

Review and Analysis of Various Mobile Ad Hoc Network Routing Protocols

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Abstract: Now days the use of mobile wireless devices is increases tremendously all over the world which leads researchers to frequently work over the new improvements in mobile ad hoc network communication protocols, which we can called as MANET routing protocols. The main aim behind these researches is to outperform the existing routing protocols by extending them with new algorithms or methods in order to present the unique communication protocol. In the literature we have studied many routing protocols which are basically categorized into three main types such as reactive, proactive and hybrid routing protocols. In this paper we are discussing all routing protocols for MANET those are comes under these three types. Apart from the main routing protocols, there are many improved routing protocols presented by different researchers and still research is going on day by day. In MANET, it is very tough task to predict the performance of routing protocol under varying network conditions and scenarios. During this paper we are discussing about all existing routing protocols with main focus on their features, functionalities and characteristics.

Keywords: Routing protocols, MANET, Proactive, Reactive, Hybrid, and Comparative Study.

I. INTRODUCTION

The concept of MANET is nothing but the group of wireless mobile nodes without using any cables, infrastructures, architecture. Every mobile node in this network is acts as peer or routing which do both the tasks packets sending (forwarding) and packets receiving. MANET does not require centralized administration or fixed network infrastructure such as base stations or access points [1]. A MANET is an autonomous group of mobile users that communicate over reasonably slow wireless links. The network topology may vary rapidly and unpredictably over time, because the nodes are mobile. Such a network may operate in a standalone fashion, or may be connected to the larger Internet. MANETs possess certain characteristics like Bandwidth-constrained, variable capacity links, Energy constrained Operation, Limited Physical Security, Dynamic network topology, and frequent routing updates [2]. The communication is the key of MANET which is conducted by routing protocols. There are many routing protocols presented for MANET. In this paper we are taking review of different MANET routing protocols and discussing the comparative study over them. We are mainly focusing unicast routing protocols in this paper.

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In following sections, section II discussing about the different categories and classification of MANET routing protocols. Section III presenting the review of unicast routing protocols, section IV presenting the summary over proactive, reactive and hybrid routing protocols [2].

II. MANET ROUTING PROTOCOLS

As we know about the MANET, the architecture or topology of such networks is not fixed which changes randomly and rapidly time by time. This network does not have architecture, no dedicated servers, no dedicated routers and also no dedicated access points. Therefore MANET is temporary network and frequently changed network which consists of mobile nodes without any infrastructure. Following are main points those are considered as application of MANET.

1. Most demanded in Military areas.
2. Search and rescue
3. While transportation for the vehicle-to-vehicle mobile communication we need such networks.
4. For the meeting rooms, conference, airports we need the temporary networks for the immediate communications.
5. Other personal network areas to which the mobile laptops, smart cards, cell phones etc connected need such mechanisms.

Mobile nodes communicating directly to each other when they resides in each other's radio waves otherwise we need to use the intermediate nodes to forward the information from the source mobile node to destination mobile node in which each mobile node acts the router in order to forward information to next mobile node in route [10]. The protocols such as RIP, OSPF etc. which used in the wired networks but they cannot be used for the MANET networks directly because of the following reasons:

- (1) Uni-directional links may be present in between the nodes.
- (2) Eligible path for the communication in between two nodes is more than one.
- (3) Routing updates frequent which leads the bandwidth consumption, consumption of the power are considerable.
- (4) As compare to the frequent topology changes, the slow coverage of routing fabrics.

Thus lots of researches are carried out in order to design and apply the routing algorithms for the mobile ad hoc networks and hence the routing protocols for the MANET are divided into the following parts:

- (1) Unicast routing protocols
 - a. Topology-based routing protocols
 - Proactive routing protocols –OLSR, FSR etc
 - Reactive routing protocols- AODV, DSR
 - Hybrid routing protocols- ZRP
 - b. Geographical-based routing protocols

- (2) Multicast routing protocols- MAODV etc (Which we are not considering during this paper)
- (3) Broadcast algorithms (This also not considering during this paper)

Above all the categories for the MANET routing protocols, even though many routing protocols available for routing mechanism in the MANET, but one protocol cannot cover or address all kinds of scenarios and traffics for the MANET applications. Let us suppose for example for broad band, small scale network with high mobility, protocols in the category proactive are more suitable for such networks. On the other hand for the large networks, for narrow band, large scale with the low mobility, the protocols from category reactive routing protocols are best suitable for such networks. In order to achieve the peer to peer network mobile nodes resort to broadcast if and only they are moving very quickly in the MANET networks. Finally, one must conclude that, each and every routing protocol in the MANET network has its own advantages of using it and disadvantages of using it and most importantly they are selected on the basis on applications [10]. And hence the routing protocols are selected on the requirements and network applications configurations. Following figure 1 are showing the MANET routing protocols hierarchy.

