Review and Analysis of Reactive Routing Protocols: AODV, DSR, TORA and DYMO in MANETS

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Abstract – *Mobile Ad Hoc Network (MANET) is a dynamic infrastructure-less system. In MANET mobile nodes connect and communicate to each other through wireless links without central administration. Mobile nodes in MANET act as both host and router to establish and maintain the process of communication. Therefore, each node is equally responsible for discovering the efficient route and performs rectification when the route becomes invalid. Routing in MANET becomes complex due to such reasons as the continuous movement of nodes, topology changes frequently, limited bandwidth, and energy depletion. Reactive routing protocols are also known as on-demand routing protocols since the routes are discovered only when a demand is raised. By maintaining information for active routes only, these protocols reduce the overhead, which occurs in proactive protocols, and hence former are preferred over later. This paper presents an overview along with a comparative analysis of reactive routing protocols namely DSR, AODV, DYMO, and TORA to identify which protocol is best suited under which circumstances.*

***Key Words*: Reactive Routing Protocols, Dynamic Source Routing, Ad-Hoc on Demand Distance Vector**

1. INTRODUCTION

MANETs are becoming more and more popular due to the heavy use of wireless communication worldwide. MANET is an autonomous system that consists of a number of mobile nodes that communicate wirelessly to each other and a network is formed spontaneously. It is an infrastructure-less network and topology is not fixed. e.g. VANET which provides wireless communication among vehicles and vehicle to roadside equipment. Spontaneous formation of the temporary network feature of MANETs makes them feasible to use in application areas such as defense applications, search and rescue operations, emergency and disaster relief communication, education virtual classrooms, etc. The nodes in MANET can move freely or join the network arbitrarily in a random way hence changing the topology of the network. There are mainly three categories of routing protocols based on route discovery mechanisms such as proactive, reactive, and hybrid protocols.

The difference between the proactive (table-driven) and reactive (demand-driven) protocols are based on when and how the routes are established and storing their information. In proactive protocols, all nodes in the network keep the routing information stored in one or more routing tables of each and every other node, and updating the routing information is performed as and when topology changes [1]. Whereas in reactive protocols as the routes are discovered and established only when demand is raised by any node and hence these are also known as demand-driven protocols. The combinations of the features of proactive and reactive protocols are included in hybrid protocols.

Reactive routing protocols make use of two mechanisms as route discovery and route maintenance. By these protocols, data is transferred to that node that has immediate demand about that message currently [2]. By using the route discovery mechanism the source node discovers whether there exists any route to a destination or not, if yes then directly sends the packet using an already available path otherwise utilizes the flooding routing mechanism to discover a new path. Flooding is a simple routing technique in which a sender node broadcasts packets on every available link. After discovering all paths their routing information is replicated in the routing table about the path chosen by the source node. On the contrary, a source node identifies the topology change in the network by utilizing the route maintenance mechanism.

There are many protocols that fall under the category of reactive routing. In this paper, four most preferred protocols such as DSR, AODV, DYMO, and TORA were studied.

1.1 Ad hoc On-demand Distance Vector (AODV)

AODV is known as source-driven routing protocol which is an extended version of DSDV(Destination Sequenced Distance Vector, a proactive routing protocol) as it makes use of sequence numbers as used by DSDV to identify the stale entries for the destination nodes.

AODV protocol follows different processes sequentially like path discovery, route table management, path maintenance, and local connectivity management [3]. Along with sequence numbers, some more fields are used by AODV like flexible loop-free, self-starting, and scales to large numbers of mobile nodes. The target of AODV is to reduce the need for system-wide broadcasts. The main difference between the AODV and Dynamic Source Routing (DSR) stems from the fact that DSR uses source routing in which a data packet carries the complete path to be traversed. A simple request-reply mechanism is utilized by the AODV protocol for routes discovery [4]. AODV grants the creation of routes to specific destinations and does not require that nodes keep these routes when they are not in active communication. Using AODV destination sequence numbers avoids the "counting to infinity" problem. This property results in the loop-free nature of AODV.

