Multipath Routing Protocols in Mobile Ad-hoc Networks - A Survey

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Abstract **- Mobile ad hoc networks (MANETs) consist of a collection of wireless mobile nodes which dynamically change topology and exchange data among themselves. MANET nodes are typically distinguished by their limited power, processing, and memory resources as well as high degree of mobility. Due to these characteristics, path connecting source nodes with destination may be very unstable. To solve the problem of stability, multiple routes are created between source and destination nodes. When a primary route fails to deliver the packets, the secondary routes can be used. The multipath routing provides efficient recovery from route failures along with better Load Balancing and fault tolerance. This paper explains basics of MANETs, design issues and challenges and various different types of multipath routing protocols in MANETs.**

Keywords **- Mobile ad hoc network; multipath routing protocols, AODV,DSR, AODVM, AOMDV,AODV-BR, SMORT, MDSR and SMR**

I. Introduction

Wireless networks provides flexible connection between users in different places by extending the network without wired connections. Networking is the process of exchanging the data and sharing the resources between the source and destination. Wireless networks can be classified into two types: range/coverage based and topology based. Topology based can further classified as: Infrastructure and Ad-Hoc. In Infrastructure based wireless networks there is an Access Point (AP) to centrally coordinate all the nodes and organizes Basic Set Services (BSS) for communicate between nodes (e.g. cellular networks).Whereas, wireless Ad-hoc networks are decentralized as they don't have any pre-specified infrastructure (e.g. MANETs, VANETs…), all the nodes in the network acts as routers. Mobile Ad-hoc NeTworks (MANETs) is a type of wireless ad-hoc network where nodes dynamically changing topology and nodes having limited power, processing and memory resources. Due to these limitation of nodes and dynamically changing topology of network routing protocols plays very important role in MANET. This leads to development of multipath routing in wireless network, in order to provide communication to nodes in different environmental conditions. The challenges and issues in MANET are as follows:

- Limited Power Support.
- Limited Bandwidth.
- Network Lifetime.
- End-to-End Delay.
- Quality of Services (QoS).
- Network Security.

II. Classification of Routing Protocols

Based on routing Ad-Hoc routing protocols can be classified as (figure 1): unipath and multipath. Unipath protocols are AODV and DSR, while multipath protocols are extensions of these protocols to provide better routing in the network. Also it can be classified into three categories: Proactive, Reactive and hybrid. AODV and DSR are two reactive routing protocol that have routing table to store the routing information. AODV uses the flooding method to discover route. Mainly both the protocols have two parameters: Route Discovery and Route Maintenance. These protocols uses single path to deliver the packet in the network that leads to vulnerability of network.

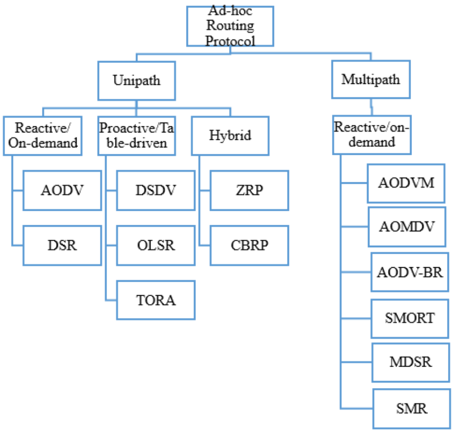

Figure 1- classification of Ad-hoc routing protocols.

III. RELATED WORK

In this section, we have given a brief review of routing protocols which are developed as a multipath extension of the AODV and DSR unipath routing. Multipath routing protocols have capability to discover multiple path from source to destination (that are node disjoint or link-disjoint paths), reduce frequency of route discovery, split the network traffic into the alternate nodes, increase the QoS of the network, increases throughput and is applicable to large networks. The design issues, guidelines for reliable and secure routing and various routing issues and challenges are discussed in [1] [2]. Also the working of basic unipath routing protocols AODV and DSR along with their simulation results is being discussed in [3].

C Perkins et.al, in [4] have proposed the Ad-hoc on demand Distance Vector routing protocol and have implemented some performance evaluation scheme and simulations. From their paper we can concluded that AODV is the suitable protocol for network with limited routing establishment latency.

L.Wang et,al, 2000 in [5] have presented MSR protocol the multipath extension of DSR. They have implemented MSR (multipath Source routing) and a probing based load balancing mechanism that helps improve throughput, end-to-end delay and drop rate, one drawback of MSR is that it increases possessing overloads.