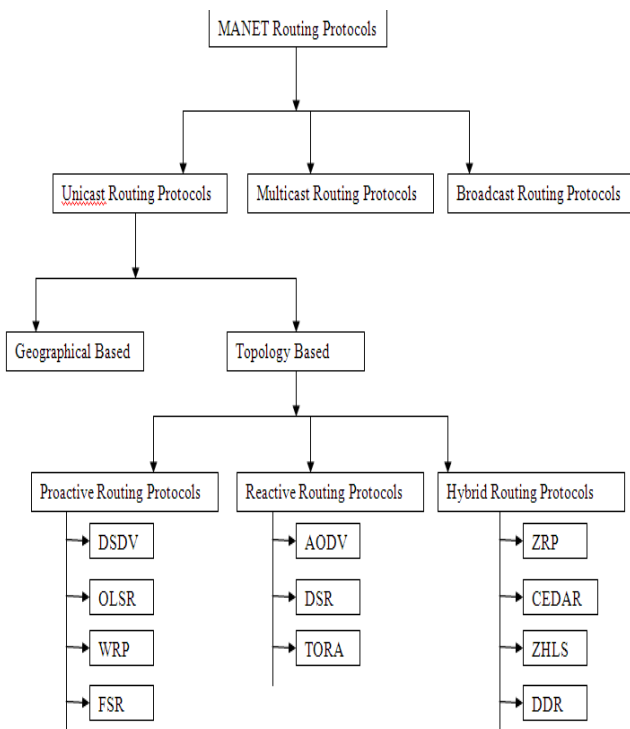


Figure 1: Ad hoc Network Routing Protocols Classification

In the next section III we will discuss Unicast Routing protocols in details.

III. REVIEW OF UNICAST ROUTING PROTOCOLS

Many MANET applications require unicast network communication and hence we need to have unicast routing communication protocols in place. This application requires that the successful transmission of the data in the form of packets from the originator node to the destination nodes over the IP layer in the MANET network. In such routing protocols, procedure for the forwarding is easy and simple in which the relay node address of the destination node from the forwarding packet itself in order to look up it in the

current routing table. If the route which is long in order reach to the destination found into the routing table, forwarding mechanism forwards to the next node in the route and hop count increases accordingly. There are many number of routing protocols which are dependent and utilizes all kinds of schemes in order to offset the impact which is introduced by the mobility [1] [2].

3.1. Proactive Unicast Routing Protocols

Best examples of the proactive unicast routing protocols is the OSPF and RIP which are traditional one. In such protocols to calculate the shortest from the source node to the destination node, network topology frequent updates broadcasting is necessary. Such calculation of the shortest path consumes lots of bandwidth of the network. In MANET we cannot use them directly because of the fact of difference between the wired network and mobile ad hoc networks even though they are frequently used in the network backbone.

3.1.1 OLSR- Optimized Link State Routing Protocol

The main aims of the OLSR (Optimized Link State Routing) Protocol were to provide the efficient routing mechanism in the MANET networks [7]. This protocol was based on the mechanism called as multipoint relaying means MPR flooding technique in order to reduce the packets broadcasting in the topology. Following is the detailed procedure for the OLSR protocol working:

- (1) Every node in the network which contains the address on the next node information periodically broadcasts the HELLO messages over the network. Every node broadcasts HELLO messages that contain one-hop neighbor information periodically. HELLO messages are not forwarded by the neighbor nodes because of TTL of such messages is 1. Because of the HELLO messages in each node local topology information is available [7].
- (2) Depending on the local information of the topology, node which is also called as the selector selects the group of all the nodes which are neighbors in order to act as multi point relaying nodes means the MPR nodes. These nodes are later specified in the HELLO messages periodically.

