An Analysis of Routing Protocols in MANETs

Ankita Bihani[1]

[1]School of Computing Sciences and Engineering, VIT University
Vellore, Tamil Nadu, India

***Abstract*— An ad hoc network is a collection of autonomous mobile nodes forming an instant multi hop radio infrastructure-less network in a dynamic topology. Each node in Ad hoc network, functions as host and router at the same time. It maintains connectivity in a decentralized manner by distributing the network control among the nodes. A large number of routing protocols for mobile ad-hoc networks are presented since last decade. Topology frequently changing, transmission power and asymmetric links are the main challenge that this type of protocols is facing. Therefore, both proactive and reactive routing protocols for mobile ad-hoc networks show incapability, and sometimes prove to be inefficient under these circumstances. This paper presents an analysis of the three routing protocols in MANETs and gives a comparative study of the three protocols.**

***Keywords*— MANET, topology, protocol, optimization, reactive, proactive**

I. INTRODUCTION

Mobile Ad-hoc Network (MANET) is a wireless Network, with a collection of self-configured mobile devices, without a centralized infrastructure, and uses radio waves as transmission medium[1][5]. It is a Multi hop Network. In MANET, each node acts both as a router and host. It functions as a router while forwarding data and as a host while receiving data and even the topology of network may change rapidly.The dynamic change in MANET topology makes routing a challenging task, as the existing path is rendered inefficient and infeasible[2]. The major issues[6] for mobile Ad-hoc networks are as under:

- Medium access control (MAC)
- Routing
- Security
- Quality of service provisioning
- Unicast routing
- Multicast routing
- Dynamic network topology
- Speed of transmission
- Frequency of updates or network overhead
- Scalability
- Mobile agent based routing
- Energy efficient or power aware routing.

A routing protocol plays a key role to measure the performance of a MANET. Routing protocols are classified under two categories:

- Proactive protocols
- Reactive protocols.

When nodes move over time from one position to another, it is less efficient to use proactive (Table driven) protocols. In these protocols routes will be already established before a packet is sent. Therefore, reactive (On-Demand) protocols are more appropriate to be used in MANET networks. A lot of competitive research is going on to find optimal solutions for MANET routing protocols. The challenges in this field are to design an effective routing protocol that responds to dynamic changes in node connectivity and works at low data rates. The primary concerns of ad-hoc routing protocols remain connectivity and reduced control overhead.

II. ROUTING PROTOCOLS

Although there are many kinds of routing protocols competing for unicast, multicast and broadcast communication for the MANET, it is clear that one protocol cannot fit all the different scenarios and traffic patterns of MANET applications. For example, proactive routing protocols are well suited for a small-scale, broad-band MANET with high mobility, while reactive routing protocols are well suited for a large-scale, narrow-band MANET with moderate or low mobility. If the mobile nodes in the MANET move too quickly, they have to resort to broadcast to achieve peer-to-peer communication. Thus we see that every routing protocol has its strengths and drawbacks, and aims at a specific application. As a result, the prospective standard for routing protocols in the MANET is very likely to combine some of the most competitive schemes[3].

A. Ad hoc On-Demand Distance Vector Routing Protocol (AODV)

AODV is a reactive protocol, even though it still uses characteristics of a proactive protocol. AODV uses the concept of route discovery and route maintenance of DSR while it takes the concept of sequence numbers and sending out of periodic hello messages from DSDV.Ad hoc On-Demand Distance Vector Routing Protocol (AODV) consists of the following procedures:

(1) Route discovery: If the route towards a destination is not available in the routing table, a RREQ (Route Request) packet is broadcast throughout the MANET with a search ring technique.

On receipt of RREQ, the node creates a reverse routing entry towards the originator of RREQ, which is used to forward replies later. The destination or the intermediate node, which has a valid route towards the destination, answers with a RREP (Route Reply) unicast packet. On receipt of RREP, the reverse routing entry towards the originator of RREP is also created, similar to the processing of RREQ. A precursor list, associated with each routing entry is a so-called precursor list, is created at the same time. This precursor list contains the upstream nodes which use the node itself towards the same destinations.

