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Survey on Multipath Routing Protocols in Wireless Ad-Hoc Networks

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Abstract— A Wireless ad hoc network consists of wireless mobile nodes. Such a network does not have a fixed infrastructure but nodes perform the networking function by acting not only as a host but also as a router forwarding packets to other nodes that may not be within direct wireless transmission range of each other. Since the inception of wireless technologies, the concept of Mobile Ad-hoc Networks is becoming increasingly popular. The disaster relief management, battlefield communication, electronic classrooms, conferences are main applications of mobile ad-hoc networks. In MANET, all nodes move freely without enforcing any network topology. Moreover, a node is free to leave or join the MANET without any notification. This behavior causes the breakup and automation of topology. Ad Hoc routing has been widely researched over the past years but widely used implementations are yet to come. Several protocols have been developed under the authority of Mobile Ad hoc Networking (MANET) working group. MANET is charter of Internet Engineering Task Force (IETF). Lots of research has also been done about the performance of ad hoc networks under varying scenarios. Different kind of metrics or characteristics may be used to analyze the performance of an ad hoc network.

Index Terms— MANET, Routing protocol, Ad-Hoc, Throughput, End-to-end delay, Normalized load, Routing overhead, Multipath.

I Introduction

Wireless networking is an emerging technology that allows users to access information and services electronically, regardless of their geographic position. Wireless networks can be classified in two types.

1. Infrastructure Networks

Infrastructure network consists of a network with fixed and wired gateways. A mobile host communicates with the help of base stations and within its communication radius. The mobile unit can move geographically while it is communicating. When it goes out of range of one base station, it connects with new base station and starts communicating through it. This is called handoff. In this approach the base stations are fixed.

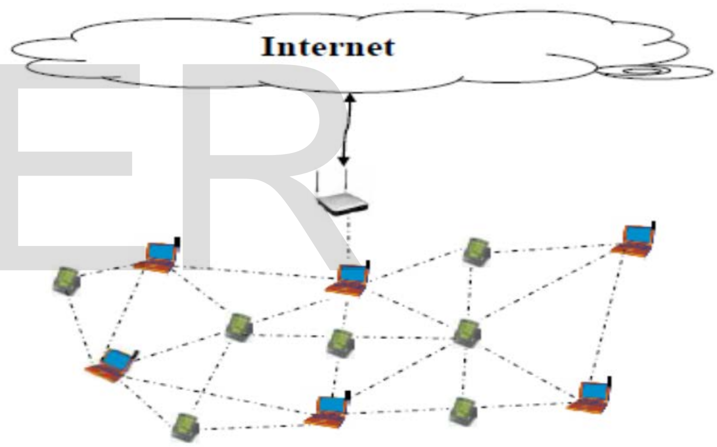
2. Infrastructure Less (Ad hoc) Networks

An ad hoc network is a collection of wireless mobile nodes dynamically forming a temporary network without the use of any existing network infrastructure or centralized administration. In ad hoc networks, all nodes are mobile and can be connected dynamically in an arbitrary manner. As the range of each host's wireless transmission is limited, so to communicate with hosts outside its transmission range, a host needs to enlist the aid of its nearby hosts in forwarding packets to the destination. So all nodes of these networks behave as routers and take part in discovery and maintenance of routes to other nodes in the network.

This ad-hoc routing protocols can be divided into two categories:

Table-Driven Routing Protocols (Proactive): In table driven routing protocols, consistent and up-to-date routing information to all nodes is maintained at each node.

