Performance Comparison of Reactive and Proactive Routing Protocols in MANETs Using the Random Waypoint Mobility Model

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Abstract: Mobile Ad Hoc Wireless Networks (MANETs) operate without the need for fixed infrastructure. They are characterized by dynamic topologies due to node mobility, limited channel bandwidth, and constrained battery power. A routing protocol is essential whenever a packet must be transmitted to a destination through multiple nodes, and numerous routing protocols have been developed for such networks. The primary challenge in designing ad hoc networks lies in creating dynamic routing protocols that can efficiently discover routes between communicating nodes. Consequently, many ad hoc routing protocols have been proposed in recent years, all aiming to achieve a high data packet delivery ratio while minimizing routing control traffic. These protocols are generally categorized into three types: proactive, reactive, and hybrid. Understanding the performance of various protocols under different scenarios and metrics is crucial. This paper presents a simulation-based evaluation of several routing protocols designed for mobile ad hoc networks using the Random Waypoint Mobility Model in NS-2.

Keywords: Ad hoc, AODV, DSDV, DSR, MANET

1. INTRODUCTION

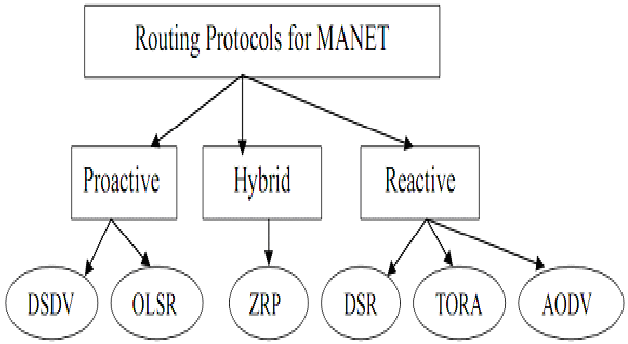
Mobile Ad-hoc Networks (MANETs) are self-configuring networks consisting of mobile nodes that are communicating through wireless links. There is a cooperative engagement of a collection of mobile nodes without the required intervention of any centralized access point or existing infrastructure. The nodes move arbitrarily; therefore, the network may experience unpredictable topology changes. It means that a formed network can be deformed on the fly due to mobility of nodes. Hence, it is said that an ad-hoc wireless network is self-organizing and adaptive. Due to infrastructure less and self-organizing nature of ad-hoc networks, it has several applications in the area of commercial sector for emergency rescue operations and in the field of military battlefield [1]. Also, MANET provides an enhancement to cellular based mobile network infrastructure. Nowadays, it is an inexpensive alternative for data exchange among cooperative mobile nodes [2]. For communication among two nodes, one node has to check that the receiving node is within the transmission range of source (Range of a node is defined with the assumption that mobile hosts uses wireless RF transceivers as their network interface), if yes, then they can communicate directly otherwise, with the help of intermediate nodes communication will take place. Each node will act as a host as well as a router. All the nodes should be cooperative so that exchange of information would be successful. This cooperation process is called as routing [3, 4]. Due to the presence of mobility, the routing information will have to be changed to reflect changes in link connectivity. There are several possible paths from source to destination. The routing protocols find a route from source to destination and deliver the packet to correct destination. The performance of MANETs is related to efficiency of the MANETs routing protocols [5] and the efficiency depends on several factors like convergence time after topology changes, bandwidth overhead to enable proper routing, power consumption and capability to handle error rates. MANETs have several salient characteristics [12]:

- **Dynamic Topologies:** Nodes are free to move arbitrarily; thus, the network topology which is typically multihop may change randomly and rapidly at unpredictable times, and may consist of both bidirectional and unidirectional links.
- **Bandwidth-constrained, variable capacity links:** Wireless links will continue to have significantly lower capacity than their hardwired counterparts. In addition, the realized throughput of wireless communications after accounting for the effects of multiple access, fading, noise, and interference conditions, etc. is often much less than a radio's maximum transmission rate.
- **Energy-constrained operation:** Some or all of the nodes in a MANET may rely on batteries or

other exhaustible means for their energy. For these nodes, the most important system design criteria for optimization may be energy conservation. A node in MANET acts as both a router and host. So, died node leads to network partition besides itself out of the network.