(2) Route maintenance: Every node along an active route periodically broadcasts HELLO messages to its neighbors. If the node does not receive a HELLO message or a data packet from a neighbor for a while, the link between itself and the neighbor is considered to be broken. If the destination with this neighbor as the next hop is believed not to be far away (from the invalid routing entry), local repair mechanism may be launched to rebuild the route towards the destination; otherwise, a REER (Route Error) packet is sent to the neighbors in the precursor list associated with the routing entry to inform them of the link failure.

Every node in DSDV maintains a sequence number. This sequence number is sent with RREQ (for source) and RREP (for destination) and stored in the routing table. It ensures loop freedom. The larger the sequence number, the newer is the route information. These message types are received via UDP, and normal IP header processing applies.

AODV uses a destination sequence number for each route entry. The destination sequence number is created by the destination for any route information it sends to requesting nodes. Using destination sequence numbers ensures loop freedom and gives the information about which of the available routes is fresher so that the requesting node always selects the one with greatest sequence number. When a node wants to find a route, it broadcasts a RREQ to all networks till either destination is reached or another node is found with a 'fresh enough' route to the destination. Then a RREP is sent back to the source and the discovered route is made available.

If hello messages stop arriving from a neighbor beyond some given time threshold, the connection is assumed to be lost. When a node detects that a route to a neighbor node is not valid, it removes the routing entry and sends a RERR message to neighbors that are active and use the route. This is possible by maintaining active neighbor lists. The above procedure is repeated at nodes that receive RERR messages. A source that receives an RERR can reinitiate a RREQ message.

B. Distance Vector Routing Protocol (DSDV)

DSDV is a distant vector routing protocol. Each node has a routing table that indicates for each destination, which is the next hop and number of hops to the destination. Each node periodically broadcasts routing updates. A sequence number is used to tag each route. It shows how new the route is. A route with higher sequence number is newer and hence more favorable. In addition, among two routes with the same sequence number, the one with fewer hops is more favored. If a node detects that a route to a destination has broken, then its hop number is set to infinity and its sequence number is updated but assigned an odd number. Only even numbers correspond to sequence numbers of connected paths.

Destination sequenced distance vector routing (DSDV) is adapted from the conventional Routing Information Protocol (RIP) to ad hoc networks routing. A new attribute, sequence number, is added to each route table entry of the conventional RIP. Using this sequence number, the mobile nodes can distinguish stale route information from the new ones and thus prevent the formation of routing loops.

A routing table is maintained by each mobile node of an ad hoc network in DSDV. This routing table lists all the available destinations, the metric and the next hop to each destination and a sequence number generated by the destination node. Using such routing information stored in each mobile node, the packets are transmitted between the nodes of an ad hoc network. Each node of the ad hoc network updates the routing table with advertisement periodically or when significant new information is available to maintain the consistency of the routing table with the dynamically changing topology of the ad hoc network.

Periodically or immediately when network topology changes are detected, each mobile node advertises routing information using broadcasting or multicasting a routing table update packet. The update packet starts out with a metric of one to direct connected nodes. This indicates that each receiving neighbor is one metric (hop) away from the node.

DSDV is an adaptation of classical distance vector routing protocol to ad hoc networks. In DSDV, two routing tables are maintained at each of the nodes.

- One is the routing table, which contains a complete list of addresses of all other nodes in the network.
- The other table contains the setting time data for each destination node. It is used to determine the time for update advertisement.

The routing of updates and packets between nodes is based on these tables. Along with each node's address, the routing table contains the address of next hop, route metric, destination sequence number, etc. Route updates are broadcasted periodically or scheduled as needed in the network. Routes with later sequence numbers are selected. If the sequence numbers are identical, the route with the smallest metric will be selected.