On-Demand Routing Protocols (Reactive): In On-Demand routing protocols, the routes are created as and when required. When a source wants to send to a destination, it invokes the route discovery mechanisms to find the path to the



Based upon Routing Information update mechanism, ad-hoc routing protocols can be classified into 3 types:

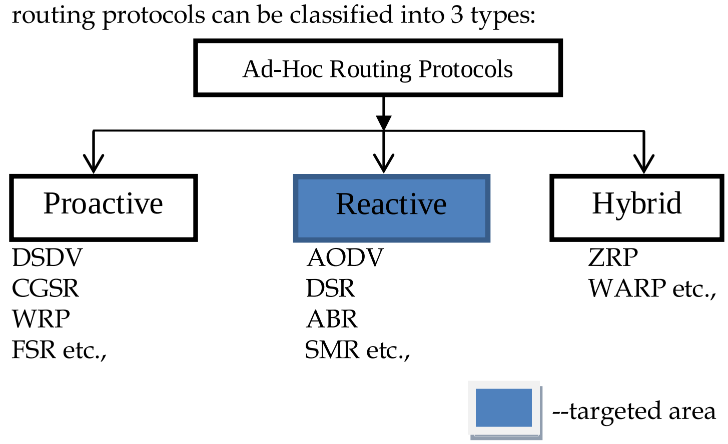


Fig: Classification of Routing Protocols

Proactive Routing:

Each node maintains a routing table, containing

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routes to all other nodes in the network. Thus, routes are computed and stored, even when they are not needed, incurring a considerable overhead and bandwidth consumption due to the number of messages that have to be exchange to keep routing information up-to-date. Proactive protocols may be impractical for large and dynamic networks.

Reactive Routing:

Also called on-demand, reactive protocols only compute routes when they are needed. The process of finding a suitable route requires the transmission of route requests and the wait for replies with a path to the destination. Due to the delays incurred in this process, this approach is not suitable for operations that require immediate route availability.

Hybrid routing:

Neither proactive nor reactive protocols provide an optimal solution for the hybrid WMNs. we aim at addressing. Ad hoc regions, the ones formed by clients, have some mobility and thus reactive protocols are most suitable because route updates are frequent. On the other side the backbone has reduced mobility, thus proactive routing allows maintaining routes with low overhead.

II.Related work

The performance of Split Multipath Routing protocols as in [2] can be improved by using route update mechanism. This proposal is useful in route recovery process. In MANET for sending the data packets through alternate path takes more time in comparison with stale route that was broken. So, here we repair the broken route through route update mechanism process and reduce the delay through new updated path. The Route Update Request (RUREQ) and Route Update Reply (RUREP) for route update mechanism at the broken link node. So we reduce the delay metric and recover the broken link.

Mobile ad hoc networks are typically characterized by high mobility and frequent link failures that result in low throughput and high end-to-end delay. To reduce the number of route discoveries due to such broken paths, multipath routing can be utilized so that alternate paths are available. Current approaches to multipath routing make use of pre-computed routes determined during route discovery. These solutions, however, suffer during high mobility because the alternate paths are not actively maintained. Hence, precisely when needed, the routes are often broken. To overcome this problem, we present an adaptive multipath solution. In this approach[5], multiple paths are formed during the route discovery process. All the paths are maintained by means of periodic update packets unicast along each path. These update packets measure the signal strength of each hop along the alternate paths. At any point of time, only the path with the strongest signal strength is used for data transmission.

Mobile ad-hoc networks (MANETs) is a collection of mobile nodes that can communicate with each other using multihop wireless links without utilizing any fixed base station infrastructure and centralized management. MANETs are typically characterized by dynamic topology, high node mobility, low channel bandwidth, limited battery power and frequent link failures, so routing protocol is crucially important. It is necessary for MANETs to have an efficient routing and quality of service mechanism to support diverse applications. Multipath routing can be utilized so that alternate paths are available to reduce link failure. A node disjoint multipath routing protocol based on AODV is proposed in the paper [6]. The main goal is to discover multiple node-disjoint paths with a low routing overhead during a route discovery.

An on-demand Node-Disjoint Multipath Routing protocol [7] is proposed to overcome the shortcomings of on-demand unipath routing protocols like AODV and DSR. The protocol has two novel aspects compared to the other on demand multipath protocols: it reduces routing overhead dramatically and achieves multiple node-disjoint routing paths.
Ad hoc On-Demand Distance Vector (AODV) and Dynamic Source Routing (DSR) are the two most widely studied on-demand ad hoc routing protocols. Previous work [8] has shown limitations of the two protocols. The main reason is that both of them build and rely on a unipath route for each data session. Whenever there is a link break on the active route, each of the two routing protocols has to invoke a route discovery process. Each route discovery flood is associated with significant latency and routing overhead.