- **Limited physical security**: Mobile wireless networks are generally more prone to physical security threats than are fixed- cable nets. The increased possibility of eavesdropping, spoofing, and denial-of- service attacks should be carefully considered. Existing link security techniques are often applied within wireless networks to reduce security threats. As a benefit, the decentralized nature of network control in MANETs provides additional robustness against the single points of failure of more centralized approaches. The figure 1 shows the prominent way of classifying MANETs routing protocols. The protocols may be categorized into three types, Proactive, Reactive and hybrid which is a combination of both proactive and reactive is referred as Hybrid.

Figure 1: Classification of MANET routing protocols



- **Proactive routing protocols:** In it, all the nodes continuously search for routing information with in a network, so that when a route is needed, the route is already known. If any node wants to send any information to another node, path is known, therefore, latency is low. However, when there is a lot of node movement then the cost of maintaining all topology information is very high [6].
- **Reactive Routing protocols:** Whenever there is a need of a path from any source to destination then a type of query reply dialog does the work [7, 8]. Therefore, the latency is high; however, no unnecessary control messages are required.
- **Hybrid routing protocols:** These protocols incorporate the merits of proactive as well as reactive routing protocols. A hybrid routing protocol should use a mixture of both proactive and reactive approaches.

In recent years, a variety of routing protocols have been proposed and a comparative analysis of routing protocols has been done either on the basis of simulation results by different simulators like OPNET, NS2, OMNET++ etc. or analytically. In some cases, the comparative analysis is done between reactive routing protocols based on some performance metrics and in other cases between proactive routing protocols. Few researchers have done the simulation-based comparison between on demand and table-driven routing protocols. The present paper comparatively analyzes two categories of MANETs routing protocols namely, proactive and reactive. In order to compare the protocols, we selected the representative protocols from two categories; DSDV from proactive, and AODV & DSR from the reactive.

2. DESTINATION SEQUENCED DISTANCE VECTOR ROUTING PROTOCOLS (DSDV)

This protocol is based on classical Bellman- Ford routing algorithm designed for MANETS. Each node maintains a list to all destinations and number of hops to each destination. Each entry is marked with a sequence number. It uses full dump or incremental update to reduce network traffic generated by rout updates. The broadcast of route updates is delayed by settling time. The only improvement made here is avoidance of routing loops in a mobile network of routers. With this improvement, routing information can always be readily available, regardless of whether the source node requires the information or not. DSDV solve the problem of routing loops and count to infinity by associating each route entry with a sequence number indicating its freshness. In DSDV, a sequence number is linked to a destination node, and usually is originated by that node (the owner). The only case that a non-owner node updates a sequence number of a route is when it detects a link break on that route. An owner node always uses even-numbers as sequence numbers, and a non-owner node always uses odd-numbers. With the addition of sequence numbers, routes for the same destination are selected based on the following rules:

i) a route with a newer sequence number is preferred;

ii) in the case that two routes have a same sequence number, the one with a better cost metric is preferred. [4]

The list which is maintained is called routing table. The routing table contains the following:

(a) All available destinations' IP address
(b) Next hop IP address
(c) Number of hops to reach the destination
(d) Sequence number assigned by the destination node
(e) Install time

The sequence number is used to distinguish stale routes from new ones and thus avoid the formation of loops. The stations periodically transmit their routing tables to require node to wait a settling time before announcing a new route with higher metric for a destination.