1.2 Dynamic Source Routing (DSR)

DSR protocol is a reactive routing protocol that has a few similar mechanisms to AODV. DSR is an especially proposed efficient routing protocol that is to be used in multi-hop mobile Ad hoc networks. It has two phases, one is Route Discovery and another one is Route Maintenance. These phases are helpful to locate and maintain the correct source routes to the destinations. Source Routing is a loop-free routing in which the intermediate nodes do not need any routing information and allows nodes to cache the routing information for further use. In DSR, each node controls each packet for source route information and later forwards it based on this routing information. When the routing information is not found in the packet, it will provide the source routing by knowing the route. When the destination is not known, in that case, the node caches the packet and finds the routing information to the destination by sending route queries to all nearby nodes. Lastly, it sends the Route acknowledgment back to the source.

1.3 Temporary Ordered Routing Algorithm (TORA)

TORA is a reactive routing protocol, which is based on the link reversal algorithm [3]. It is effective in solving the existing limitations of MANETs[4]. TORA consists of four chief functions similar to creating, optimizing, removing, and upholding routes[2]. TORA locates the number of routes from a source mobile node to a particular destination node. As a result, there often exist multiple routes to a given destination but none of them is necessarily the shortest route. Instead of using the shortest path for finding routes, the TORA algorithm maintains the direction of the next destination to forward the packets.

It is a source-initiated on-demand Routing Protocol. It not only finds the best route from source to destination but locates all available routes. In TORA the control messages are exchanged to only the neighbor nodes near the topological change occurrence. For this, routing information is maintained about adjoining nodes. The protocol performs functions such as Route creation, Route maintenance, and Route erasure. TORA reduces the control messages in the network by having the nodes query for a path only when it needs to send a packet to a destination. TORA followed three steps for network establishment.

1. Creating the routes from source to destination.
2. Maintaining the routes
3. Erasing invalid routes.

1.4 Dynamic MANET On-demand (DYMO)

The Dynamic MANET On-demand (DYMO) is a simple and fast reactive routing protocol for multi-hop wireless communication in ad-hoc networks, currently standardized by the Internet Engineering Task Force (IETF). DYMO significantly reduces the routing overhead using the path accumulation function, simplifying the protocol implementation [5]. DYMO is built based upon the AODV reactive routing protocol with some extra features embedded in it [6]. DYMO performs two operations named Route Discovery and Route Maintenance.

Route Discovery

DYMO's route finding process resembles the AODV routing protocol besides the path buildup feature. The discovery of routes operation is performed when a need arises by the source node in order to communicate with a destination node that is not present in its routing table. A source node generates an RREQ packet and sends it to its neighbors. If a neighbor has an entry to the destination node then it replies with an RREP packet to the discovered and accumulated path. But if the source node does not receive the RREP packet within the given TTL value then it rebroadcasts the RREQ packet. DYMO is popular as an energy-efficient protocol. As node with low energy has a choice to not take part in the process of route discovery.

Route Maintenance

This process is done to avoid the already available routes from the routing table and to minimize packet loss while link failure occurs. When a link to any other node breaks then a node generates a RERR packet and forwards it to nodes that are concerned with the link failure. A node that receives the RERR packet, updates the routing table and deletes entry with the broken link.

Advantages

1. DYMO does not support unnecessary HELLO packets and its operation is based on the sequence number assigned to each packet which is used for loop-free routing.

2. As a reactive protocol, DYMO does not explicitly store the network topology. Instead, nodes compute a unicast route towards the desired destination only when needed [7].

3. As a result, little routing information is exchanged, which reduces network traffic overhead and thus saves bandwidth and power.

Disadvantages

1. It does not perform well with low mobility [8].

2. The control message overhead is high and undesired.

2. LITERATURE REVIEW

Reactive routing protocols in mobile Adhoc networks are a field of research that attracted many researchers in the last decades. In this section, the related work done in the domain by other researchers is represented.

Geethu Mohandas et al. [1] conducted a survey on routing protocols in MANET. They divided routing protocols into three different categories like basic routing protocols, location-based protocols, and security-based protocols. Further, they compared these protocols to find out the efficient protocol. Thus the study of papers concluded that research in the private areas is limited. Basic protocols like AODV are concentrating only on identity-based routing. Those protocols neither focus on location nor o2n security for routing.

Anuj K. Gupta et al. [8] implemented DYMO routing protocol to do this Fedora 10 as the Operating System has used. For simulations, Ns2.34 has been installed on the platform with add-on software such as Tracegraph, etc. The simulation has been conducted by varying pause times. They observed that DYMO being the successor of AODV performs better in all cases.

