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A Review on Dynamic MANET On Demand Routing Protocol in MANETs

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ABSTRACT
Mobile Ad-hoc Network is one of the types of Wireless Ad-Hoc Networks which has distinguished characteristics like: self configuring, decentralized and infrastructure less. Mobile nodes in such a network communicate with each other through wireless links since the nodes are always on move, routing in such a set up is always a challenge. To overcome this challenge, Internet Engineering Task Force (IETF) has developed Dynamic MANET On-demand (DYMO) routing protocol which is successor to the popular Ad hoc on Demand Distance Vector Protocol(AODV), so it is also known as AODVv2. This paper presents a comprehensive study about the working of the DYMO protocol and also discusses its comparison with the working of the AODV protocol.

Keywords: MANETs, DYMO, AODV, AODVv2.

1. INTRODUCTION

Wireless networks are classified as: Infrastructure-based wireless network and Infrastructure-less wireless network. In an Infrastructure-based wireless network (e.g. GSM networks and WLANs) nodes connect to an external network like Internet or Intranet with the help of an access point. On the other hand an Infrastructure-less network is a network in which mobile nodes communicate with each other through wireless links, such a network is also known as an Ad-hoc network. For example two laptops with wireless adapter cards can set up an Ad-hoc network. An Ad-hoc network can be further classified as MANET, WSN (Wireless Sensor Network), WMN (Wireless Mesh Network). MANET[1,2] is a temporary network in which mobile nodes communicate without any aid of centralized administration and may operate in either stand alone fashion or connected to the Internet. Because of features like quick deployment and easy to use makes them useful in wide number of applications like Military operations, emergency rescue operations and wireless sensor network etc. Figure 1 shows the two types of Wireless Networks we have discussed above: an Ad-hoc Network and Infrastructure-based network.

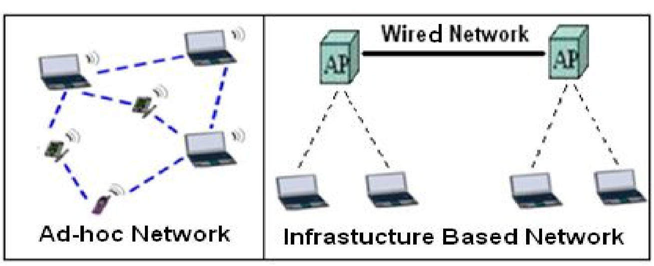

Figure 1. Types of Wireless Networks: Adhoc & Infrastructure based.

In MANETs, routing is needed to find path from source to destination which is done with the help of routing protocols. Vast amount of research is going on to make such a routing protocol which can work in a changing topology environment of a Hybrid Ad-hoc network. The goal of this paper is to give a review on the working of a latest reactive routing protocol i.e. DYMO[3,4] and compare its working with the conventional AODV protocol.

The organization of this paper is as follows. In next section II, we give a brief overview about the classification of MANET routing protocols as On Demand, Table Driven and Hybrid Protocols. Section III and IV explains the working of AODV protocol and DYMO[3,4] Protocol respectively. Section V gives a comparison of AODV[15] and DYMO[3.4] Protocol. Finally section VI concludes the paper with direction to future work.

2. MANET ROUTING PROTOCOLS

An ad-hoc routing protocol is a convention that controls how nodes decide which way to route packets in MANETs. Routing Protocols[19,20] can be classified into three categories as shown in the figure 2: Reactive (On-demand), Proactive (Table-driven) or Hybrid. The table-driven ad hoc routing approach is similar to the connectionless approach of forwarding packets, with no regard to when and how frequently such routes are desired. This is not the case, however, for on-demand routing protocols. When a node using an on-demand protocol[1,2] desires a route to a new destination, it will have to wait until such a route can be discovered. On the other hand, because routing information is constantly propagated and maintained in table-driven routing protocols, a route to every other node in the ad hoc network is always available, regardless of whether it is needed or not.