3. DYNAMIC SOURCE ROUTING (DSR)

Dynamic Source Routing DSR [6-9] is a reactive protocol. This protocol is one of the example of an on-demand routing protocol that is based on the concept of source routing. It is designed for use in multi hop ad hoc networks of mobile nodes. It allows the network to be completely self-organizing and self-configuring and does not need any existing network infrastructure or administration. DSR uses no periodic routing messages like AODV, thereby reduces network bandwidth overhead, conserves battery power and avoids large routing updates. However, it needs support from the MAC layer to identify link failure. The DSR routing protocol discovers routes and maintains information regarding the routes from one node to other by using two main mechanisms:

- Route discovery: Finds the route between a source and destination and
- Route maintenance: In case of route failure, it invokes another route to the destination. DSR has a unique advantage by virtue of source routing. As the route is part of the packet itself, routing loops, either short
- lived or long: lived, cannot be formed as they can be immediately detected and eliminated. This property of DSR opens up the protocol to a variety of useful optimizations. If the destination alone can respond to route requests and the source node is always the initiator of the route request, the initial route may the shortest? This routing protocol apply the concept of source routing, which means that the source determines the complete path from the source node to the destination node, that the packets have to traverse, and hence ensures routing to be trivially loop-free in the network. The packet in DSR carries all information pertaining to route in its preamble (header) thus permitting the intermediate nodes to cache the routing information in their route tables for their future use. In DSR Protocol, Route discovery is the process in which a source, in order to send data to a destination, obtains the route to the destination, even if it does not have a route to the destination. Route maintenance is the mechanism by which the node keeps the record of dynamic changes of the network topology. In other words, source node checks for any link failure between source and destination. If a link failure is found between source and destination, the source node tries to find another route to the destination or invokes Route Discovery; thereby communication between source and destination continues to be established.

4. AD HOC ON-DEMAND DISTANCE VECTOR ROUTING (AODV)

The Ad Hoc On-Demand Distance Vector routing protocol as described in [10] is a modified version of the DSDV and aims at reducing system-wide broadcasts that are a feature in DSDV. Routes are discovered on an as- needed basis and are maintained only as long as they are necessary. Each node maintains monotonically increasing sequence numbers and this number increases as it learns about a change in the topology of its neighborhood. This sequence number ensures that the most recent route is selected whenever route discovery is initiated.

AODV uses routing cache to maintain network information collected by beaconing. This route information is used to store the destination and next-hop IP addresses as well as the destination sequence number. Associated with each routing table entry is a lifetime, which is updated whenever a route is used. Routing in AODV is carried out by the process of Route Discovery and Route Maintenance.

When a node wishes to send a packet to some destination node, it checks its route table to find whether it has a route to the destination node. If it does, it forwards the packet to the next hop towards the destination. However, if the node does not have any valid route to the destination, it must initiate a route discovery process. The source node creates a route request (RREQ) packet that contains the source node's IP address, current sequence number, destination's IP address and last known sequence number. The RREQ also contains a broadcast ID and this is incremented every time the source node initiates a RREQ. Thus, the broadcast ID and the source IP address uniquely identify a route request. Once the RREQ is created, the node broadcasts this packet and ets a timer to wait for a reply. When a node receives a RREQ, it first checks whether it has seen

it before noting the source IP address and broadcast ID pair. If it has already seen a RREQ with the same source IP address and broadcast ID, it silently discards the packet. Else, it records this information and processes the packet. The node sets up a reverse route entry for the source node in its route table. This reverse route entry contains the source node's IP address and the IP address of the neighbor from which the RREQ was received. If the route entry is not used within a certain timeout period, it is deleted to prevent the presence of stale routing information in the route table.
The destination node responds with a unicast route reply (RREP) packet to the source. If the node is not the destination node, it increments the RREQ's hop count by one and re-broadcasts this packet to its neighbors. If the RREQ is lost, the source node is allowed to re-broadcast a route discovery again. The number of retries is fixed and if there is no route to the destination after the maximum number of retries, the destination is labeled unreachable.
Once a route has been discovered for a given source/destination pair, it is maintained as long as needed by the source node. Movement within the Ad Hoc network affects only the routes that contain those nodes. If the source node moves, it can re-initiate a route discovery to establish a new route to the destination. When a link breaks, a route error (RERR) message is sent to the affected source nodes whenever a packet tries to use the link.

5. SIMULATION OF ROUTING PROTOCOLS

Simulation of different routing protocols has been carried over to evaluate the performance. Various parameters that are considered for simulation are listed in table 1.