Mohammad Ali Mostafavi et al. [9] analyzed the performance of ADOV, DSR, and OLSR routing protocols by performing simulation on OPNET 14.5 Modeler with three proposed scenarios that are: network delay, network load, and network throughput. They found that the DSR protocol has a moderate average network load but it has the largest average network delay compared to OLSR, and AODV. Whereas in terms of average network delay and network throughput AODV performs better than DSR.

Dilip Singh Sisodia et al. [10] presented a review on performance analysis of Intra and Inter-Group MANET Routing Protocols. They found that all the reactive protocols of which comparative study was done include AODV, DSR, and AOMDV; AODV is better in terms of throughput, PDR. The end-to-end delay and routing overhead was found less in AODV than DSR and AOMDV. The simulated experiments were recorded with varying speeds of nodes. These are four performance metrics: PDR, throughput, an end-to-end delay, and routing overhead, against which performance of routing protocols was evaluated. They found that the performance is varied to the small extent of all routing protocols.

Naveen Garg et al. [11] reviewed various reactive and hybrid routing protocols (FSR, DSDV, AODV, DSR, etc). They compared the categories of each protocol separately which means under reactive protocols category: DSR and AODV etc. The survey indicates that for a large number of mobile nodes and at faster speeds the performance of the AODV protocol keeps on upgrading. They experienced that AODV is more flexible and contains less routing overhead than DSR. It has been found that overall AODV performs well than DSR.

C. E. Perkins et al. [12] have simulated AODV by using a simulator called PARSEC. The main objective of their simulations was to show that with AODV, on-demand route establishment is both immediate and correct. They concluded that AODV is a better choice for the establishment of the ad-hoc network because the overall performance of AODV was excellent as it offered less network overhead, it had not flooded the network with unnecessary broadcasts, its quick route maintenance feature, etc. They stated the applications areas where it will be useful are: battlefield communications, conferencing, emergency services, and community-based networking.

Daxesh N. Patel et al. [13] have performed a survey on reactive routing protocols in MANET. They explained AODV, ad-hoc on-demand multipath distance vector routing protocol, dynamic source routing protocol, dynamic MANET on-demand routing protocol with their working mechanism in detail. Later they compared the reactive routing protocols and concluded that each of the protocols studied performs well in some cases and has certain limitations in others.

Basu Dev Shivahare et al. [14] compared the reactive and proactive routing protocols and experienced that performance of AODV is the best in terms of its ability to maintain connection by exchanging information periodically, which is necessary for TCP, based traffic. Hence AODV is preferred over DSR and DSDV in real-time traffic applications.

Lubdha M. Bendale1 et al. [15] have not only discussed the classification of routing protocols but also carried out the comparative analysis of routing protocols for wireless ad hoc networks. They stated that AODV performs well in the case of packet delivery ratio but its performance is poor in terms of average End-to-End delay and throughput when the network load is low. Overall, DSR performs well as compared to AODV due to its less routing overhead when nodes have high mobility.

Walid Abushiba and P. Johnson [16] performed simulation using NS2 of the two routing protocols viz. DSR and AODV employed within an Ad hoc Network consisting of mobile nodes, is carried out. Random positioning of the sensor nodes is adopted in this experiment. Also, the evaluation of the performance of the network is done under the mobile network scenario. They concluded that the overall performance of AODV was found better over most of the scenarios than DSR in case of energy consumption. AODV should be the preferred protocol for applications where energy conservation is vital.

Suresh Kumar and J. Kumar [17] did simulations on QualNet 5.0.2 simulator and decided the parameters for the performance evaluation of DSR, AODV, DYMO, etc routing protocols under different pause times using Random Waypoint Mobility Model. They examined the performance differences of these protocols and found DSR is the best one in terms of total bytes received. In some cases, AODV outperformed DSR such as end-to-end delay, throughput, and average jitter but in the case of First Packet Receive, Last Packet Receive, Total Bytes Receive.

S. Kaur and A. K. Gupta [18] chose Network Simulation2(NS2.34) as the simulator for evaluating the performance of DSR, AODV, DSDV, and DYMO routing protocols by using three performance metrics such as packet delivery ratio, end to end delay, and control packet ratio. They installed the Dymoum-0.3 version of the DYMO protocol on NS-2.34 and considered two scenarios for evaluating DYMO. In the first scenario varying no. of nodes is considered and in the second scenario no. of nodes are varied by taking constant bit rate traffic. From their simulation results, DYMO performed better than AODV. It has also less end-to-end delay than DSR in both scenarios. But DYMO has a slightly lower packet delivery ratio than the other two protocols.