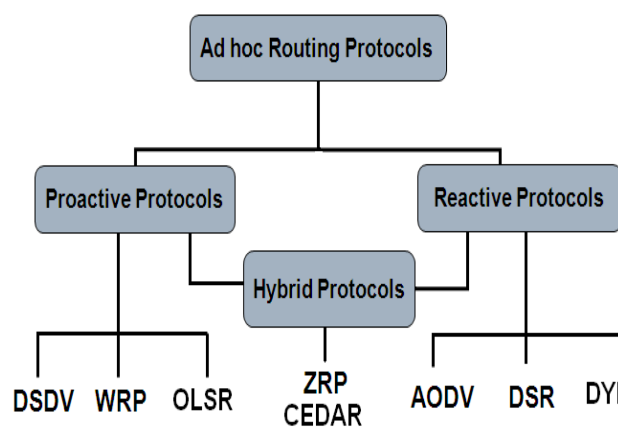

Figure 2. Classification of Routing Protocols.

2.1 Proactive or Table-Driven Routing Protocol

Proactive routing protocols[19,20] rely on the periodic collection and exchange of topology information by all the nodes to its neighboring nodes. Proactive or Table Driven Routing protocols perform route discoveries automatically & periodically without any request from the nodes. It builds up a routing table for each node which contains information on how to reach every other node and to maintain the consistency the algorithm tries to keep updating its routing table periodically. Each node shares this table with its neighbor nodes. Therefore, routes are discovered for every mobile node of the network, without any requests from the nodes. Each node has to maintain one or more tables to store routing information, & response to changes in network topology by broadcasting & propagating. Examples: DSDV (Destination-Sequenced Distance-Vector Routing), WRP (Wireless Routing Protocol) and OLSR[5,17] (The Optimized Link State Routing Protocol). The main disadvantages of Proactive Routing protocols are:

- Wastage of bandwidth due to unnecessary advertising of routing information.
- Maintaining a routing table for each node and advertising of this table leads to overhead, which consumes more bandwidth.
- Regular update of its routing tables uses up battery power.
- Slow reaction on restructuring and failures.
- Many redundant route entries to the specific destination needlessly take place in the routing tables.

2.2 Reactive or On-Demand Routing Protocols

Reactive routing protocols[19,20] have been introduced to prevent the periodic routing information exchange as in Proactive routing protocols, which consumes an essential amount of the available network resources. In reactive routing protocols, when a node requires a route to a destination, it initiates a route discovery process. Reactive protocols perform route discovery and path establishment by using specialized sets of control packets such as RREQ (Route Request), RREP (Route Reply) and RERR (Route Error). When a node wants to communicate with any other node in the network it sends a RREQ packet to its neighboring nodes and if the neighboring node is the required destination it replies with a RREP packet to the source thus acknowledging the RREQ packet from source. If there is an error in a link it sends a RERR to its source. On-demand routing protocols were designed with the aim of reducing control overhead, thus increasing bandwidth and conserving power at the mobile stations. These protocols limit the amount of bandwidth consumed by maintaining routes to only those destinations for which a source has data traffic. Examples: AODV (Ad-hoc On Demand Distance Vector Routing), DSR[12] (Dynamic Source Routing), and DYMO (Dynamic MANET On Demand). The main disadvantages of Reactive Routing protocols are:

- High latency time is required in finding the route to the destination,
- Flooding to can lead to network clogging.
- RREP, RREQ & RERR messages leads to Control overhead.

2.3 Hybrid Routing Protocols

Hybrid protocols[19,20] combine the features of reactive and proactive protocols. These protocols have the advantage of both proactive and reactive routing protocols to balance the delay which was the disadvantage of Table driven protocols and control overhead (in terms of control packages). Main feature of Hybrid Routing protocol is that the routing is proactive for short distances and reactive for long distances. The common disadvantage of hybrid routing protocols is that the nodes have to maintain high level topological information which leads to more memory and power consumption. Examples: ZRP (Zone Routing Protocol), CEDAR (Core Extraction Distributed Ad Hoc Routing). The main disadvantages of Hybrid Routing Protocols are:

- Large overlapping of routes.
- Longer delay if route not found immediately.
- Core nodes movement affects the performance of the protocol
- In case of CEDAR the route establishment and computation is relied on core nodes.

