MANET Routing Algorithms

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Abstract

Wireless mobile ad-hoc networks are characterized as networks without any physical connections. In these networks there is no fixed topology due to the mobility of nodes, interference, multipath propagation and path loss. Hence a dynamic routing protocol is needed for these networks to function properly. Many Routing protocols have been developed for accomplishing this task. The purpose of this paper is to study, understand, analyze and discuss mobile ad-hoc routing protocols where the first one is a proactive protocol depending on routing tables which are maintained at each node. The other one is reactive protocols, which find a route to a destination on demand, whenever communication is needed. There is also a protocol which uses the property of both proactive and reactive called Hybrid protocol. Considering the bandwidth, throughput and packet loss, in both DSDV and AODV routing protocols, DSDV is best suited for only smaller networks and AODV is suited for general Ad-hoc networks. Here in this paper there are also some protocols which are the improved version of previous one such as AODV-PA, I-DSDV and also one example of Hybrid protocol, ZRP.

Keywords: MANET, DSR, AODV, AODV-PA, DSDV, I-DSDV, ZRP.

1. Introduction

A MOBILE *Ad hoc* NETwork (MANET) consists of wireless mobile nodes (MNs) that communicate with each other without the existence of a fixed network infrastructure. Depending on different geographical topologies, the MNs are dynamically located and continuously changing their locations. The fast-changing characteristics of MANETs make it difficult to discover routes between MNs. It becomes important to design efficient and reliable routing protocols to maintain, discover, and organize the routes in MANETs. Recent interest in the design of ad hoc routing algorithms includes applications for the military, intervehicle communication, personal communication services, and sensor networks.

Routing is the act of moving information from a source to a destination in an internetwork. During this process, at least one intermediate node within the internetwork is encountered. The routing concept basically involves, two activities: firstly, determining optimal routing paths and secondly, transferring the information groups (called packets) through an internetwork. The later concept is called as packet switching which is straight forward, and the path determination could be very complex. Routing protocols use several metrics to calculate the best path for routing the packets to its destination.

2. MANET Routing Protocols

Numerous protocols have been developed for adhoc mobile networks to deal with the typical limitations of these networks, which include high power consumption, low bandwidth, and high error rates. Routing protocols in ad hoc networks are categorized in three groups: Proactive (Table Driven) and Reactive (On-Demand) routing and third one is the combination of these two called Hybrid Protocol.

2.1. Proactive

Proactive protocols attempt to maintain consistent, up-to-date routing information from each node to every other node in the network. These protocols require each node to maintain one or more tables to store routing information, and they respond to changes in network topology by propagating updates throughout the network in order to maintain a consistent network view. The areas in which they differ are the number of necessary routing-related tables and the methods by which changes in network structure are broadcast. Various table-driven protocols differ in the way the information about a change in topology is propagated through all nodes in the network. Several proactive routing protocols are addressed in[1] such as DSDV.

2.2. Reactive

A different approach from table-driven routing is source initiated on-demand routing. This type of routing creates routes only when desired by the source node. When a node requires a route to a destination, it initiates a route discovery process within the network. This process is completed once a route is found or all possible route permutations have been examined. Once a route has been established, it is maintained by a route maintenance procedure until either the destination becomes inaccessible along every path from the source or until the route is no longer desired. These reactive or on demand protocols include Dynamic Source Routing (DSR) and Ad-hoc On- demand Distance Vector Routing (AODV), as well as the classical flooding algorithms. Compared to the reactive protocols, the proactive protocols incur shorter delay in sending out packets and they also maintain the entire network topology information. However, they use up more bandwidth since they need to periodically broadcast the routes for all nodes in the network .In fact, the bandwidth usage for control messages is proportional to the size of the network.[1].

2.3. Hybrid protocol

Hybrid protocol combines the advantages from proactive and reactive routing. It takes the advantage of pro-active discovery within a node's local neighborhood (Intrazone Routing Protocol (IARP)), and using a reactive protocol for communication between these neighborhoods (Interzone Routing Protocol (IERP)). The Broadcast Resolution Protocol (BRP) is responsible for the forwarding of a route request. ZRP divides its network in different zones. That's the nodes local neighborhood. Each node may be within multiple overlapping zones, and each zone may be of a different size. The size of a zone is not determined by geographical measurement. It is given by a radius of length, where the number of hops is the perimeter of the zone. Each node has its own zone.