Multi-path routing [9] represents a promising routing method for wireless mobile ad hoc networks. Multi-path routing achieves load balancing and is more resilient to route failures. Recently, numerous multi-path routing protocols have been proposed for wireless mobile ad hoc networks. Performance evaluations of these protocols showed that they achieve lower routing overhead, lower end-to-end delay and alleviate congestion in comparison with single path routing protocols. However, a quantitative comparison of multi-path routing protocols has not yet been conducted. Furthermore, even when multiple disjoint paths are longer than the shortest path, the overall average end-to-end delay is smaller, particularly in high density scenarios. We conclude that multi-path routing in general, distributes the traffic over uncongested links and, as a consequence, the data packets experience smaller buffering delays.

III. Existing system

Numerous of the proposed multipath routing protocols produce disjoint paths which have the desirable property that they are more likely to fail independently. Thus they have a better utility. There are two types of disjoint paths: node disjoint paths and link disjoint paths. Node disjoint paths do not have any nodes in common, except for the source and the destination. Whereas, link disjoint paths do not have any common links, but may have common nodes.

WORKING OF SMR

Split Multipath Routing (SMR) protocol is written by Sung-Ju Lee and Mario Gerla [1]. It works on the basis of DSR, i.e. it uses the same source routing mechanism. It constructs its multiple routes on-demand. The shortest delay path is one of these routes. The other paths are maximal disjoint according to this first one. To avoid delays, traffic jams and to use the network resources efficiently, data traffic is distributed onto these multiple routes. Since SMR uses Source Routing and hence intermediate nodes doesn't reply from their cache and only source node maintains routing information. Although each node uses less memory, packet header length is more.

Route Establishment:

The RREQ is flooded in order to find routes. Intermediate nodes forward RREQ without replying; even if they have routes to the destination (this is to allow the destination to select disjoint paths). Intermediate nodes do not need to discard duplicate RREQs. Instead, they forward RREQs that are received through a different incoming link, and whose hop count is no larger than the previously received RREQs. The proposed algorithm selects two routes, but it can be easily extended to return more routes. The selection procedure is done the following way. The destination node replies to the first RREQ, which represents the shortest path. Then, it waits to receive more RREQs and selects the path that is maximally disjoint from the shortest delay path. If more than one exists, the shorter is selected. Then, a RREP for the selected path is sent.

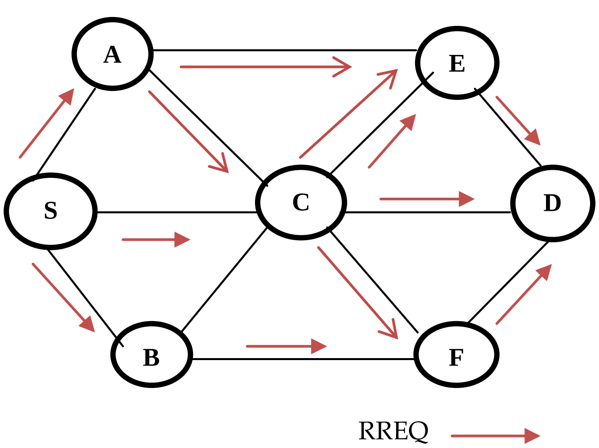

Fig: Flooding of RREQ packets by source S

The Source S will flood the RREQ packets to its neighbours in order to establish path to the Destination. Since SMR follows Source Routing, none of the intermediate nodes reply to the RREQ packets even if they know the path to the destination. Thus, seven RREQ packets (S-a-e-D, S-c-D, S-b-f-D, S-a-c-D, S-b-c-D, S-c-e-D and S-c-f-D) are generated by the source (Fig: (i)). When these seven RREQ packets arrive at the Destination D, D selects the maximally disjoint, shortest paths to the source (S-a-c-D and S-b-f-D), and sends RREP in those paths (Fig: (ii)).