3. WORKING OF AODV PROTOCOL

AODV stands for Ad-hoc On Demand Distance vector Routing Protocol. AODV is essentially a combination of both DSR[15] and DSDV[11,12]. It borrows the basic Route Discovery and Route Maintenance steps from DSR[12], and the use of hop-by-hop routing it borrows from DSDV. It is a reactive/on-demand routing protocol means route discovery process is started only when source node raises the demand for it. AODV avoids the counting-to infinity problem unlike other distance vector protocols by using sequence number for each RREQ route and this sequence number feature is most distinguishing feature of AODV compared to the other routing protocols.

In AODV, all nodes maintain a routing table containing the entry for each destination node. Each entry includes the next hop, sequence number and number of hops requires for reaching destination node. Using the destination sequence number ensures loop freedom. AODV makes sure the route to the destination does not contain a loop and is the shortest path. Route Requests (RREQs), Route Replay (RREPs), Route Errors (RERRs) are control messages used for establishing a path from source to the destination as shown in the Figure 3 below. The following sections describe the basic working of AODV protocol in detail

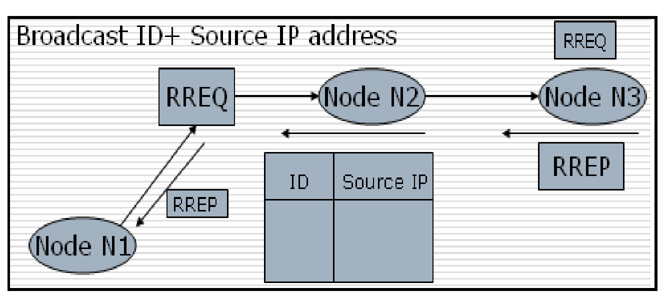

Figure 3. Overview of AODV Protocol

3.1 AODV Route Discovery

AODV does not depend on network-wide periodic advertisements of identification messages to other nodes in the network as in the case of DSDV Protocol. It periodically broadcasts "HELLO" messages to the neighboring nodes as shown in the Figure 3 below.

Failure to receive three consecutive HELLO messages from a neighbor is taken as an indication that the link to the neighbor in question is down.

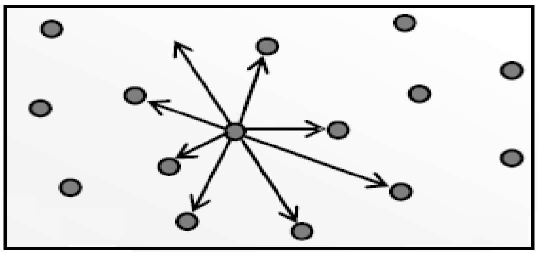

Figure 3. Broadcasting of Hello Messages.

Whenever any node needs to send a message to some node that is not its neighbor, the source node initiates a Route Discovery process as shown in the Figure 4 below. When the source node wants to make a connection with the destination node, it broadcasts an RREQ message. This RREQ message is sent by the source to its neighbor nodes, if the node receiving a RREQ does not have a route to the destination. It then rebroadcast the RREQ to its immediate neighbors. When searching for a route to the destination node, the source node uses the expanding ring search technique to prevent unnecessary network-wide dissemination of RREQs. This is done by controlling the value of the time to live (TTL) field in the Packet header.

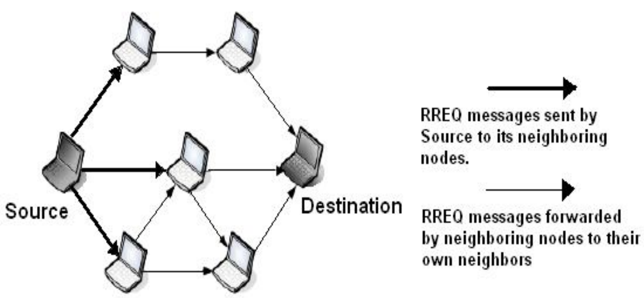

Figure 4. Route Discovery process: via RREQ Messages.

When the RREQ reaches a node that either is the destination node or a node with a valid route to the destination, a RREP is generated and unicasted back to the requesting node. While this RREP is forwarded, a route is created to the destination and when the RREP reaches a source node, there exists a route from the source to the destination as shown in the Figure 5.