3. Dynamic Source Routing (DSR) Protocol

The Dynamic Source Routing protocol (DSR)[2] is a simple and efficient routing protocol designed for use in multi-hop wireless ad hoc networks of mobile nodes. DSR allows the network to be completely self-organizing and self-configuring, without the need of any existing infrastructure network or administration. The protocol is composed of the two mechanisms: Route Discovery and Route Maintenance, which work together to allow nodes to discover and maintain source routes to arbitrary destinations in the ad hoc network. The use of source routing protocol allows the packet routing to be little important loop-free and avoids the need for up-to-date routing information in the intermediate nodes through which packets are forwarded, and allows nodes forwarding or overhearing packets to cache the routing information in them for their own future use. All aspects of the protocol operate entirely on-demand, allowing the routing packet overhead of DSR to scale automatically to only that needed to react to changes in the routes currently in use.

The two processes can be described as : Route Discovery is the mechanism by which a source node S wishing to send a packet to a destination node D obtains a source route to D. Route Discovery is used only when S attempts to send a packet to D and does not already know a route to D and Route Maintenance is the mechanism by which node S is able to detect, while using a source route to D, if the network topology has changed such that it can no longer use its route to D because a link along the route no longer works. When Route Maintenance indicates a source route is broken, S can attempt to use any other route it happens to know to D, or can invoke Route Discovery again to find a new route. Route Maintenance is used only when S is actually sending packets to D.

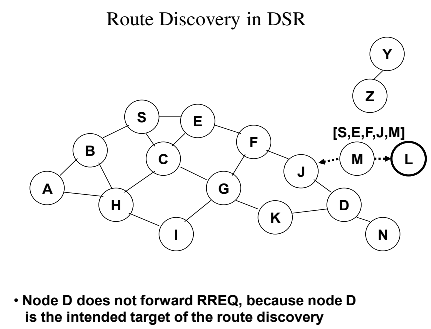


Figure1.1: Route Discovery in DSR

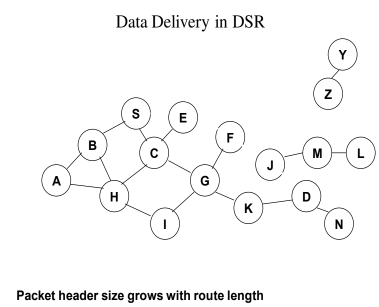


Figure1.2 data delivery

In the figure 1.1 when some source node S originates a new packet destination to some other node D, it places in the header of the packet a source route giving the sequence of hops that the packet should follow on its way to D. Normally, S will obtain a suitable source route by searching its Route Cache of routes previously learned, but if no route is found in its cache, it will initiate the Route Discovery protocol to dynamically find a new route to D. In this case, it call S the initiator and D the target of the Route Discovery.
In the situation illustrated in Figure 1.2, node S has originated a packet for D using a source route through intermediate nodes C, G, and K. In this case, node S is responsible for receipt of the packet at C, node C is responsible for receipt at G, node G is responsible for receipt at K, and node K is responsible for receipt finally at the destination D.

There are some limitations of DSR such as Packet header size grows with route length due to source routing, flood of route requests may potentially reach all nodes in the network and. Potential collisions between route requests propagated by neighboring nodes.

4. AODV

Ad hoc On-Demand Distance Vector (AODV)[3] Routing is a routing protocol for mobile ad hoc networks(MANETs) and other wireless ad-hoc networks. Ad hoc On Demand Distance Vector routing (AODV) is capable of both unicast and multicast routing. It is a reactive routing protocol, meaning that it establishes a route to a destination only on demand. AODV is, as the name indicates, a distance-vector routing protocol. AODV avoids the counting-to-infinity problem of other distance-vector protocols by using sequence numbers on route updates. AODV is essentially a combination of both DSR and DSDV. It borrows the basic on-demand mechanism of Route Discovery and Route Maintenance from DSR, plus the use of hop-by-hop routing, sequence numbers, and periodic beacons from DSDV.

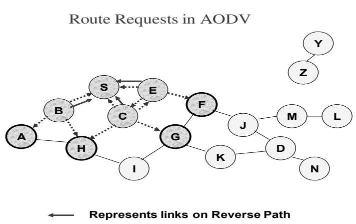


Figure2.1 RREQ in AODV

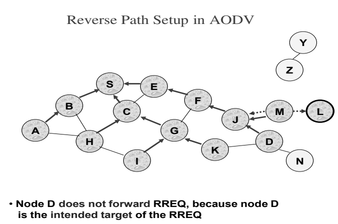


Figure2.2 Reverse path setup in AODV

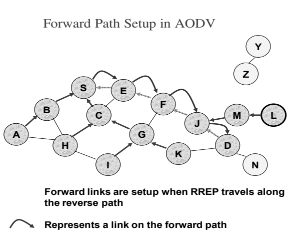


Figure2.3 forward path setup in AODV

In AODV (i) Route Requests (RREQ) are forwarded in a manner similar to DSR. (ii) When a node re-broadcasts a Route Request, it sets up a reverse path pointing towards the source. (iii) When the intended destination receives a Route Request, it replies by sending a Route Reply (RREP). (iv)Route Reply travels along the reverse path set-up when Route Request is forwarded. (v)When any node X is unable to forward packet P (from node S to node D) on link (X,Y), it generates a RERR message.