G.Parissidis et.al. 2006[7] have provided a quantitative comparison between the multipath routing protocols AODVM, AOMDV and SMR. From their work we have concluded that AOMDV protocol is most robust and performs well in all the scenarios. AODVM performs well with low mobility and SMR performs best in networks with low node density.

T.Sharma and S.Singh in their paper [8] reviews some multipath extensions of AODV routing protocol like AODVM, AOMDV, SMORT and AODV-BR , these protocols are extended from AODV by modifying the route discovery mechanism to support multipath routing and enhance the efficiency of the ad-hoc networks.

M.Gerla et.al, in their paper [9] proposed a scheme to improve the existing on demand routing protocols by creating a mesh and providing multiple alternate routes. We can conclude that their technique provides robustness to mobility and enhances protocol performance in heavy traffic networks.

V.Maheshwari et.al, 2012 in their paper [10] have proposed the extension of AODV routing protocol as delay-aware multi-path routing protocol AOMDV to improve the QoS in MANETs. Finally, reduction in the frequent route discovery increases QoS and the error rate metrics in order to improves the reliability of data communication and prolong the network lifetime.

M.Marina et.al., 2001 their paper [11] have proposed on-demand Multipath distance vector routing protocol (AOMDV) and from their simulations we can conclude that AOMDV discovers loop-free and node-disjoint paths. Also, it reduces routing load and delay and frequency of route discovery.

L. Reddeppa Reddy et.al., 2007 in [12] proposed on-demand routing protocol (SMORT) to reduce the routing overhead generated due to route recovery of broken route using alternate path (Fail-safe multiple paths). Hence, SMORT provides better fault-tolerance and increases the throughput.

Lee and Gerla (2000) in [14] have shown the Split multipath routing protocol based on DSR. The main objective of SMR is to reduce the frequency of route discovery processes and thereby reduce the control over- head in the network. Since an intermediate node is not dropping a duplicate request message, the frequency of the route discovery process needs to be reduced to remove the overhead.

Nasipuri and Das 1999 in [15] have shown multipath protocol that can reduce the frequency of query flooding. MDSR protocol reduces the flooding problem of DSR protocol. This protocol is suitable only for network with less nodes and low traffic.

IV. MULTIPATH ROUTING PROTOCOL

Multipath routing [6] is the routing technique of using multiple alternative paths through a network, which can yield a variety of benefits such as fault tolerance, increased bandwidth, or improved security. The multiple paths computed might be overlapped, edge-disjointed or node-disjointed with each other. Multipath routing protocols classified in figure-2 are the extension of the unipath routing protocols. The multipath routing protocols are developed to find more than one route from Source to Destination so that the drawbacks of unipath routing protocols can be overcome and the routing efficiency, packet delivery ratio, fault tolerance and other factors can be enhanced to increase the network utility.

AOMDV (Ad-hoc on demand Multipath Distance Vector)

AOMDV extends AODV protocol to discover multiple paths between the source and destination. Mahesh K. Marina and Samir R. Das [11] developed AOMDV with route maintenance phase similar to that of AODV but the route discovery process has been modified to enable multiple paths. In AODV, the requirement of addressing issues, splitting traffic along each path and packet reordering at the destination don't allow to choose more than one path for communication. Also in AOMDV the usage of periodic HELLO message helps detect the stale path.

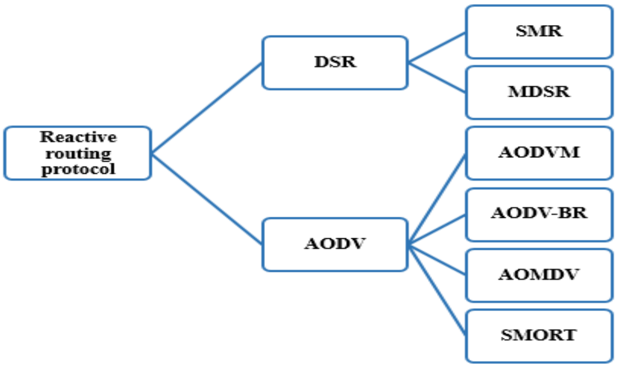

Figure 2- taxonomy of multipath routing protocols in MANET.