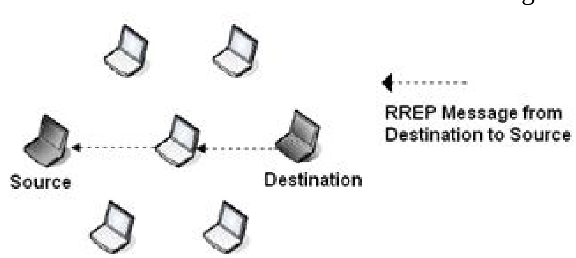

Figure 5. Route Discovery process: via RREQ Messages.

While this RREP is forwarded, a route is created to the destination and when the RRP reaches a source node, there exists a route from the source to the destination. Once the source node receives the RREP[1,2], it may begin to forward data packets to the destination. If the source later receives a RREP having a greater sequence number or contains the same sequence number with a smaller hop count, it may update its routing table for that destination and begin using the better route.

3.2 AODV Route Maintenance

When a node detects that a route to a neighbor is no longer valid, it will remove the routing entry and send a link failure, a triggered route reply message to the neighbors that are actively using the route, informing them via RERR message that this route no longer is valid. The RERR message contains the IP address of each destination which has become unreachable due to the link break. Upon receiving a RERR message, a node searches its routing table to see if it has any route(s) to the unreachable destination(s) (listed in the RERR message) which use the originator of the RERR as the next hop. If such routes exist, they are invalidated and the node broadcasts a new RERR message to its neighbors. This process continues until the source receives a RERR message. The source invalidates the listed routes and restarts the route discovery process if needed.

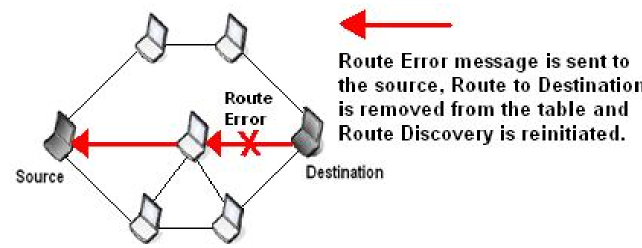

Figure 6. Route Maintenance process: via RERR Messages.

3.3 Advantages of AODV Protocol

- AODV greatly reduced the number of routing messages in the network.
- Since it is bandwidth efficient so it consumes less battery power.
- The main advantage of AODV protocol is that routes are established only when one node raises a demand to communicate with another node.
- To overcome the counting to infinity problem like in other distance vector routing protocols AODV uses sequence numbers to find the fresh route to the destination.

3.4 Disadvantages of AODV Protocol

- Overhead on the bandwidth, because RREQ & RREP packets needs to carry a lot information to validate a route.
- If the intermediate node does not have the latest destination sequence number it can lead to stale entries.
- Multiple RREP packets in response to a single RREQ packet can lead to large control overhead.
- The hello messages add a significant amount of overhead to the protocol.

- The messages can be misused for insider attacks including route disruption, route invasion and resource consumption.
- AODV requires more time to establish a connection, and the initial communication to establish a route is heavier than some other approaches.
- AODV does not discover a route until route discovery process is not initiated. Route discovery latency result can be high in large-scale hybrid and mesh networks.

4. WORKING OF DYMO PROTOCOL

The DYMO routing protocol is a successor to AODV routing protocol and shares many of its features, so it is also called as AODVv2[6,7]. DYMO routing protocol has been undergoing development by the IETF after its first Internet Draft was released in 2005 and so far, there have been 25 versions of the DYMO Internet draft, each updating and improving on the previous draft. Version 5 and version 17 of DYMO Internet Draft presented more complete statements based on previous experimental drafts. Currently it is in its 26th versions and is still in progress. DYMO inherits features of AODV like sequence numbers, route discovery methodology, RERR messages and it also inherits features from DSR[12] protocol like Path Accumulation function.

DYMO can work both as a proactive and reactive routing protocol, i.e. routes can be discovered just when they are needed. These entire features make DYMO makes it useful in MANET and VANET scenarios. DYMO consists of two protocol operations: route discovery and route maintenance. Route discovery is performed when an AODVv2 router[13,16] must transmit a packet towards a destination for which it does not have a route. Route maintenance is performed to avoid prematurely expunging routes from the route table, and to avoid dropping packets when an active route breaks. These two operations are discussed in detail in the following subsections.