Priyanka Sarkar and H. Paul [19] evaluated AODV, DSR, DYMO, and TORA routing protocols in MANET by doing a performance comparison. Initially, they provided a brief description and overview of reactive routing protocols, after that, they simulated them under different network conditions such as the packet delivery ratio, throughput, and end-to-end delay. They concluded that AOMDV performs better in all different network scenarios.

Wanpracha Nuansoi and S. Khamkleang [20] analyzed the performance of AODV, DSR & TORA routing protocols. They considered two parameters: throughput and end-to-end delay and performed simulation by using NS-2. They found that AODV performed well in all circumstances. DSR is a good choice for moderate mobility rate networks by virtue of its low overhead. On the other hand, TORA is suitable for large mobile networks because it offers excellent support for multiple routes and multicasting.

M. K. Reddy et al. [21] compared the proactive and reactive routing protocols against throughput and delay in MANET. The protocols they compared in their research paper are DSDV, AODV, DSR, DYMO, and TORA protocols against throughput and delay. They presented the comparison of these protocols in two different tables. In the first table, they compared the parameters and in the second table, the properties of these protocols are compared. They found that reactive topology-based protocols perform well than proactive topology-based routing protocols. AODV protocol secured the first position among all due to its lesser end-to-end delay and stable throughput. DSR comes after while DSDV, DYMO, TORA performed worse under defined criteria.

Sampoornam and G. R. Darshini [22] evaluated the performance analysis of routing protocols such as Bellman-Ford, AODV, DSR, ZRP, and DYMO in MANET using the EXATA 5.1 simulator. The parameters that were evaluated in their research are throughput, average delay, average jitter, the total number of packets enqueued, the total number of packets dequeued, and the total number of packets dropped. They keenly observed the performance of routing protocols with fault nodes and without fault nodes in MANET. From the simulation results that they obtained, the ZRP protocol performed well for all the mentioned parameters even with the presence of a fault node.

Vishal Sharma et al. [23] evaluated the performance of reactive routing protocols in MANET with different mobile nodes transmitting GSM voice traffic data. They performed simulation by using OPNET 14.5 simulator. They found that AODV possesses maximum average throughput and traffic with lower network load and has the lowest end-to-end contrast to DSR. On the other hand, DSR does not perform well in a dense network. From simulation results, they also concluded that ADOV is an excellent choice for the dense number of nodes in MANET whereas, DSR performance was dull QoS in the denser MANET with GSM voice traffic data.

Padmalaya Nayak [24] analyzed two models named the random waypoint and random walk mobility model for reactive routing protocols in MANET. They used the NetSim simulator for conducting the research. Forty mobile nodes were considered to analyze the performance of AODV and DSR under a grid area of 1000*1000m. They have shown the simulation results of these protocols in graph form for different parameters. It is clear from their simulation results that DSR performed well than AODV in terms of throughput and packet delivery ratio but in case of less average end-to-end delay, AODV is a good choice than DSR.

A. M. Shantaf et al. [25] presented the performance evaluation of three MANET Routing Protocols in Different Environments. In their research, they evaluated the performance for three protocols by using the different performance metrics like Packet Delivery Ratio (PDR), Average, Throughput, and Average End-to-End Delay. To compare them they considered two different scenarios for three protocols AODV, DSR, and DSDV. One scenario in a different density of nodes and other scenarios in a different area with the same density of nodes(100). They experienced that DSR performed well in the PDR so DSR is better than AODV and DSDV in two scenarios (different areas with the same density of nodes (100)). However, AODV protocol's result was good but DSR was best choice because of the feature to avoid the loop in the network.

S. Mahajan and V. Chopra [26] evaluated the Performance of (AODV, OLSR, and TORA with Scalability using QoS Metrics of VOIP Applications in terms of network throughput, delay and network load, jitter, and MOS(Mean Opinion Score). The simulation was carried out on Opnet Simulator. Finally, it is concluded by them that by and large performance of OLSR is better for small and large networks. In the case of TORA, the performance as well with medium to fully dense network as compared to AODV.