The two main difference between AODV and AODVM is (i) the hop count is replaced with the advertised hop count in AOMDV. (ii) The next hop is replaced by the route list. Route list contain a list of the next-hops along with the corresponding hop counts. All the next hops have the same sequence number as in figure-3. For each destination, a node maintains the advertised hop count, which is defined as the maximum hop count for all the paths. Each duplicate route advertisement received by a node defines an alternate path to the destination.

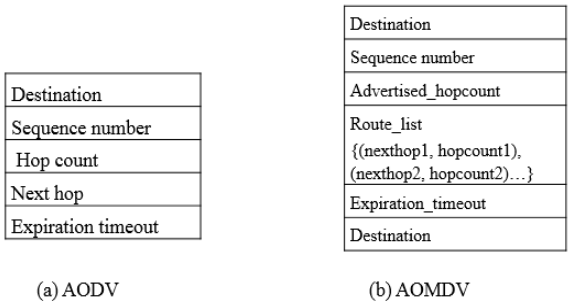

Figure 3- Structure of routing table entries of (a) AODV and (b) AOMDV.

To ensure loop freedom, a node only accepts an alternate path to the destination if it has a lower hop count than the advertised hop count for that destination. When a route advertisement is received for a destination with a greater sequence number, the next-hop list and advertised hop count are reinitialized. AOMDV can be used to find node-disjoint or link-disjoint routes. To find node-disjoint routes, each node does not immediately reject duplicate RREQs. Each RREQ arriving via a different neighbor of the source defines a node-disjoint path. As nodes cannot broadcast duplicate RREQs, so any two RREQs arriving at an intermediate node via a different neighbor of the source could not have traversed the same node.

To get multiple link-disjoint routes, the destination replies to duplicate RREQs regardless of their first hop. To ensure link-disjoint-ness in the first hop of the RREP, the destination only replies to RREQs arriving via unique neighbors. After the first hop, the RREPs follow the reverse paths, which are node-disjoint and thus link-disjoint. The trajectories of each RREP may intersect at an intermediate node, but each takes a different reverse path to the source to ensure link-disjoint-ness.

AODV-BR (Backup Routing AODV)

AODV-BR [9] protocol is based on AODV, it uses route discovery process of AODV to maintain multiple paths. After the broadcast of RREQ, the multiple paths are established during RREP phase. Also a mesh is structured from the overheard packets and the neighboring nodes are recorded as the next hops to destination in corresponding node's alternate route table as in figure- 4.

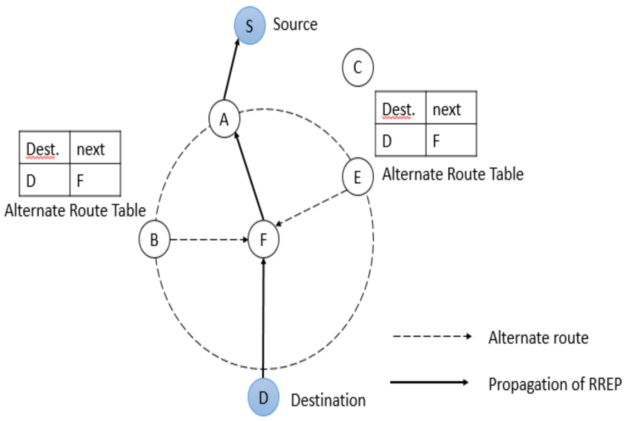

Figure 4- procedure of alternate path construction in AODV-BR

Alternate paths are used only when the primary link fails and to prevent packets tracing a loop. The mesh nodes forward a data packet only if the packet is not from their next hop to destination. Since one path is used at a given time, AODV-BR is not a genuine multipath idea. The destination sends a RREP via the selected route when it receives the first RREQ or later RREQs that traversed a better route (with fewer hops). When a node that is not part of the selected route overhears a RREP packet, it records the sending neighbor as the next hop to the destination in its alternate route table. When an RREP finally reaches the source of the route, a primary route between that source and destination has been established. All the nodes that have an alternate route to the destination in their alternate route table form a fish bone structure as shown in figure- 5.

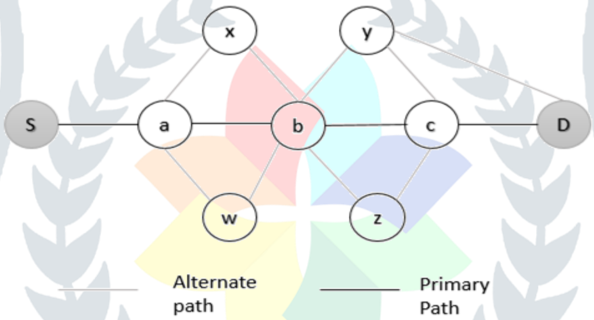

Figure 5: Multiple routes in network making fish bone structure.

