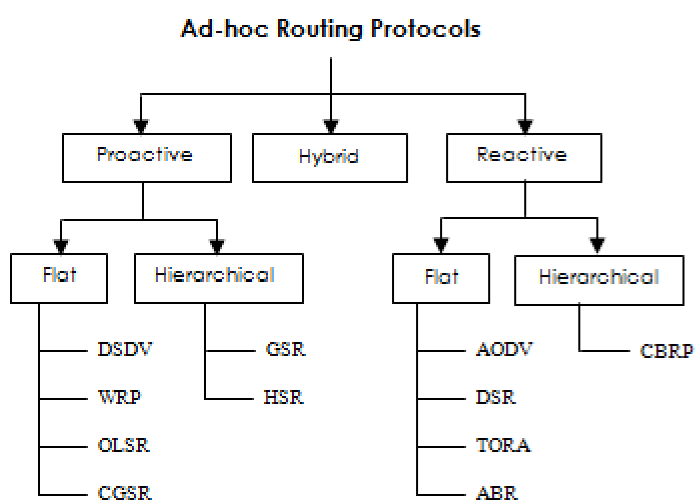

Figure 1. Classification of Routing Protocols

3.1 Table-driven Routing Protocols (Proactive)

Proactive protocols are also known as “table-driven” routing protocols. In this protocol, each and every node maintains complete information about the network topology by continuously evaluating routes to all the nodes. Hence, they maintain consistent and up-to-date routing information. These protocols are known as proactive since they maintain the routing information before it is needed. Each and every node in the network maintains routing information about how to reach every other node in the network. The route information in proactive routing is maintained in the routing tables and is updated as and when the network topology changes. This causes more overhead in the routing table leading to consumption of more bandwidth.

There are various existing proactive routing protocols. The areas in which they differ are the number of necessary routing tables and the methods by which changes in the network topology are broadcast. Some of the existing proactive protocols are Destination-Sequenced Distance Vector (DSDV) [5], Global State Routing (GSR) [13], Fisheye State Routing (FSR) [11].

3.2 On-demand Routing Protocols (Reactive)

A different approach from table-driven routing is on-demand routing. In this approach, a routing path is discovered only when the need arises. These are called reactive since it is not necessary to maintain routing information at the nodes if there is no communication. When needed, a route discovery operation in turn invokes a route-determination procedure. The discovery procedure terminates either when a route has been found or no route available after examination of all the route permutations.

The primary advantage of reactive routing is that the wireless medium is not subject to the routing overhead for the routes that may never be used. Although reactive protocols do not have the fixed overhead (required in maintaining continuous updated routing tables), they may have significant route discovery delay. Some of the existing reactive protocols are Ad hoc On-Demand Distance Vector (AODV) [6], Dynamic Source Routing (DSR) [2], Associativity Based Routing (ABR) [10], Signal stability based adaptive Routing (SSR) [9].

Table 1 compares the table-driven and on-demand routing protocols.

	Table-driven	**On-demand**
Availability of Routing Information	Always available (in routing table)	Available when needed
Route Updates	Periodic	When requested
Routing Structure	Both flat and hierarchical	Mostly flat
Storage Requirements	High	Usually lower than proactive
Routing Overhead	Proportional to the size of network	Proportional to the number of communicating nodes
Latency	Small	Most applications suffer a long delay

4. ROUTING PROTOCOLS

This section describes some of the important proactive and reactive routing protocols.

4.1 Destination-Sequence Distance Vector (DSDV) routing protocol

The DSDV protocol described in [6] is a table-driven protocol based on the classical Bellman-Ford algorithm [9].

Each node in the network maintains a routing table that contains a list of all the possible destinations within the network. Each entry in the table contains the destination address, the shortest metric to that destination in terms if hop count, the next hop address and a sequence number generated by the destination node. The route with the greater sequence numbers is preferred. Sequence numbers are used to distinguish stale routes from fresh ones, thereby avoiding the routing loops.

Routing table updates are periodically transmitted throughout the network in order to maintain updated information in the table and its consistency. The route updates can be either time-driven or event-driven. Every node periodically transmits routing information to its immediate neighbours. Instead of transmitting the entire routing table, a node can also propagate its changed routing table since the last update.

To reduce the large amount of network traffic that such updates can create, route updates can employ two possible types of packets. The first is known as a *full dump.* This type of packet carries complete routing information and can require multiple network protocol data units (NPDUs). During periods of infrequent movement, these packets are transmitted occasionally. Smaller *incremental packets* are used to transmit only that information which has changed since the last full dump.

Advantages

- Guarantees loop free paths.
- Sequence number ensures the freshness of routing information available in the routing table.
- DSDV avoids extra traffic by using incremental updates instead of full dump updates.
- DSDV maintains only the best path or shortest path to every destination. Hence, amount of space in routing table is reduced.