Route Maintenance:

During the link break route maintenance process is used to maintain the route. In this process upstream node of broken link send a route error (RERR) message to the source node. The source node receives this message and selects the new alternate path from its routing table as shown in figure (Fig iii). If the multiple routes are broken in the network then source node remove all entry from its routing table and reinitiate the route discovery process, and this will cause a large delay.

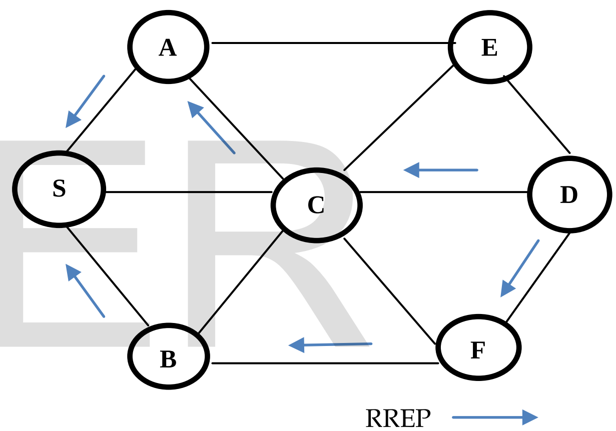

Fig (ii): Destination D sends RREQ packets to Source S

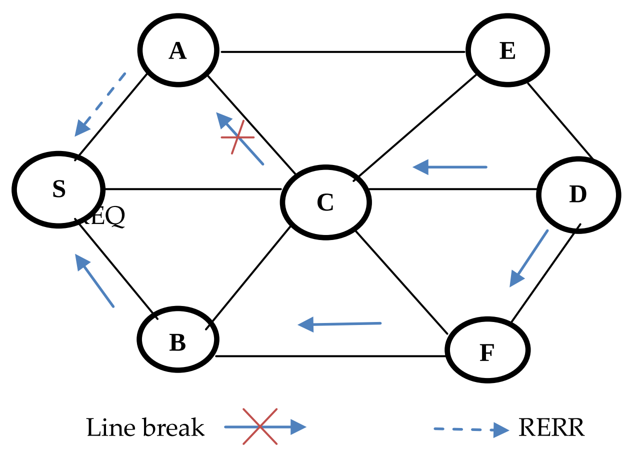

Fig (iii): Route Maintenance

Traffic distribution:

The protocol considers splitting the traffic into two available routes, using a simple per-packet allocation scheme.

WORKING OF AOMDV

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As proposed in [3], Ad Hoc On-Demand Multipath Distance Vector Routing (AOMDV) protocol discovers multiple routes during route discovery. AOMDV creates multiple loop-free link disjoint paths. However one limitation is that all the routes are not maintained simultaneously and as a result they timeout, thereby nullifying the advantage of multiple paths.

The Ad-hoc On-demand Multipath Distance Vector protocol (Marina & Das 2001) is a AODV-based protocol, proposed to reduce routing overhead. It is possible to discover multiple routes with a single route discovery procedure. The intermediate nodes maintain at most one forwarding table per flow. In addition to the routing table in AODV (Fig (iv)) there exist a RREQ table in AODVM (Fig (v)).

Destination	Source	Last Hop	Next Hop

Fig (iv): A simple AOMDV routing table

Destination	Source	Neighbour who transmitted the RREQ (received hop)	Hops to Source	Expiration Timer

Fig (v): A simple AOMDV RREQ table

Destination
Sequence Number
Advertised_Hopcount
Route List {(Nexthop1, Hopcount1), (Nexthop2, Hopcount2),…}
Expiration_Timeout

Fig (vi): Structure of routing table entry for AOMDV protocol

Route establishment:

As in AODV (Perkins & Royer 1999), route discovery procedure is triggered when a node wants to communicate with a destination to which a path is not known. The route establishment procedure is the same as in the base protocol with the following change: to form multiple routes, all duplicates of the RREQ arriving at a node are examined (but not propagated), as each one defines an alternate route.