There are some advantages of AODV given as

(i) It has Minimal space complexity
(ii) Maximum utilization of the bandwidth
(iii) Most effective routing info
(iv) Most current routing info
(v) Loop-free routes.

There are some disadvantage of AODV given as

(i) No reuse of routing info
(ii) Overhead on the bandwidth
(iii) High route discovery latency.

5. AODV with Path Accumulation[4]

AODV can be modified to enable path accumulation during the route discovery cycle. When the RREQ and RREP messages are generated or forwarded by the nodes in the network, each node appends its own address on these route discovery messages. Each node also updates its routing table with all the information contained in the control messages. As the RREQ (route request) messages are broadcast, each intermediate node that does not have a route to the destination forwards the RREQ packet after appending its own address in the packet. Hence, at any point the RREQ packet contains a list of all the nodes traversed. Whenever a node receives a RREQ packet, it updates the route to the source node. It then checks for intermediate nodes accumulated in the path. A new entry is made in the routing table for any of the intermediate nodes, if one did not already exist. If a route entry for a node does exist, and if the hop count to any of the intermediate nodes is less than the previously known hop count to that node, the routing table entry is updated for that node. The entry is updated by retaining the previously known sequence number for that node.

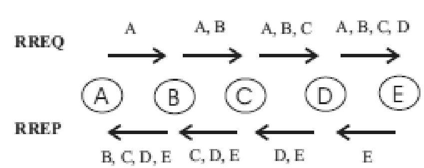


Figure 3.1: Path Accumulation in AODV-PA

As an example, consider five nodes A, B, C, D and E as shown in figure 3.1. Node A wants to send data to node E. Since A does not have any route for E in its routing table, so it broadcasts a route request (RREQ). B receives the route request, updates its routing table for the reverse route to A, and forwards the request since it also has no route to E. However, before forwarding, it appends its own address to the request. When C receives the RREQ, it updates its routing table for both node A and B and appends its address to the request. Similarly, when D receives the request it updates its routing table for nodes A, B and C, while E learns about nodes A, B, C and D. Thus, the routing table is populated and during subsequent route requests, there is a high probability of routes being present in the routing table. This should decrease the number of route discovery cycles as compared to basic AODV. So this AODV-PA increases the efficiency of AODV.

6. DSDV

In DSDV[5] each node in the network maintains routing table for the transmission of the packets and also for the connectivity to different stations in the network. These stations list for all the available destinations, and the number of hops required to reach each destination in the routing table. The routing entry is tagged with a sequence number which is originated by the destination node. In order to maintain the consistency, each node transmits and updates its routing table periodically. The packets being broadcasted between stations indicate which stations are accessible and how many hops are required to reach that particular station. The packets may be transmitted containing the layer 2 or layer 3 address. Routing information is advertised by broadcasting or multicasting the packets which are transmitted periodically as when the nodes move within the network. The DSDV protocol requires that each mobile station in the network must constantly; advertise to each of its neighbors, its own routing table. Since, the entries in the table may change very quickly, the advertisement should be made frequently to ensure that every node can locate its neighbors in the network. This is placed, to ensure the shortest number of hops for a route to a destination; in this way the node can exchange its data even if there is no direct communication link.

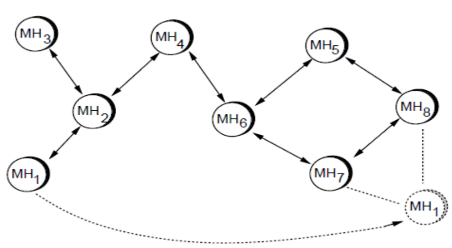


Figure 4.1: Movement of Mobile host in Adhoc Networks

Consider the above fig. 4.1 which has 8 hosts in the network. It will have a look at the changes to the MH4 routing table with reference to the movements of MH1. Initially, all the nodes advertise their routing information to all the nodes in the network and hence the routing table at MH4 initially looks like:

Destination	Next Hop	Metric	Seq. No
MH_4	MH_4	0	$S406\_MH_4$
MH_1	MH_2	2	$S128\_MH_1$
MH_2	MH_2	1	$S564\_MH_2$
MH_3	MH_2	2	$S710\_MH_3$
MH_5	MH_6	2	$S392\_MH_5$
MH_6	MH_6	1	$S076\_MH_6$
MH_7	MH_6	2	$S128\_MH_7$
MH_8	MH_6	3	$S050\_MH_8$

Table 1.1Routing table of MH4

Destination	Next Hop	Metric	Seq. No
MH_4	MH_4	0	$S820\_MH_4$
MH_1	MH_6	3	$S516\_MH_1$
MH_2	MH_2	1	$S238\_MH_2$
MH_3	MH_2	2	$S674\_MH_3$
MH_5	MH_6	2	$S502\_MH_5$
MH_6	MH_6	1	$S186\_MH_6$
MH_7	MH_6	2	$S238\_MH_7$
MH_8	MH_6	3	$S160\_MH_8$

Table1.2 Routing table after MH1 movement

When the host MH1 moves its location as shown in the fig. 4.1 nearer to MH7 and MH8 then, the link between MH2 and MH1 will be broken resulting in the assignment of infinity metric at MH2 for MH1 and the sequence number will be changed to odd number in the routing table at MH2. MH2 will update this information to its neighbor hosts. Since, there is a new neighbor host for MH7 and MH8; they update their information in the routing tables and they broadcast. Now, MH4 will receive its updated information from MH6 where MH6 will receive two information packets from different neighbors to reach MH1 with same sequence number, but different metric. The selection of the route will depend on less hop count when the sequence number is the same. Now the routing table will look like table 1.2.

Advantages of DSDV:

(i) The DSDV protocol guarantees loop free paths
(ii) Count to infinity problem is reduced in DSDV.
(iii) It can avoid extra traffic with incremental updates instead of full dump updates.
(iv) Path Selection: DSDV maintains only the best path instead of maintaining multiple paths to every destination. With this, the amount of space in routing table is reduced.

Limitations of DSDV:

(i) Wastage of bandwidth due to unnecessary advertising of routing information even if there is no change in the network topology.
(ii) DSDV doesn't support Multi path Routing.
(iii) It is difficult to determine a time delay for the advertisement of routes.

7. Improvement of DSDV (I-DSDV)[6]

In DSDV the low packet delivery is due to the fact that, it uses stale routes in case of broken links. In DSDV the existence of stale route does not imply that there is no valid route to the destination. The packets can be forwarded thru other neighbors who may have routes to the destination. When immediate links from the host say 'A' to the destination say 'T' breaks, the proposed[4] protocol creates a temporary link thru a neighbor which has a valid route to the desired destination. The temporary link is created by sending one-hop ROUTE-REQUEST and ROUTE-ACK messages. The host 'A' upon finding the next hop broken link broadcasts a one-hop ROUTE-REQUEST packet to all its neighbors. In turn, the neighbors returns the ROUTE-ACK if it has a valid route to the destination and the host 'A' is not the next hop on the route from the neighbor to the destination. Each entry in the routing table has an additional entry for route update time. This update time is embedded in the ROUTE-ACK packet and is used in selecting a temporary route. In case of receiving multiple ROUTE-ACK with the same number of minimum hops, ad hoc host 'S' chooses that route which has the latest update time.

Figure 5.1 shows how host 'S' creates a provisional route to the destination 'D', when the intermediate link from 'S' to 'A' breaks. Host 'S' suspends sending packets Figure 5.1(a). After which it broadcasts ROUTE-REQUEST packets to its immediate one hop neighbors. The Ad Hoc hosts B, C, I and E responds with ROUTE ACK packets along with hop count and the route update time to Ad Hoc host S Figure 5.2 (b). Table 2.1 shows the snapshot of the routing information received by Ad Hoc host S. From the table it can be seen that, Ad Hoc Host B and E have the same value for hop count metric, but the routing update time for E is greater than that of B, meaning the path thru E is updated more recently. Therefore Host S resumes sending packets to the destination D Figure 2.12(c). Later on whenever any Ad Hoc host moves in the range of the host S then the routing table of host S gets updated by the regular DSDV routing process. Then the updated route will be taken for forwarding the packets from the host S to the destination D.