Limitations

- Large amount of overhead due to the requirement of periodic update messages, which makes them un-effective in large networks.
- It doesn't support multi path routing.
- Wastage of bandwidth due to needless advertising of routing information even if there is no change in the network topology

4.2 Dynamic Source Routing (DSR)

DSR [2], a reactive unicast protocol is based on source routing algorithm. In source routing, each data packet contains complete routing information to reach its destination. There are two major phases in DSR: *route discovery* and *route maintenance*.

When a source node wants to send a packet, it first searches for an entry in its route cache. If the route is available, the source node includes the routing information inside the data packet before sending it. Otherwise, the source node initiates a route discovery operation by broadcasting route request (RREQ) packets. Each RREQ packet is uniquely identified by the source address and the request id (a unique number). On receipt it the RREQ packet, an intermediary node checks its route cache. If the node doesn't have routing information for the requested destination, it appends its own address to the route record field of the route request packet. Then, the request packet is forwarded to its neighbors. A node processes route request packets only if it has not seen the packet before and its address is not presented in the route record field. If the route request packet reaches the destination or an intermediate node has routing information to the destination, a route reply packet is generated. When the route reply packet is generated by the destination, it comprises addresses of nodes that have been traversed by the route request packet. Otherwise, the route reply packet comprises the addresses of nodes the route request packet has traversed concatenated with the route in the intermediate node's route cache.

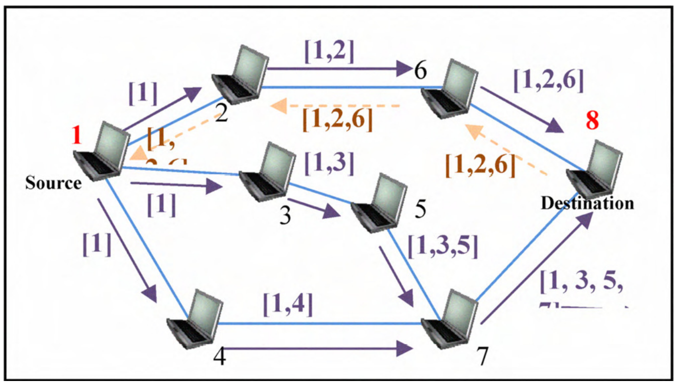

Figure 2.DSR

Advantages

- Reduction of route discovery overheads with the use of route cache.
- Supports multi path routing.
- Does not require any periodic beaconing or hello message exchanges.

Limitations

- DSR is not very effective in large networks, as the amount of overhead carried in the packet will continue to increase as the network diameter increases.
- Because of source routing, packet size keeps on increasing with route length.
- Being a reactive protocol, DSR suffers from high route discovery latency.

4.3 Ad-Hoc On-Demand Distance Vector (AODV) Routing protocol

As a reactive protocol, AODV [7] only needs to maintain the routing information about the active paths. Every node keeps a next-hop routing table, which includes only those destinations to which it currently has a route. A route entry in the routing table expires if it has not been used for a pre-specified expiration time. Moreover, AODV adapts the destination sequence number technique used by DSDV.

In AODV, when a source node wants to send packets to the destination, it initiates a route discovery operation if no route is available. In the route discovery operation, the source broadcasts route request (RREQ) packets. A RREQ includes addresses of the source and the destination, the broadcast ID, which is used as its identifier, the last seen sequence number of the destination as well as the source node's sequence number. Sequence numbers ensure loop-free and up-to-date routes.

In AODV, each node maintains a cache to keep track of RREQs it has received. The cache also stores the path back to each RREQ originator. When the destination or a node that has a route to the destination receives the RREQ, it checks the destination sequence numbers it currently knows and the one specified in the RREQ. In response to RREQ, a route reply (RREP) packet is created and forwarded back to the source only if the destination sequence number is equal to or greater than the one specified in RREQ. This in turn guarantees the freshness of the routing information. Upon receiving the RREP packet, each intermediate node along the route updates its next-hop table entries with respect to the destination node. The redundant RREP packets or RREP packets with lower destination sequence number will be dropped.