There are two types of role of the MPR nodes:

- I) broadcast packet when forwarded or sends by the selector node, then only the nodes which MRP of the selector node will forward such packet;
- II) The selector node list is periodically broadcasted by the MRP nodes of the selector node in the whole MANET by using the flooding technique of the MRP. This resulted into the fact that every node in the network knows that how other node reached using which MRP node.

Advantages of OLSR

- 1) This protocol reduces the multiple retransmissions of the existing topology information broadcasting.
- 2) More network bandwidth saved in this case as compared to the link state routing protocol due to the reduced broadcast packet size.

- (3) Using the Dijkstra’s algorithm, the shortest path from the source node to destination node is computed which is possible by using the global topology information which is stored and frequently updated at every node in the network.

3.1.2 FSR: Fisheye State Routing Protocol

This is one more type of proactive routing protocol proposed with the aims for the large scale mobile ad hoc networks with the high level of mobility throughout MANET the network. The Fisheye State Routing name came from the one of the property of the fish eye in which the fish gets picture of the object which nearby the eye of the fish with high resolution, same resolution gets decreases when the object moves far away from the fish eye. Same mechanism of the fish eye was adopted by the FSR protocol in which the source of information sending needs to know way which directed towards the node which is destination for the information arrival. The packets movement will then corrected by the all the intermediate nodes. Following are the points which will describe detailed working of the FSR:

- (1) In this case, all the nodes in the network divided into the different areas which is depend on the distances of the other nodes in the network from the specific node. Such areas called as scopes for specific node. Depending on the distances from the specific node scopes are divided into two types such as inner scope and outer scope [5] [6] [7] [8] [9].
- (2) The frequent updates of the link state are broadcasted to the all its neighbors, but the routing entries which are related to the nodes from the different scopes at various frequencies such as routing entries related to the inner scope nodes are sent with the highest frequency, rest of the routing entries are sent in with lower frequency.

Advantages

In the scenario in which the source of information needs to find the route to reach the destination node which is at far distance from it, source node first uses the most recent information about the link state in order to compute the shortest path. Thus using such information packets from the source node approaches first inner scope towards to the destination and hence the path accuracy increases and finally packets get arrived at the destination node. In this protocol overhead of routing traffic is increases which is reduced further by doing the propagation of the information link state periodically only.

3.1.3 TBRPF: Topology Broadcast Based on Reverse-Path Forwarding Routing Protocol

One more protocol from the category proactive routing protocols was proposed with aim of MANET network of hundreds of mobile nodes and higher mobility. In such protocol each node maintains the partial information about the network topology. When any node in the network wants to communicate other node, it needs the shortest path to reach the destination node which is computed here by Dijkstra’s algorithm using the minimum spanning tree mechanism [5] [6] [7] [8] [9]. But in such case routing overhead increases which is reduced by the following optimization techniques:

- (1) The HELLO messages which are differential and periodic are gets exchanged in between the all the neighbor nodes. In the HELLO messages, the updates

- of neighbor status include which resulted into size of message smaller as compared to the protocol OLSR.
- (2) Spanning tree only broadcasting only the nodes which are near to the source node. In order to make it more robust, every node in the MANET network could choose to broadcast the whole source tree instead.
- (3) If it’s possible then add the updates related to the topology in the HELLO messages.

Thus from all above discussion related to the proactive protocols such FSR, OLSR and TBRPF, we conclude that this all are used in different scenarios of applications and depends on the scope of the application. In following table, comparison of these protocols is presented for the different characteristics.

3.1.4 Comparison of Proactive Routing Protocols

Following table 1 is showing the comparative study for above discussed three proactive routing protocols.

	OLSR	FSR	TBRPF
Scope	Large and dense MANETs	Large scale MANETs with high mobility	MANETs with hundreds of nodes and high mobility
Network organization	Flat	Hierarchical	Flat
Neighbor detection	Periodical HELLO messages	Periodical link state updates	Differential HELLO messages
Optimized broadcast	Multipoint relaying	Combined with neighbor detection	Combined with HELLO messages
Broadcast information	MPR selector list	Link state update	(Partial) Spanning tree
Route freshness	Up-to-date	Maybe not up-to-date	Up-to-date

Table 1: Comparative Study of Proactive Routing Protocols

3.2 Reactive Unicast Routing Protocols

Under this category there are two major routing protocols those are frequently used in many applications due to their advantages such as AODV and DSR. The information of topology which is global and stored at every node frequent updates needed because of the dynamic and distributed nature of the MANET network topology. In such case more bandwidth gets consumed which is most of the time resulted into the wastage of bandwidth as the updates related to the link states updates gets expired, before making use of such information regarding to the link state [10].