Table 1: Simulation Parameters for simulating routing protocols

Metric	**Value**
Simulator	NS-2 (ver2.33)
No of nodes	10
Routing protocol	AODV, DSR, DSDV
Traffic type	CBR (Constant Bite Rate)
Simulation time	250 sec.
Simulation area	500mx500m

Metrics used for Simulation

To analyze the performance of our solution, various contexts are created by varying the number of nodes and node mobility. The performance metrics are purposely chosen to show the difference in performance among the different routing methods. These metrics are the most crucial and common yardstick to measure the overall performance of the network routing algorithms. Similar types of metrics were also used in many other comparisons related work. The performance metrics are defined as the followings.

- **Average End-to-End Delay or Mean Overall Packet Latency:** This implies the delay a packet suffers between leaving the sender application and arriving at the receiver application (Figure 2).

Figure 2: Relationship between Pause Time and Routing Overhead for MANET

- **Routing Overhead:** The total number of routing control packets transmitted during the simulation. i.e. the sum of all transmissions of routing control packets sent during the simulation. For packets transmitted over multiple hops, each transmission over one hop, counts as one transmission.

Routing overhead = ∑Transmissions of routing packets

Routing overhead is important to compare the scalability of the routing protocols, the adoption to low-bandwidth environments and its efficiency in relation to node battery power (in that sending more routing packets consumes more power). Sending more routing packets also increases the probability of packet collision and can delay data packets in the queues.

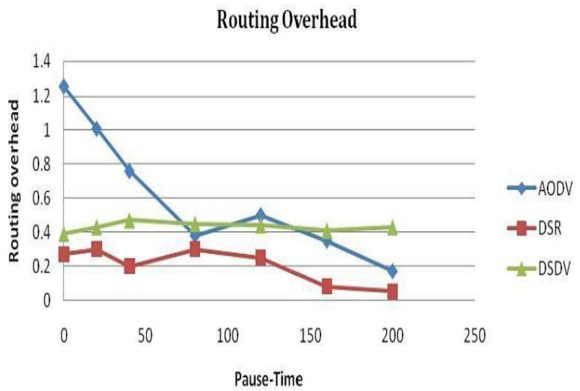


Figure 3: Relationship between Pause Time and Routing Overhead for MANET

This figure 3 illustrates the variation in routing overhead as a function of pause time for different MANET routing protocols. As pause time increases, the routing overhead for DSDV decreases significantly, while AODV shows greater variability. DSR consistently maintains lower routing overhead compared to the other protocols across varying pause times.

- **Packet delivery ratio:** The packet delivery ratio in this simulation is defined as the ratio between the number of packets sent by constant bit rate sources (CBR,‖application layer‖) and the number of received packets by the CBR sinks at destination. It describes percentage of the packets which reach the destination.

Packet delivery ratio = ∑packets received / ∑CBR packets sent

Figure 4: Impact of Pause Time on Packet Delivery Ratio for MANET Routing Protocols

This figure 4 demonstrates the effect of pause time on the packet delivery ratio for various MANET routing protocols. Reactive protocols like DSR and AODV achieve a high packet delivery ratio (95% to 99%) at shorter pause times, while DSDV consistently lags behind with a lower packet delivery ratio, averaging around 75%. As pause time increases, the packet delivery ratios for all protocols stabilize, with reactive protocols maintaining superior performance.

6. CONCLUSION

In this study, we conducted a performance analysis of MANET routing protocols within the Random Waypoint environment. Our analysis revealed that reactive routing protocols experienced minimal packet loss when the pause time was short, achieving a packet delivery ratio of approximately 95% to 99%, with the exception of DSDV, which was closer to 75%. Both DSR and DSDV demonstrated lower routing overhead compared to AODV, which exhibited significant variability. Additionally, DSDV showed a high average end-to-end delay at shorter pause times, which decreased as the pause time increased. DSR, on the other hand, maintained low end-to-end delay throughout. When comparing the three routing protocols under the Random Waypoint Mobility Model, DSR emerged as the best performer in the analyzed scenario.

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