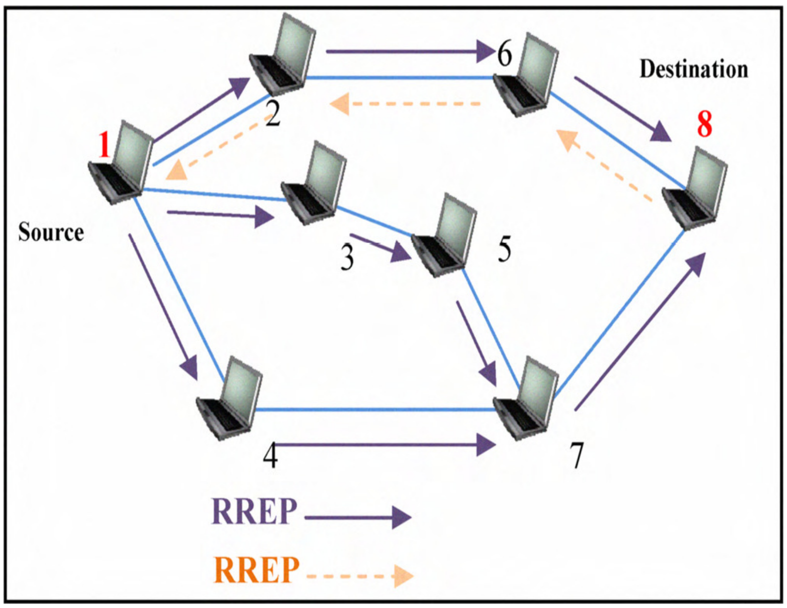

Figure 3. AODV protocol

If a link break occurs in an active route, the node broadcasts a route error (RERR) packet to its neighbors, which in turn propagates the RERR packet towards the source node. Then, the affected source can re-initiate a route discovery operation to find a route to the desired destination.

Advantages

- AODV can handle highly dynamic MANETs.
- Less amount of storage space as compared to other reactive routing protocols, since routing information which is not in use expires after a pre-specified expiration time.
- Supports multicasting.

Limitations

- AODV lacks an efficient route maintenance technique. The routing information is always obtained on demand [26].
- Similar to DSR, AODV also suffers from high route discovery latency.
- More number of control overheads due to many route reply messages for single route request.

5. COMPARATIVE STUDY

This section provides comparative analysis between routing protocols described in the previous section. Refer table 2 for the same. Time complexity is defined as the number of steps needed to perform a protocol operation and communication complexity is the number of messages needed to perform a protocol operation [10], [17]. Also, the values for these metrics represent the worst-case behaviour.

Control traffic overhead and loop-free properties are two important issues with proactive routing protocols in MANETs. The proactive routing used for wired networks normally have predictable control traffic overhead because topology changes rarely and most routing updates are periodically propagated.

As stated earlier, DSDV is essentially a modification of the basic Bellman-Ford routing algorithm. The modification includes the guarantee of loop-free routing and a simple route update protocol. DSDV selects the shortest path by using number of hops required to reach the destination as the routing metric. It utilizes destination sequence number to avoid route loops. Both periodic and triggered updates are utilized in DSDV. However, DSDV is inefficient because of the requirement of periodic update transmission, regardless of the number of changes in the network topology.

Reactive routing protocols were proposed to reduce the traffic control overhead and improve scalability. The DSR algorithm is intended for networks in which the mobiles move at moderate speed with respect to packet transmission latency [2]. As compared to the other reactive protocols, DSR does not make use of periodic routing advertisements, thus saving bandwidth and reducing power consumption. However, because of the small diameter assumption and the source routing requirement, DSR is not scalable to large networks.

Similar to DSR, AODV employs a route discovery procedure, but the DSR overhead is potentially larger than that of AODV since AODV packet only contain the destination address instead of the complete routing information. Another advantage of AODV is that it supports multicasting [7].

AODV exploits both the distance vector used in DSDV and source routing from DSR. Among the three protocols, AODV has less traffic control overhead and is most scalable (because of the smaller size of data packets as compared to DSR and no periodic route updates as compared to DSDV). However, AODV does require hello messages exchanges periodically with their neighbours to monitor link disconnections.

	DSDV	AODV	DSR
Protocol Type	Distance vector	Distance vector & Source routing	Source routing
Route Computation	Proactive	Reactive	Reactive
Routing Structure	Flat	Flat	Flat
Update Period	Periodic and as required	Event-driven	Event-driven
Loop-free	Yes	Yes	Yes
Multicast capability	No	Yes	No
Routing metric	Shortest path	Freshest & shortest path	Shortest path
Updates transmitted to	Neighbors	Source	Source
Hello message requirement	No	Yes	No
Multiple routes	No	No	Yes
Route maintained in	RT	RT	RC
Utilizes sequence numbers	Yes	Yes	No
Utilizes route cache/table expiration times	No	Yes	No
Time Complexity (initialization/post failure)	O(d)	O(2d)	O(2d)
Communication Complexity (initialization/post failure)	O(N)	O(2N)	O(2N)
Storage Complexity	O(N)	O(D')	O(d)
Advantages	Loop-free	Adaptable to highly dynamic topologies	Multiple routes
Limitations	High overhead	Scalability problems, large delays	Scalability problems due to source routing & flooding

Table 2: Comparison of DSDV, AODV and DSR

d- Network diameter
N- Number of nodes in network
D'- the number of maximum desired destinations

RT- Route table
RC – Route cache

In AODV & DSR, a node notifies the source to initiate a new route discovery operation when a routing path disconnection is detected. Both use flooding to inform nodes. Both AODV and DSDV use sequence numbers to avoid formation of route loops. Since DSR employs source routing approach, formation of a loop can be avoided by checking addresses in route record field of data packets.