Thus, a reactive routing protocol comes here and which are working in following two parts:

- (1) Route discovery: As we know in the wired network source node broadcast the ARP packet request to all the nodes in the existing wired network before sending any information in the form of packet to any node. Using the ARP request packet, source gets the information about the nodes MAC addresses. Same mechanism used here for the route discovery except the thing that route discovery works over the IP layer. Route discovery looks almost the same, but it works in IP layer and also keep the information regarding to the nodes out of source range of transmission.



Thus in the MANET, if the source does not find any route towards to the destination, then source node broadcast the route discovery packet among all the mobile nodes in the network in order to find out the route and reach destination. The intermediate nodes in the route forward the route discovery packet to next node in path [10].

(2) Route maintenance: After the route discovery over in which route between the source node and destination node has been find out, the next step is start working in order to maintain that route still the message delivery to the destination, such mechanism is called as route maintenance. Route maintenance check the validity of route because in the MANET nodes move freely not at fixed position. If the during the transmission links get failed due to some reason, source node again start the route discovery mechanism find out the new path towards the destination [11] [12] [13]. DSR and AODV are most efficient protocols for the MANET from the reactive routing protocols which are presented in detail below sections:

3.2.1 Dynamic Source Routing Protocol (DSR)

The first reactive protocol which was proposed is called as Dynamic source routing protocol which had goal of imposes the routing mechanism in MANET network which size up to the 200 mobile nodes, with the high mobility [11]. As compare to other unicast routing protocols, dynamic source routing protocol does not use the concept on routing table. Rather than the routing tables, DSR uses the source routing option in the packet itself which is on transmit and the mechanism of route cache which stores the full list of IP addresses of the mobile nodes in the MANET network in order to recognize the route towards to destination node. Following the basic working of the DSR protocol in the The basic procedure of DSR is:

(1) Route discovery: Here the route request packet is used to find out the route towards the destination if the source node doesn't find any route in the route cache. Throughout the MANET such route request packet is broadcasted. While packet traversing from the source to destination using the intermediate mobile nodes, each intermediate nodes add its own IP address into that route request packet IP list. Thus when the destination node receives the packet, the request packet contains the all the route from source to the destination which is called as path accumulation also. After receiving the packet from the source node, destination node again start the route discovery mechanism in order to transfer the route reply packet back to the destination again. It can either use the source route which is recorded into the request packet in order to send the route reply packet in reverse order. Finally in this approach after the route discovery mechanism, both source node and destination node have the complete route from source to the destination [10].

(2) Route maintenance: In the DSR protocol, there is no concept like HELLO messages which are periodically updated as like in proactive routing protocols as well as AODV protocol. Rather every mobile node in the network is responsible for the maintenance of the routing protocol in between the node and next hop in route from source to the destination. This route is detected by the MAC layer or software acknowledgement which is DSR specific. In the any link lost in between, then source route error packet is used to notify by the source node of particular route path and again initiate route discovery mechanism. In the DSR,

route cache is mostly used for the same purpose. Routing overhead is greatly reduced by the routing cache concept in following way:

(1) While route discovery phase, if the intermediate node encounters the route from the source to destination or route towards the destination from the its own routing cache, then this node reply with the route reply packet and then send the route from the source to destination on same time.

(2) DSR is based on the multi paths concept, thus if any link break and source receives the route error packet, then it can directly use the alternate route which is available in source route cache, this resulted into the reduced routing overhead.

(3) The concept of packet salvaging, in which if the any intermediate route from the source to destination route detects next hop link breakage, then in such case if that intermediate route has another route available towards the destination in its route cache, it can directly used the same route to forward the packet towards the destination. Next section presents AODV.