4. 1 DYMO Routing Table

According to the DYMO IETF[3] Draft 26, a route table entry has the following fields:

- Route.Address: The (host or network) destination address of the node(s) associated with the routing table entry
- Route.PrefixLength: The length of the netmask/prefix.
- Route.SeqNum: The Sequence Number associated with a route table entry.
- Route.NextHopAddress: An IP address of the adjacent AODVv2 router on the path toward the Route.Address.
- Route.NextHopInterface: The interface used to send packets toward the Route.Address.
- Route.LastUsed: The time that this route was last used.
- Route.ExpirationTime: The time at which this route must expire.
- Route.Broken: A flag indicating whether this Route is broken. This flag is set to true if the next-hop becomes unreachable or in response to processing to a RERR
- Route.MetricType: The type of the metric for the route towards Route.Address.
- Route.Metric: The cost of the route towards Route.Address

A route table entry (i.e., a route) may be in one of the following states:

- Active: An Active route is in current use for forwarding packets
- Idle: An Idle route can be used for forwarding packets, even though it is not in current use.
- Expired: After a route has been idle for too long, it expires, and may no longer be used for forwarding packets
- Broken: A route marked as Broken cannot be used for forwarding packets but still has valid destination sequence number information.

4.2 DYMO Route Discovery

The DYMO route discovery is very similar to that of AODV except for the path accumulation feature. Figure 3 shows the DYMO route discovery process. If a source has no route entry to a destination, it broadcasts a RREQ message to its immediate neighbors. If a neighbor has an entry to the destination, it replies with an RREP message else it broadcasts the RREQ message as shown in the small boxes of Figure 7. While broadcasting the RREQ message, the intermediate node will attach its address to the message. Every intermediate node that disseminates the RREQ message makes a note of the backward path. As show in Figure 7, node H will enter the routes to A and C in its routing table while appending its own address and forwarding the RREQ packet. The Destination replies with RREP message. A similar path accumulation process takes place along the backward path. This makes sure that the forward path is built and every intermediate node knows a route to every other node along the path. IETF DYMO[3] Draft 26, states that each node maintains a unique sequence number in order to avoid loops in the route and also to discard the stale packets if any. Every time a RREQ is sent, the router updates its sequence number. Messages with superior sequence numbers are updated in the routing table. If the sequence number associated with the incoming route is the same as the node sequence number then a loop is possible. In such case, the incoming packet is discarded.

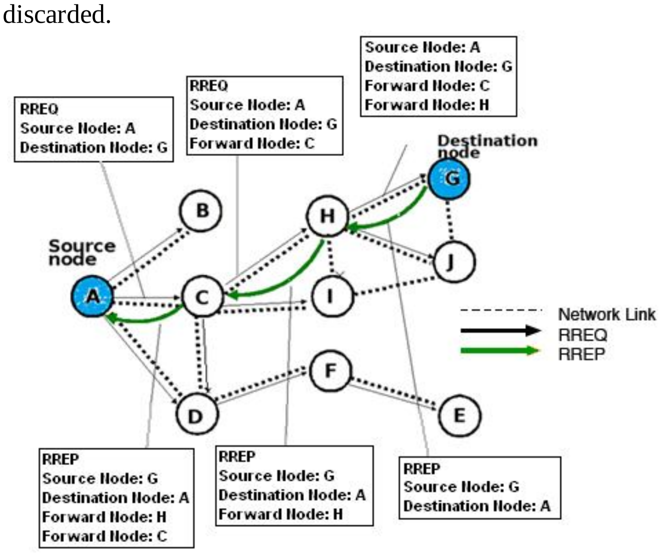

Figure 7: DYMO Route Discovery.

One of the special features of DYMO is that it is energy efficient. If a node is low on energy, it has the option to not participate in the route discovery process. In such a case, the node will not forward any of the incoming RREQ messages. It however will analyze the incoming RREP messages and update its routing tables for future use.

4.3 DYMO Route Maintenance

Route maintenance consists of two steps. First, in order to preserve the existing routes in use, the lifetime[3,4] of the route is extended upon successful forwarding of a packet. Whenever a packet is successfully forwarded, the lifetime of the route is extended automatically to use it for further communication. Second, when a route to a destination is lost or a route to a destination is not known, then a RERR message is sent towards the packet source node, to notify it about a particular route being invalid or missing. Upon receiving RERR message the source node[12] deletes the route. If the source node has another packet to forward for the same invalid or missing destination node, it will again initiate a route discovery process.