When the link between nodes b and c fails, node y of the mesh forwards the packet from node b directly to the destination node D without sending it through node c. An alternate path with the same path length as the primary route is used as backup. Data packets are not dropped when the route break occurs. The node that detects the link break also sends a RERR to the source node to initiate a route discovery. AODV-BR have higher packet delivery ratio because it uses a longer route to deliver the packet that are dropped but the routing overhead remains the same as that in AODV.

This protocol has two disadvantages. Firstly, after a node detects a link break, the future data packets it receive are broadcasts for which it has no link layer acknowledgement. Hence, the recipient that has a backup path has to send an explicit network layer acknowledgement to inform the safe reception of data packets, this increases the control overhead. Secondly, AODV-BR works on if the nodes that moved away are within the transmission range of its immediate upstream node.

AODVM (AODV-Multipath)

AODVM [6] is the first modified version of AODV protocol. This protocol is designed to discover multiple node disjoint paths between the source and the destination. The RREQ and RREP process are modified for this protocol while the route recovery and maintenance are the same as that of AODV. In AODVM, the intermediate nodes are not allowed to send the route reply directly to the source. It is more reliable and achieves better overall performance compared to AODV.

In this protocol, the duplicate RREQ packet are not systematically discarded as in AODV. Instead of neglecting all the received duplicate RREQ packets, the intermediate nodes store the information of the RREQ packet in the RREQ Table as a new entry (as in figure- 6) and rebroadcasts the RREQ packet.

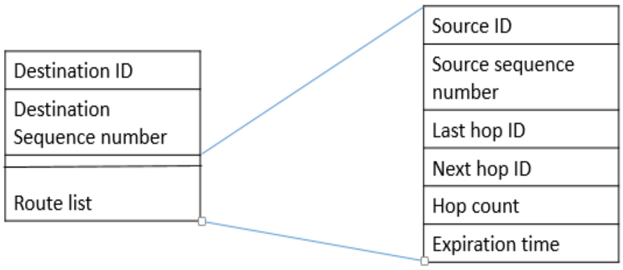

Figure 6– routing table in AODVM.

The destination node then generates RREP packet, containing a new field called "last-hop-ID", for every required RREQ-packet and sends it back to the related node. To ensure the nodes do not participate in more than one route, whenever a node overhears one of its neighbor broadcasting an RREP packet, it deletes that neighbor from its RREQ table as in figure 7. Hence, only the destination node replies to a request since we want to guarantee node-disjoint routes.

Figure 7- RREQ table in AODVM

As the nodes are not allowed to forward more than one RREP packet the routing loops are prevented. For the confirmation of the route, the source sends back a Route Confirmation (RRCM) message to the destination upon receiving an RREP.

SMORT (Scalable multipath on-demand routing)

SMORT [12] is the extension of AODV to overcome routing overheads generated by a unipath on-demand routing protocol. The overheads generated by the additional routing discoveries and route error transmission, during the route breakage recovery are reduced using the alternate paths to destination. This help the protocol to scale to large networks. The multiple paths from a source to the destination are basically of two types, Node-disjoint and link-disjoint.

In figure-8, Nodes labeled S and D are the source and destination nodes, respectively. Node-disjoint paths are used for traffic load-balancing (by dispersing the data over multiple paths) and provide fault-tolerance towards route breaks. One of the advantage of node-disjoint multiple path is that they fail independent of each other. The breakage of any link on one path can be corrected by resuming the data session through one of the other paths.

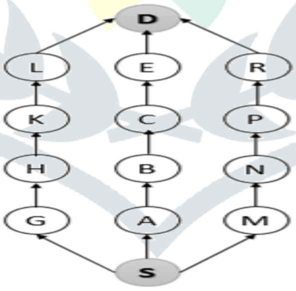

Figure 8: node-disjoint multipath only at source.

Link-disjoint paths do not have common links but may have nodes in common. A series of node-disjoint paths form a set of link-disjoint paths. Below shown is a link-disjoint multiple path between the S and D, formed with two segments as in figure-9. Although, link-disjoint paths are more in number than the node-disjoint paths, the movement of the node at the junction cause the failure of all the paths going to that node.