3.2.2 AODV: Ad hoc On-Demand Distance Vector Routing Protocol

This is one more ad hoc routing protocol which is somewhat different from the DSR protocol in working and has the following procedure to follow:

(1) Route discovery: in this case, routing cache mechanism not applicable rather source node uses the routing tables. If the source node not gets the route in the routing table towards the destination, then it can start broadcasting the RREQ packets all over the MANET network. Route Request packets usage the search engine technique. Node starts creating the reverse routing entry in routing table such that route path reach to the destination, once that node receive the route request packet. After that, the intermediate node or the destination node acknowledge route request RREQ packet by route reply RREP unicast packet and on the receipt of route reply packet, similar to the route request packet, reverse routing entry towards the source of route reply packet is also created [11] [12]. At the same time one more list is created which is called as precursor list is created which is associated with the all the routing entries.

(2) Route maintenance: All the nodes which are along with active route start broadcasting the HELLO messages periodically to all its neighbors in MANET. During this period, if any node doesn't get any kind of packet of HELLO message, then it is considered as link broken between that node and its neighbor node. Here also the REER packet is used to indicate the source about the link breakage or link failure. Sometimes local route mechanism is also used to repair the link between the source and destination mobile nodes, or else the route error packet for the same [11] [12].

Finally in this section, following table gives the comparison n between the source node and destination node characteristics such as source route, destination paths, detection of neighbors etc.

3.2.3 Comparison of Reactive Routing Protocols

Following table 2 is showing the comparative study for above discussed three reactive routing protocols:

	DSR	AODV
Source route	Yes	No
Neighbor detection	No	HELLO messages (along active routes)
Route storage	Route cache	Routing table
Loop freedom maintenance	Source route	Sequence number
Multiple paths	Yes	No
Multicast capability	No	Yes
Route maintenance	Send RERR, packet salvage / Choose another route, route rediscovery	Send RERR, local repair / Route rediscovery

Table 2: Comparative Study of Reactive Routing Protocols

3.3 Hybrid Unicast Routing Protocols

In above points we have discussed the two types of routing protocols in the MANET with advantages and disadvantages of using them. To combine the advantages of proactive routing algorithms and reactive routing protocols, one more category came in place which is called Hybrid Unicast Routing Protocols which is combining the advantages of both. The most famous and hybrid protocol is Zone Routing Protocol means ZRP which is described in the following section.

3.3.1 ZRP: Zone Routing Protocol

ZRP (Zone Routing Protocol) is nothing but the one kind of framework for the hybrid routing protocols and which consists of different modules such as:

- (1) Intrazone routing protocol- This protocol is adopted from the proactive routing protocols which is used to maintain only the local topology. This protocol works in the within the specified zone only.
- (2) Interzone routing protocol: On the other hand, this is the protocol which is adopted from the reactive protocol which is used when the route between the different zones is needed for the communication in between the source and destination.
- (3) Bordercast resolution protocol: This is also one more module of the ZRP which provides the most efficient broadcast technique. This protocol minimizes the redundant forwarding quantity in the case of route discovery.

Advantages of ZRP

- (1) As the intrazone routing protocol is adopted from the proactive protocol, routes which are directed towards the destination within the zone are available before their demand within the zone. This is resulted into the reduced route discovery and delay reduced.
- (2) The change in link status which is at one end of the MANET network is not affects the network at other end because of the fact topology information periodic broadcasting within the network zone [10].
- (3) One more advantage of ZRP is that the routes between the different zones is created depending on the current requirement which ultimately saves the overhead that is required for the periodic broadcasting of the topology information throughout the MANET network.
- (4) As the intrazone routing protocol is adopted from the proactive routing protocol, route maintenance of the interzone routing protocol which is based on the reactive routing protocol. By using the local topology information,

the link which is broken is bypassed and thus within the zone only route optimization can be obtained.

(5) Using the local topology information in the intrazone routing protocol, efficient forwarding of the broadcast packets. This resulted into the advantage is that it can help to transmits the packet from the network covered area to the network uncovered area.

In the zone routing protocol different routing zones in the network has different radius, as the radius is the configurable parameter of zone routing protocol. Depending on the radius of the zones, the performance of the ZRP depends as properly configured radius of the zone will resulted into the better performances [10].