The protocol can find node-disjoint or link-disjoint routes. To find a node-disjoint route, Intermediate nodes do not reject duplicate RREQs. To get link-disjoint routes, the destination replies to duplicate requests even if they have the same last hop. To ensure link- disjointness 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.

Source S forwards RREQ (Fig(vii)) across all its node disjoint paths to make route discovery. If a node receives a RREQ packet, it behaves in the following three ways:

- If RREQ has already been received, then it is dropped.
- If RREQ has not been received, and it is not a destination node, then the node simply floods it to other nodes.
- If RREQ is received by destination node or a node that has a path to the destination, then it sends RREP in those paths.

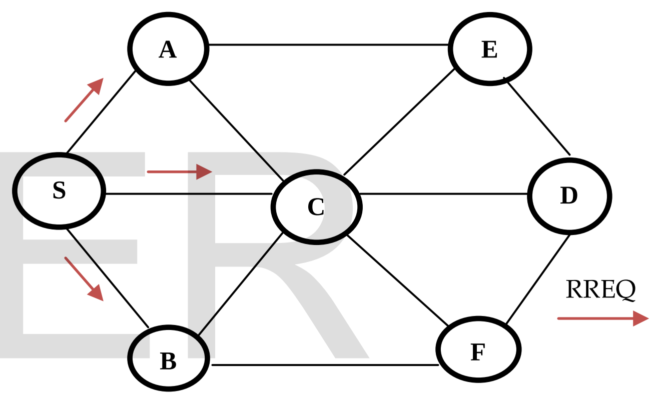

Fig (vii): Source floods RREQ to neighbors

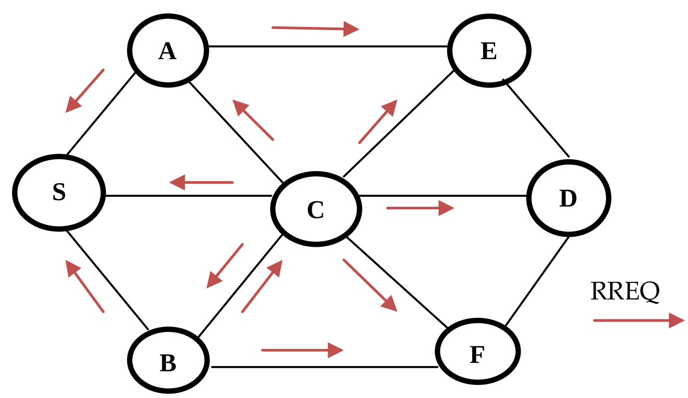

Fig viii: Intermediate nodes A, C and B doesn't have a path to destination and hence floods RREQ packets again

Route maintenance:

To preserve connectivity information, each node executing AOMDV can use link-layer feedback or periodic Hello messages to detect broken links to nodes that it considers as its

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immediate neighbors. As in AODV, in case a broken link is detected, a RERR message is sent to the active neighbors that were using that particular route.

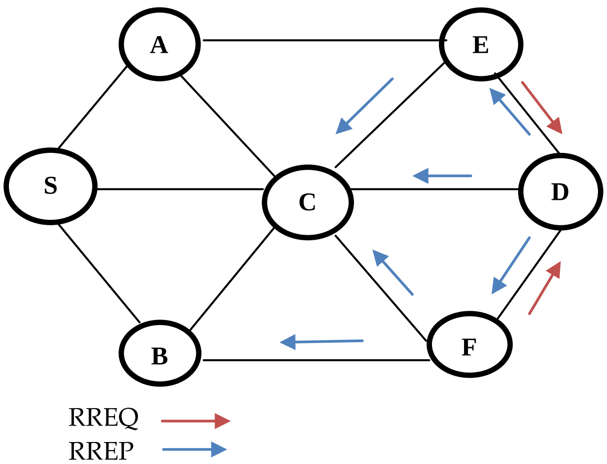

Fig (ix): Intermediate nodes E and F have paths to destination and hence reply with RRER on the path to the Source S.