These features guarantee loop-free routes, but they also induce routes fluctuation. DSDV is a bi-directional protocol, which unavoidably has the unidirectional links problem in ad hoc networks.

DSDV is one of the most well-known table-driven routing algorithms for MANETs. The DSDV routing algorithm is based on the classical Bellman-Ford Routing Algorithm (BFRA) with certain improvement .Every mobile station maintains a routing table with all available destinations along with information like next hop, the number of hops to reach to the destination, sequence number of the destination originated by the destination node, etc. DSDV uses both periodic and triggered routing updates to maintain table consistency. Triggered routing updates are used when network topology

changes are detected, so that routing information is propagated as quickly as possible.
Routing table updates can be of two types:

- Full dump
- Incremental

"Full dump" packets carry all available routing information and may require multiple Network Protocol Data Units (NPDU); "incremental" packets carry only information changed since the last full dump and should fit in one NPDU in order to decrease the amount of traffic generated.

Mobile nodes cause broken links when they move from place to place. When a link to the next hop is broken, any route through that next hop is immediately assigned infinity metric and an updated sequence number. This is the only situation when any mobile node other than the destination node assigns the sequence number. Sequence numbers assigned by the origination nodes are even numbers, and sequence numbers assigned to indicate infinity metrics are odd numbers. When a node receives infinity metric, and it has an equal or later sequence number with a finite metric, it triggers a route update broadcast, and the route with infinity metric will be quickly replaced by the new route. When a mobile node receives a new route update packet; it compares it to the information already available in the table and the table is updated based on the following criteria:

- If the received sequence number is greater, then the information in the table is replaced with the information in the update packet
- Otherwise, the table is updated if the sequence numbers are the same and the metric in the update packet is better.

C. Dynamic Source Routing Protocol (DSR)

Dynamic Source Routing (DSR) is an Ad Hoc routing protocol which is based on the theory of source-based routing rather than table-based. This protocol is source-initiated rather than hop-by-hop. This is particularly designed for use in multi hop wireless ad hoc networks of mobile nodes.
Basically, DSR protocol does not need any existing network infrastructure or administration and this allows the network to be completely self-organizing and self-configuring. This protocol is composed of two essential parts of

- Route discovery
- Route maintenance.

Every node maintains a cache to store recently discovered paths. When a packet is to be sent to some node, first its entry in the cache is checked. If it is there, then it uses that path to transmit the packet and also attaches its source address on the packet. If it is not there in the cache or the entry in cache has expired (because of long time idle), the sender broadcasts a route request packet to all of its neighbors asking for a path to the destination. The sender will be waiting till the route is discovered. During waiting time, the sender can perform other tasks such as sending/forwarding other packets.

As the route request packet arrives to any of the nodes, they check from their neighbor or from their caches whether the destination asked is known or unknown. If route information is known, they send back a route reply packet to the destination otherwise they broadcast the same route request packet. When the route is discovered, the required packets will be transmitted by the sender on the discovered route. Also an entry in the cache will be inserted for the future use. The node will also maintain the age information of the entry so as to know whether the cache is fresh or not. When a data packet is received by any intermediate node, it first checks whether the packet is meant for itself or not. If it is meant for itself, the packet is received otherwise the same will be forwarded.

III. ANALYSIS OF THE ROUTING PROTOCOLS

This paper compares the performance of DSDV, AODV and DSR routing protocols for ad hoc networks using NS-2 simulations.

1. DSDV uses the proactive table-driven routing strategy while both AODV and DSR use the reactive on-demand routing strategy.

2. Both AODV and DSR perform better under high mobility simulations than DSDV. High mobility results in frequent link failures and the overhead involved in updating all the nodes with the new routing information in DSDV is much more than that involved in AODV and DSR. This is because in AODV and DSR, the routes are created as and when required.