Performances of DSDV, DSR & AODV are compared in [3] based on simulation. The simulation results showed that every protocol perform well for different simulation scenarios.

6. CONCLUSION

This article described the classification of several routing schemes according to the routing strategy. We discussed some important characteristics of the two routing strategies (table-drive and on-demand). Table 1 highlighted few differences between them.

In this paper, an effort has been made to concentrate on the comparative study of DSDV, AODV & DSR. Moreover, a single routing protocol can't perform best in all situations. So, the choice of routing protocol should be done carefully according to the requirements of the specific application. The focus of the study in our future research work is to propose an extension of the existing conventional routing protocols which will be better in terms of security, throughput, efficient utilization of limited resources and quality of service.

References

[1] Mehran Abolhasan, Tadeusz Wysocki, and Eryk Dutkiewicz. "A review of routing protocols for mobile ad hoc networks". Technical report, Telecommunication and Information Research Institute, University of Wollongong, Wollongong, NSW 2522; Motorola Australia Research Centre, 12 Lord St., Botany, NSW 2525, Australia, 2003.

[2] David B. Johnson and David A. Maltz. "Dynamic source routing in ad hoc wireless networks". Technical report, Carnegie Mellon University, 1996.

[3] J. Broch, David B. Johnson, David A. Maltz, "A performance comparison of multi-hop wireless ad hoc network routing protocols". Proc. MOBICOM, 1998, 85-97.

[4] Charles E. Perkins. Ad Hoc Networking. Addision Wesley, 2001.

[5] C. E. Perkins and P. Bhagwat. Highly dynamic Destination-Sequenced Distance-Vector Routing (DSDV) for mobile computers, ACM Computer Communication Review, Vol. 24, No.4, (ACM SIGCOMM'94) Oct. 1994, pp.234-244.

[6] Charles E. Perkins and Elizabeth M.Royer. "Ad-hoc on-demand distance vector routing". Technical report, Sun Micro Systems Laboratories, Advanced Development Group, USA.

[7] Elizabeth M. Royer and Chai-Keong Toh. "A review of current routing protocols for ad hoc mobile wireless networks". Technical report, University of California and Georgia Institute of Technology, USA, 1999.

[8] A. S. Tanenbaum, Computer Networks, 3rd ed., Ch. 5, Englewood Cliffs, NJ: Prentice Hall, 1996, pp. 357-58.

[9] R. Dube et al., "Signal Stability based Adaptive Routing (SA) for Ad- Hoc Mobile Networks," PerS. Commun., Feb. 1997, pp. 36-45.

[10] C-K. Toh, "Associativity-Based Routing for Ad-Hoc Mobile Networks," Wireless Pers. Commun., vol. 4, no. 2, Mar. 1997, pp. 1-36.

[11] G. Pei, M. Gerla and T.-W. Chen, Fisheye State Routing in Mobile Ad Hoc Networks. In Proceedings of the 2000 ICDCS Workshops, Taipei, Taiwan, Apr. 2000, pp. D71-D78

[12] G. Pei, M. Gerla, and X. Hong, LANMAR: Landmark routing for large scale wireless ad hoc networks with group mobility. In Proceedings of the ACM Symposium on Mobile Ad Hoc Networking and Computing (MOBIHOC), pages 11-18, 2000.

[13] T.-W. Chen, M. Gerla, Global state routing: a new routing scheme for ad-hoc wireless networks, in: Proceedings of the IEEE ICC, 1998.

[14] V.D. Park, M.S. Corson, A highly adaptive distributed routing algorithm for mobile wireless networks, in: Proceedings of INFOCOM, April 1997.

[15] Krishna Ramachandran, Aodv-st, Technical report, University of California, Santa Barbara, USA. http://www.cs.ucsb.edu/AODV/adofv.html.

[16] Mohammed Bouhorma, H.Bentaouit & A. Boudhir, "Performance Comparison of Ad Hoc Rouitng Protocols AODV & DSR", IEEE 2009.

[17] M.S. Corson and A. Ephremides, "A distributed routing algorithm for Mobile Wireless Networks", ACM/Baltzer Wireless Networks J., vol. 1, no. 1, Feb. 1995, pp. 61-81.