Prasad Patel et al. [27] evaluated the performance of AODV and DSR routing protocols in MANET. The experimental tools setup and parameters used by them in the simulation are: Ubuntu 11(OS) and Network Simulation 2 (NS2.35). Parameters used by them are: Sending time, Access time, Transmission time, Propagation time, Reception time, etc to measure their performance. Finally, they observed that DSR protocol turned out to be the best in case of efficiency for less than 700 bytes packet size.

Dhananjay Bisen et al. [28] examined the effect of pause time on DSR, AODV, and DYMO Routing Protocols in MANET by using QualNet wireless network simulator version 4.0. The parameters against which performance was examined are: Throughput (bits/s), Total Packets Received, Drop Packet Ratio, End-To-End Delay and Average Jitter Effect. From the deep analysis of simulations results, it can be concluded that the performance of DSR was excellent than DYMO and AODV under different situations with variations in pause time. Even though DYMO is a refined version of AODV, thus the performance of DYMO is found sometimes better than AODV, DSR in some situations.

Rutvij H. Jhaveri et al. [29] studied routing protocols in MANET and analyzed the Wormhole Attack against AODV. They have depicted several categories of attacks on AODV such as Attacks using Modification, Attacks using Impersonation, Attacks using Fabrication, etc, and their further subcategories. Further, they explained the operation of Wormhole Attacks in AODV protocol and procedure to secure AODV protocol in their research. Finally, they concluded that AODV is susceptible to attacks like modification of hop count, cache poisoning, tunneling of source route, spoofing, and fabrication of error messages. Although AODV is not affected by cache poisoning like DSR is susceptible to it. They are concerned about the AODV protocol is prone to Wormhole attacks in MANET.

Many researchers have compared reactive routing protocols with either proactive or/and hybrid protocols depending on different criteria. In this work a different type of comparison of reactive routing protocols such as DSR, AODV, DYMO and TORA is done by taking into consideration several parameters.

Table -1: Comparison of DSR, AODV, TORA and DYMO protocols

Parameters	**DSR**	**AODV**	**TORA**	**DYMO**
Packet Delivery Ratio **[19]**	Lowest	Highest	High	Low
End-to-end delay **[19]**	Less	Highest	Same as DSR	Lowest
Through-put **[19]**	Lowest	Highest	Lower than AODV	Low
Routing Approaches **[21]**	Reactive Dynamic Source Routing	Reactive adhoc on-demand distance vector routing	Reactive	Reactive
Route Selection **[21]**	Shortest path and updated path	Shortest path and updated path	Link reversal	Unicast multipath route
Routing Structure **[21]**	Flat structure	Flat structure	Flat structure	Flat structure
Route **[21]**	Multiple Route	Multiple Route	Single Route	Multipath
Loop Free **[21]**	Yes	Yes	Yes	Yes
Unidirectional Link Support **[21]**	Yes	No	Yes	Yes
Multicast **[21]**	No	Yes	No	Yes
Distributed**[21]**	Yes	Yes	Yes	Yes
Parameters	**DSR**	**AODV**	**TORA**	**DYMO**
Routing Table Utilization **[29]**	Maintains route cache to store full route to the destination	Routing table maintained by each node which stores next hop address	Make use of Direct Acyclic Graph	Route.Address, Route.Prefix, Route.SeqNum, Route.NextHopAddress, Route.NextHopInterface, Route.Forwarding, Route.Broken
Operations of protocols **[29]**	1.RREQ broadcast 2.RREP Propagation 3.RERR message	1.RREQ broadcast 2.RREP Propagation 3.RERR message	1.Route creation 2.Route maintenance 3. Route erasure	1.RREQ broadcast 2.RREP Propagation 3.RERR message

3. CONCLUSIONS

MANET is advantageous as the network can be set up at any time and at any place, and is efficient where a fixed infrastructure can't be formed. Due to its dynamic nature routing becomes a challenging task. This work is an attempt towards a comprehensive performance evaluation of four commonly used flat-routing protocols namely DSR, AODV, TORA, and DYMO in MANET. These routing protocols were analyzed to assess their relative strength and weaknesses. It was examined that choosing an efficient protocol out of these is very difficult. Each protocol studied performed well in some cases and has certain drawbacks in others.

This work opens new avenues for future research. Extension of the existing conventional routing protocols can be proposed in terms of security, efficient utilization of limited resources, and QoS. Performance analysis of these protocols against various security attacks can be observed.

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