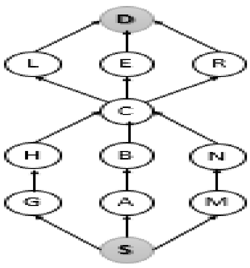

Figure 9: link-disjoint multiple path.

SMORT uses the fail-safe multiple paths. A path between S and D is said to be fail-safe to the primary path, if it bypasses at least one intermediate node on the primary path. This means, the fail-safe path can be used to send the data packets in case the bypassed node(s) on the primary path move away.

In the below shown figure- 10, the path S-A-H-C-E-D and S-A-B-C-L-D are fail-safe paths to the primary path S-A-B-C-E-D. Here, the data session remains unaltered even if the node B and E moves away at the same time, as the packets can redirected through the fail-safe paths. The on-demand routing schemes that computes fail-safe multiple paths reduces the route recovery time and path maintenance overhead more effectively than the node-disjoint and the link-disjoint multiple path routing schemes. As a result, SMORT performs well in highly dynamic network.

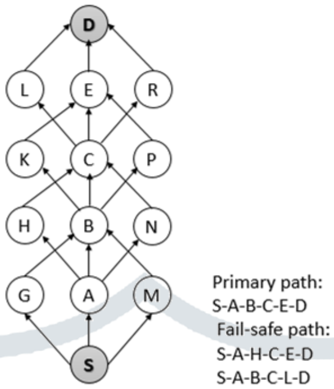

Figure 10: fail-safe multiple paths.

MDSR (Multipath Dynamic Source Routing)

Multipath Dynamic Source Routing [15] protocol is a multipath extension of DSR routing protocol. MDSR overcomes the problem of flooding. This query flooding techniques generates a large amount of overhead packets as they occupy a substantial portion of the bandwidth of the network. In DSR protocol, the destination node replies to every RREQ packet, whereas in MDSR protocol, the destination node replies to only a selected set of RREQ. That means, the destination node after getting all the RREQ's replies back only to those RREQ that are link-disjointed from the primary source route (i.e., the shortest path route). A source keeps all the routes in the cache. If the shortest route is broken it uses an alternate route which is the shortest among the remaining routes in the cache, if that route is also broken then nodes looks for other alternate route and this process goes on till all the routes in the cache are used.

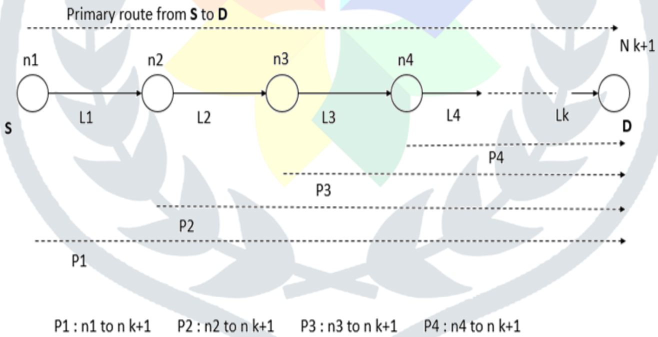

Figure 11: Multipath Dynamic source Routing (MDSR).

In the figure-11 the primary route is depicted by the link sequence L1-L2- - - Lk. Each node in the primary route ni has an alternative path Pi to the destination. The source S uses the primary route for transmitting data packets to a destination node D until it breaks. Let us assume that the link Li is broken, in this scenario, the node ni responds to the situation by replacing the unused portion of the route Li - Lk in the data packet header by an alternative route Pi breaks, it will cause an error packet transmitted backward up to node ni-1, which will quench the error packet and switch data packets to its own alternative route Pi-1 by modifying the source route in the packet header as before.

SMR (Split Multipath Routing)

Split Multipath Routing [14] protocol follows the basic route discovery mechanism of DSR protocol, but an intermediate node is not allowed to reply from its route cache if it has some routes available to that destination. The main objective of SMR is to reduce the frequency of route discovery process and thereby reduce the control over-head in the network. This protocol uses a per packet allocation scheme to distribute a load into multiple paths. When a destination node receives a RREQ from different paths, it chooses multiple disjoint routes and send replies back to the source.