4.4 Special Features of DYMO Protocol

A. Adjacency Monitoring[3.4]

Detecting link failures can be done with HELLO messages, link layer feedback, route timeouts or using the MANET Neighborhood Discovery Protocol (NHDP). But DYMO protocol does not use any kind of HELLO messages to make sure that the adjacent neighbors are still active.

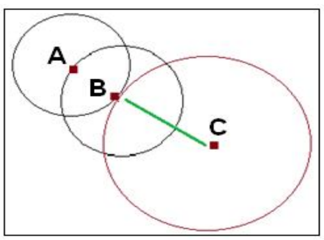

Figure 8: Adjacency Monitoring

The interesting feature is that DYMO protocol uses the lower layer feedback to ensure that the adjacency is maintained. Figure 7 describes such a scenario where the lower layer protocol feedback may be useful. Here, node B is within the range of node A. When node B is transmitting to node C, link layer[11] of node A will be implementing some Carrier Sense technique of detecting whether the channel is free to transmit. This can be used as a feedback to indicate that node B is transmitting and hence it is still active.

B. Path Accumulation[3,4]

During route discovery, the source router initiates the Route discovery process via a RREQ message throughout the network to find a route to the destination's router. Upon receiving the RREQ, each intermediate router records a route to the originator and rebroadcasts the RREQ including its own information which is called the path accumulation function. When the destination's router receives the RREQ, it sends a RREP to the originator. When the originator receives the RREP, the route is established. The route maintenance of DYMO is similar to that of AODV. The path accumulation function[3,4] of DYMO includes source routing characteristics, thereby allowing nodes listening to routing messages to acquire knowledge about routes to other nodes without initiating route request discoveries themselves. As a result, this path accumulation function can reduce the routing overhead, although the packet size of the routing packet is increased.

4.5 Advantages of DYMO Protocol

- The protocol is energy efficient when the network is large and shows a high mobility.
- The routing table of DYMO is comparatively less memory consuming than AODV even with Path Accumulation feature.
- The overhead for the protocol decreases with increased network sizes and high mobility.
- Applicable to memory constrained devices.

4.6 Disadvantages of DYMO Protocol

- It does not perform well with low mobility scenarios.
- The control message overhead for low mobility scenarios is high and uncontrollable.
- Another limitation lies in the applicability of the protocol as stated in the DYMO Draft [17] which states that DYMO performs well when traffic is directed from one part of the network to another.
- It shows a degraded performance when there is very low traffic and routing overhead outruns the actual traffic.

5. COMPARISON OF DYMO AND AODV

On the basis of few parameters we have made comparison[5] between the two widely used On Demand Routing Protocols as show in the Table1 below.

Table 1: Comparison between AODV and DYMO.

Parameters	**AODV**	**DYMO**
Route Creation	By Source	By Source
Routing Metric	Newest Route & Shortest Path	Fresh Route or Already known route & Shortest Path.
Route Maintained in	Routing Table	Routing Table
Route Reconfiguration Methodology	Delete Route by notifying Source & Fresh RREQ.	Delete Route by notifying Source & Fresh RREQ.
Loop Free	No	Yes
Periodic Updation	No	No
Multiple Routes	No	No
Caching Overhead	Low	High
Routing Overhead	High	High but less than AODV
Throughput	High but less than DYMO	High

6. CONCLUSION

In this paper, we have reviewed the working of DYMO Routing Protocol in comparison with the existing AODV protocol. Since it is an enhanced version of AODV protocol it is also known as AODVv2, which aims at simplifying AODV by removing unnecessary features and adopting successful features from DSR like path accumulation. Our overall study shows that DYMO is a better protocol when it comes to networks with high mobility and changing topology, moreover its performance outperforms the conventional AODV protocol when it comes to large networks with large number of nodes and changing topology. Future enhancements can be to further improve the performance of DYMO protocol with the help of ACO based techniques and to obtain better result in terms of the packet delivery ratio, network lifetime and the average end to end delay with less routing overhead. We hope that the comparison and detailed discussion of the DYMO and AODV protocol presented in this paper will be helpful and provide researchers a platform for choosing the right protocol for their work.

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