3.4 Comparison of Unicast Routing Protocols

For the comparative analysis of all three types of unicast routing protocols we have considered AODV, DSR, FSR and ZRP. In table 3 we are presenting the comparative analysis for these protocols.

IV. SUMMARY OF ROUTING PROTOCOLS

Below we are discussing the advantages and disadvantages of the protocols which we studied previously such as FSR, AODV, DSR and ZRP protocols

1) FSR

Advantages of FSR

- The main advantage of this routing protocol is that it can significantly reduce the consumption of the bandwidth because here the periodic link state packets are needed only in between the neighboring nodes.
- Due to the different types of frequencies of updates in between the different scopes nodes, overhead of the routing is also reduced.
- Size of the messages gets reduced by the FSR by removing the topology information from the message.

Disadvantage of FSR

Very poor performance in the MANET networks with small sizes.

	AODV	DSR	FSR	ZRP
Network organization	Flat	Flat	Hierarchical	Hierarchical
Neighbor Detection	HELLO Messages	No	Periodic Link state updates	Periodic updates and messages as well.
Scope	LIMITED MANETS	Limited MANETS	Large Scale MANETS	Medium
Communication overhead	Low	Low	High	Medium

Table 3: comparison between the AODV, DSR, FSR and ZRP protocols

2) DSR (Reactive Routing Protocol)

Advantages and Disadvantages of DSR

- As this protocol comes into the category of the reactive routing protocol, it reduces the need flooding the MANET network with the periodic table update messages as compared to the proactive routing protocols like DSDV.



- In this protocol as the rule of reactive routing protocol, routes are created only when they are required means totally on demand; hence extra overhead which required in the proactive routing protocols is eliminated.
- The mechanism of route cache is significantly reduces the network control overhead because the intermediate nodes make proper use of route cache.
- The major disadvantage of using this DSR protocol is that broken link is does not locally repaired by the route maintenance mechanism of the DSR protocol.
- While reconstructing the route from source to the destination node, the information related to the stale route cache is gets in inconsistencies.
- Delay in the connection establishment in DSR is more as compared to the proactive protocols.
- Even though the protocol performs well in static and low-mobility environments, the performance degrades rapidly with increasing mobility. Also, considerable routing overhead is involved due to the source-routing mechanism employed in DSR. This routing overhead is directly proportional to the path length.

3) AODV (Reactive Routing Protocol)

Advantages and Disadvantages of AODV

- Route in the protocol are created totally on demand basis.
- The mechanism of the destination sequence number is used to get fastest and recent route towards the destination.
- Network setup doesn't take too much time as compare to proactive routing protocols.
- This is most average efficient protocol in the MANET network.
- This protocol is caused by the steal route problem most of time which is the major disadvantage of this routing protocol. This happens because of the inconsistent state routes which is because of intermediate node uses the source sequence node which is old one which makes the steal route entries.
- Route Reply packets increase the load heavily because in response to the one RREQ packet so many Route Reply Packets RREP generated.
- Bandwidth consumption increases sometimes.

4) ZRP (Hybrid Routing Protocol)

Advantages and Disadvantages of ZRP

The main advantage of this protocol is that it adopts the functionality of both proactive and reactive protocols.

- This protocol provides the scalability as compared to reactive routing protocols.
- Congestion is reduced at most due to fact that the hierarchies are not used.

In the previous section as well we discussed the advantages of the ZRP protocol which is actually the combination of the advantages of the two kinds of routing protocols such proactive and reactive routing protocols.

V. CONCLUSION AND FUTURE WORK

In this paper we have discussed over the MANET routing protocols, investigate their characteristics and presented comparative study over the same. We basically focused on three major categories of MANET routing protocols such as proactive, reactive and hybrid routing protocols. We have discussed the different protocols under these categories with their advantages and disadvantages. Related to routing, MANET is still facing many research challenges. Every

routing protocol in MANET having unique features and advantages, and hence depending on the network conditions we have to use suitable MANET routing protocol. Security is also one of the main challenges of MANET routing protocol. There are many secured routing protocols presented still they are suffered from limitations. For the further work, we will suggest to present routing performance of all categories of routing protocol under the different network conditions and then based on it choose which protocol is best suit for MANET routing in an average under all networking conditions. Further we are suggesting improving the same protocol by using unique features.

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