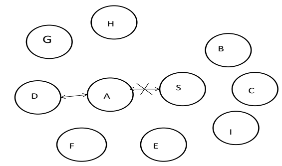


Figure5.1 (a): Link from S to A breaks

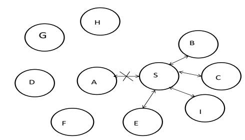


Figure 5.1(b): A Broadcast RREQ to its neighbors

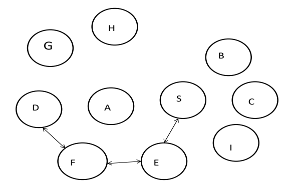


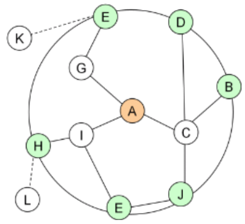
Figure 5.3(c): S choices E as the next hop to reach D

2.1Route Update at Host S:

Neighbor	No. of Hops	Via Node	Update Time
B	2	H	1765
E	2	F	1860
I	3	E	1050
C	3	S	805

8. Zone Routing Protocol

ZRP is either a proactive or reactive protocol. It is a hybrid routing protocol. It combines the advantages from proactive (for example AODV) and reactive routing (OLSR). It takes the advantage of pro-active discovery within a node's local neighbourhood (Intrazone Routing Protocol (IARP)), and using a reactive protocol for communication between these neighbourhoods (Interzone Routing Protocol(IERP)). The Broadcast Resolution Protocol (BRP) is responsible for the forwarding of a route request. ZRP divides its network in different zones. That's the nodes local neighbourhood. Each node may be within multiple overlapping zones, and each zone may be of a different size. The size of a zone is not determined by geographical measurement. It is given by a radius of length, where the number of hops is the perimeter of the zone. Each node has its own zone. To reduce the routing overhead while performing reactive route requests, Boardercast Resolution Protocol (BRP) is used which broadcasts the route queries through the borders of the zones.[7]



Radius=2-Hop and E, D, B, J, E and H are border-nodes
Figure 8.1: Zone Routing Protocol

When the node for example node A gets a response from a node B which has received the "Hello"-messages, the node A notice that it has a direct point-to-point connection with that node B. The NDP selects nodes on various criteria,such as signal strength, frequency/delay of beacons.

Some advantages of ZRP is given as[8]

(i) Fast convergence and very flexible algorithm. Its main advantage is that it can incorporate any newly developed protocol with little or none further effort.
(ii) Provides multiple loop free routes increasing robustness and performance.
(iii) Uses flat-routing instead of hierarchical and so it reduces the organization overhead.
(iv) The protocol finds fast optimal routes, reducing the threat of congestion and minimizes route acquisition time.

9. Result

Performance Metrics: The following metrics are used in varying scenarios to evaluate the different protocols:

1) Packet delivery ratio - This is defined as the ratio of the number of data packets received by the destinations to those sent by the CBR sources.

2) Normalized routing load - This is defined as the number of routing packets transmitted per data packet delivered at the destination. Normalized routing load gives a measure of the efficiency of the protocol.

3) End-to-end delay of data packets - This is defined as the delay between the time at which the data packet was originated at the source and the time it reaches the destination. Data packets that get lost in route are not considered.

Now on the basis of these performance metrics the following result can be given (i) DSR is not scalable to large network so AODV is used. But as velocity is increases AODV-PA has significantly higher packet delivery ratio than DSR & AODV. but the normalized routing load is better for DSR than AODV &AODV-PA and end to end delay is less for AODV-PA (ii) As no. of connections are varying the packet delivery ratio for DSR decreases as compared to AODV-PA for higher number of connections and the routing load of AODV-PA decreases as compared to AODV as the number of connections increases and Delay values for both AODV and AODV-PA are better than for DSR under all conditions.

Now if AODV, DSDV, I-DSDV [6] is compared (i) as no. of nodes are varying, AODV perform better when the number of nodes increases, I-DSDV is better than DSDV. I-DSDV improved the PDF since it find new route to destination when link breaks existed and AODV didn't produce so much delay even the number of nodes increased. It is better the other two protocols. (ii) The performance of AODV is far superior compared to the other two. Regular DSDV and I-DSDV is almost close to each other for varying number of speed. But I-DSDV is slightly better the regular DSDV when the number of nodes is high.

10. Conclusion

From this paper it can be concluded that DSR is not scalable to large network so AODV is used.AODV-PA modifies AODV to improve its performance. The protocol, AODV-PA, incorporates path accumulation during the route discovery process in AODV to attain extra routing information. It is evident from the results that AODV-PA improves the performance of AODV under conditions of high load and moderate to high mobility.

AODV-PA also scales better than AODV in large networks. And also there is one more new protocol I-DSDV. The performance of I-DSDV is superior to regular DSDV. It is also observed that the performance is better especially when the number of nodes in the network is higher. The performance of both proactive (I-DSDV n DSDV) degenerated due to the facts that a lot of control packets are generated. It is also observed that I-DSDV is even better than AODV protocol in PDF but lower than AODV in E2E delay and Routing Overhead.

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