In order to introduce a different route request forwarding scheme, instead of dropping a duplicate RREQ, an intermediate node forwards this RREQ in a different incoming link other than the link from which the first request was received and whose hop count is not larger than that of the first RREQ. When a destination node receives a RREQ, it selects two paths that are maximally disjointed and have shortest path. It is chosen to minimize the route discovery time because it is the earliest discovered route. After processing the first request, for the second path selection, a destination waits for a certain duration of time to receive more RREQ's to know all possible routes. It then selects a route from source of the alternative paths, which is maximally disjointed with the shortest path (i.e. a path that has the least number of common nodes compared to the shortest path, if the shortest hop path is selected between them). In DSR protocol, an intermediate node does not need to maintain a route cache. For this reason, a node has a smaller cache.

Whereas the SMR uses the less frequent route discovery mechanism compared to DSR protocol.

V. COMPARISON OF MULTIPATH ROUTING PROTOCOL

The multipath routing protocols described above reduces various drawbacks of the unipath routing protocols. These protocols help improving the routing efficiency based on various network environment. For the network with heavy load and more number of nodes routing protocols like AODVM, SMORT, MDSR or SMR can be used. Whereas, AOMDV and AODV-BR can be used for networks with less traffic.

Table 1- Comparison of multipath routing protocols in manet.

Protocol	Route Selection & Re-Confoguration	Stored & Update Information	Routing Mechanism	Advantages	Disadvantages
Aomdv	*Select:* Newest And First Available Path. *Re-Configure:* Delete Route, Notify Source	*Store:* Next Hop, Last Hop, Hop Count For Desired Destination. *Update:* Route Error Packet	Advertise Hop-Count Mechanism	Low Intermodal Coordination Overhead	Do Not Scale Well In Moderate To Sparse Networks
Aodv-Br	*Select:* Newest And Shortest Path. *Re-Configure:* Local Repair, Notify Source And Neighbor.	*Store:* Next Hop, Number Of Hops, Destination *Update:* Route Error Packet	Overhearin g Of Rreps	Better Throughput Performance Than Aodv	Not Efficient In Heavily Loaded Dynamic Networks.
Aodvm	*Select:* Strictly Node-Disjoint And Selected By Destination *Re-Configure:* Delete Route, Notify Source	*Store:* Source Id, Next Hop, Last Hop, Hop Count *Update:* Error Message And Route Discovery	Last-Hop Id And Route Confirmatio n.	Efficient Load Balancing	Consumes Too Much Memory With Increase In Routing Overhead
Smort	*Select:* Newest Path *Re-Configure:* Replace Primary Route With Secondary Route.	*Store:* Next Hop, Number Of Hops, Life Time, Full Path. *Update:* Route Error Packet.	Fail-Safe Multipath.	Reduced Overhead, Increased Scalability Even In Large Networks	Transmission Of Rerr Over Multiple Paths Increases Overhead
Mdsr	*Select:* Destination Replies Only To Selected Set Of Request Message.	Destination Node Maintains The Record For The Shortest Path To Select The Route.	Same As Dsr.	Reduces The Query Flooding Problem Of Dsr.	Alternative Path Is Longer Hence, Delay Per Packet Increases.
Smr	*Select:* Shortest Path Is Selected To Minimize The Route Discovery Time.	The Intermediate Node Doesn't Maintain The Route Cache	Same As Dsr, Intermediat e Node Doesn't Reply Form Its Cache.	Reduces The Frequency Of Route Discovery Process, Reduce The Control Overhead In The Network.	Redundant Overhead Packets.

VI. CONCLUSION

The Mobile Ad-hoc NeTworks (MANETs) have been a subject of new researches in recent years. Many of the researches are motivated by the efficient routing protocol for ad-hoc networks. The need of the Reliable routing protocol in order to increase the efficiency of the network by balancing the load and fault-tolerance lead to discovery of Multipath routing protocols by modifying the defined unipath routing protocol.

This article represents a brief description of several multipath routing protocols that are the extension of unipath on-demand routing protocol (AODV). It also presents the detailed working of AODV, DSR, AOMDV, AODV-BR, AODVM, SMORT protocols. Also the protocols are summarized based on their routing techniques, advantages, disadvantages, features and characteristics.

In future work, a good reliable multipath routing protocol can be developed to overcome the limitations of these protocols, enhance the features of then and provide higher through put and better performance in highly mobile Ad-hoc networks. It can be developed by combining both the protocols or develop a new protocol.

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