3. DSR and AODV both use on-demand route discovery, but with different routing mechanics.DSR uses source routing and route caches, and does not depend on any periodic or timer-based activities. DSR exploits caching aggressively and maintains multiple routes per destination. AODV, on the other hand, uses routing tables, one route per destination, and destination sequence numbers, a mechanism to prevent loops and to determine freshness of routes.

4. For application-oriented metrics such as packet delivery fraction and delay AODV, outperforms DSR in more "stressful" situations (i.e., smaller number of nodes and lower load and/or mobility), with widening performance gaps with increasing stress (e.g., more load, higher mobility). DSR, however, consistently generates less routing load than AODV.

5. The poor performances of DSR are mainly attributed to aggressive use of caching, and lack of any mechanism to determine the freshness of routes when multiple choices are available. Aggressive caching, however, seems to help DSR at low loads and also keeps its routing load down.

The following parameters have been analyzed in this paper[6]:

1. **Packet Delivery Fraction**: is the ratio of received packets by CBR sink at the destination over sent packets by constant bit rate Source. This metric actually tells us how much reliable the protocol is. It describes the loss rate that will be seen by the transport protocol, which in turn affects the maximum throughput the ad hoc network can support.

2. **Average End-to-End Delay**: It is the delay that could be caused by buffering during route discovery, queuing delays at interface queues, retransmission delays at the MAC, and propagation and transfer times.

3. **Throughput**: Throughput refers to how much data can be transferred from one location to another in a given amount of time.

IV. CONCLUSIONS

The following graphs were obtained on combing the results of compilations of the different protocols on NS2.

The degradation in Packet Drop Ratio is less in DSR than AODV under heavy traffic load. The performance degradation in PDR is due to packet drops by the routing algorithm after having failed to transfer data in the active routes. The packet drops are due to link break, collision and congestion in the ad hoc network. The packets dropped for DSR is less than that of DSDV and AODV as it outperforms with fewer nodes and no periodic update is maintained in DSR. The graph below shows Packet Drop Comparison for the three protocols:

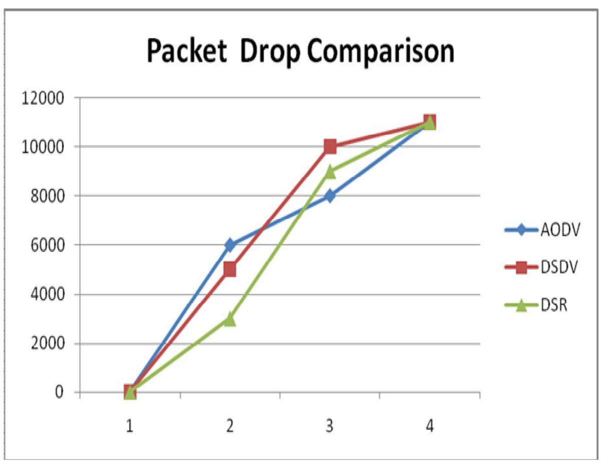

Fig. 1. Graph for Packet drop Comparison for the 3 protocols in MANETs

Congestion is the possible reason for higher delay at high traffic load. Delay variation is less in DSR. Among AODV and DSDV protocol, end-to-end delay is high for DSR. DSDV has shortest end-to-end delay than AODV and DSR because DSDV is a proactive protocol, which means all the routing information is already stored in tables hence it consumes lesser time than others. As AODV needs more time in route discovery it produces more end-to-end delay. On average case, DSR shows better performance than AODV but worse than DSDV. So, DSDV has higher reliability than AODV and DSR. The figure below shows Average end to end delay comparison of the three routing protocols:

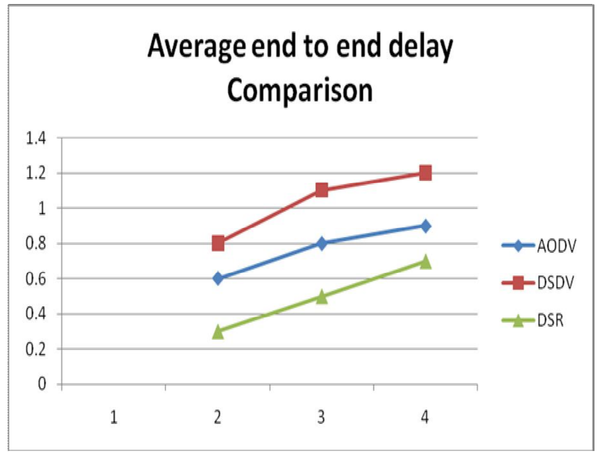

Fig. 2 Graph for Average end to end delay comparison for the 3 protocols in MANETs

AODV shows higher throughput than DSR and DSDV. AODV has much more routing packets than DSR because AODV avoids loop and freshness of routes while DSR uses stale routes. Its throughput is higher than other two routing protocols at higher mobility.

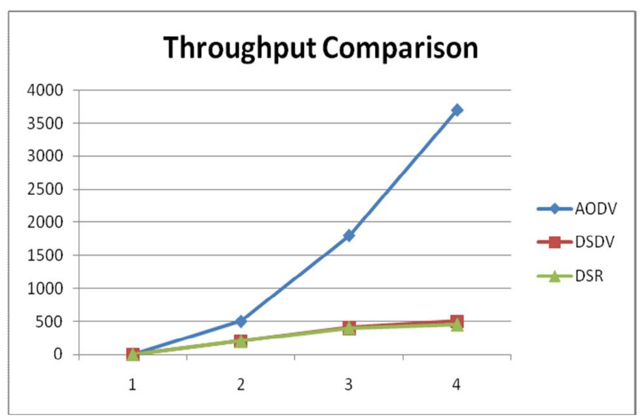

Fig. 3 Graph for Throughput Comparison for the 3 protocols in MANETs

V. RESULTS

This paper compares the three routing protocols of MANETs. The comparative study is shown in the table under:

Table 1. Comparative study of the three routing protocols of MANETs

	Average End-to-End Delay	**Packet Drop Fraction**	**Throughput**
AODV	Performance degrades with increase in the number of nodes	Best	Best
DSDV	Least and remains constant increases	Least	Least
DSR	Degrades when the number of nodes increases in the network	Performs well when the number of nodes is less but it declines when the number of nodes increases	Better than DSDV

The above parameters have been compared based on NS2 simulations and the graphs have been obtained from the analysis.

ACKNOWLEDGMENT

The author would like to thank Prof. Abdul Gaffar for his constant support and constructive criticism throughout the work.

REFERENCES

[1] Perkins, C. E., Royer, E. M., Das, S. R., & Marina, M. K. (2001). Performance comparison of two on-demand routing protocols for ad hoc networks. Personal Communications, IEEE, 8(1), 16-28.

[2] Abolhasan, M., Wysocki, T., & Dutkiewicz, E. (2004). A review of routing protocols for mobile ad hoc networks. *Ad hoc networks*, *2*(1), 1-22.

[3] Johansson, P., Larsson, T., Hedman, N., Mielczarek, B., & Degermark, M. (1999, August). Scenario-based performance analysis of routing protocols for mobile ad-hoc networks. In *Proceedings of the 5th annual ACM/IEEE international conference on Mobile computing and networking* (pp. 195-206). ACM.

[4] Bansal, M., Rajput, R., & Gupta, G. (1998). Mobile ad hoc networking (MANET): Routing protocol performance issues and evaluation considerations.

[5] Paul, H., & Das, P. (2012). Performance Evaluation of MANET Routing Protocols. *International Journal of Computer Science Issues(IJCSI)*, *9*(4).

[6] Ibrahim, I. S., King, P. J., & Pooley, R. (2009, September). Performance Evaluation of Routing Protocols for MANET. In *Systems and Networks Communications, 2009. ICSNC'09. Fourth International Conference on* (pp. 105-112). IEEE.