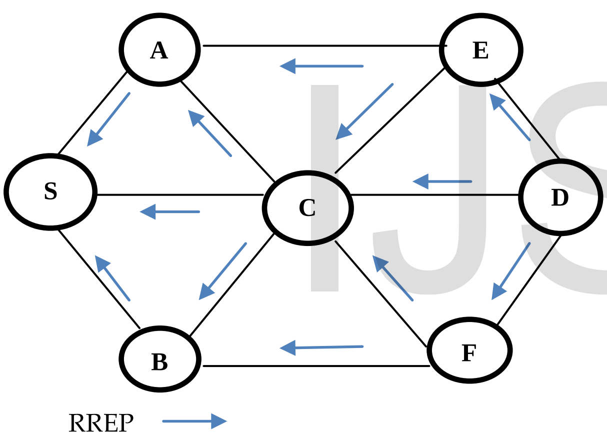

Fig (x): Reverse paths to Source S

Traffic distribution:

With multiple redundant paths available, the protocol switches routes to a different path when the path in use fails. Thus a new route discovery is avoided. Route discovery is initiated only when all paths to a specific destination fail. For efficiency, only link disjoint paths are computed so that the paths fail independently of each other.

WORKING OF AODV_MULTIPATH

AODV_Multipath extends the AODV protocol with new features such as the path accumulation and reverse-route-table. The path accumulation feature is similar to the one of DSR. If a (intermediate) node receives a RREQ packet, it appends its own address, after that the destination node selects node-disjoint paths. AODV_Multipath protocol can get more node-disjoint multipath routing. In the case of link break, source node can quickly find a node disjoint route as backup path and continue to transfer data, thus there is no need to perform route discovery, as a result there is a significant reduction in the number of control messages.

Ad hoc On-demand Distance Vector Multipath (AODV_Multipath) is a modification to the AODV routing protocol that discovers multiple node-disjoint paths from a source to a destination. Instead of discarding the duplicate RouteRREQuest (RREQ) packets (Fig (xi)), intermediate nodes store the information included in these packets in a table called RREQ table.

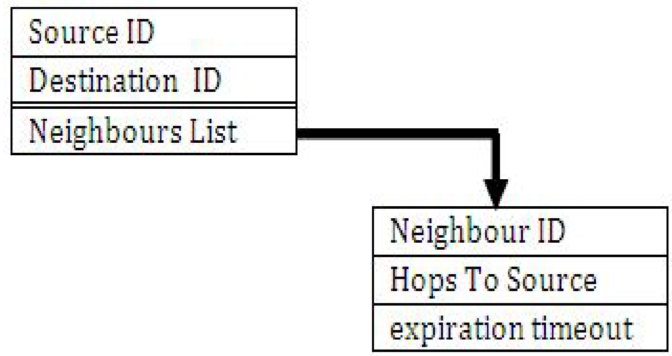

Fig (xi): The Structure of each RREQ table entry in AODVM

There are 3 steps:

- RREQ Path Accumulation
- Decrease routing overhead
- Selection of node disjoint paths.

Path Accumalation

We modify AODV to include path accumulation in RREQ packets. When the RREQ packets are generated or forwarded by the nodes in the network, each node appends its own address to the routing request packets. If an intermediate node receives a RREQ packet, it checks the hop count of the RREQ packet with respect to the "too-large-hop-count-rule". This means that the hop count of the duplicated RREQ packet is not larger than the hop count of the first RREQ packet. If the RREQ packet has an acceptable count, the intermediate node adds itself to the RREQ packet and rebroadcasts it; otherwise, the RREQ packet is discarded. When a RREQ packet arrives at its destination, the destination is responsible for judging whether or not the routing path is a node-disjoint path.

As an example, consider five nodes A, B, C, D and E as shown in Fig(xii). Node A wants to send data to node E. Since A does not have a route for E in its routing table, it broadcasts a route request. Node B receives the route request, appends its own address to the request, and forwards the request since it also has no route to E. Similarly, when node C and node D receive the RREQ, they append their address to the request and forward it.

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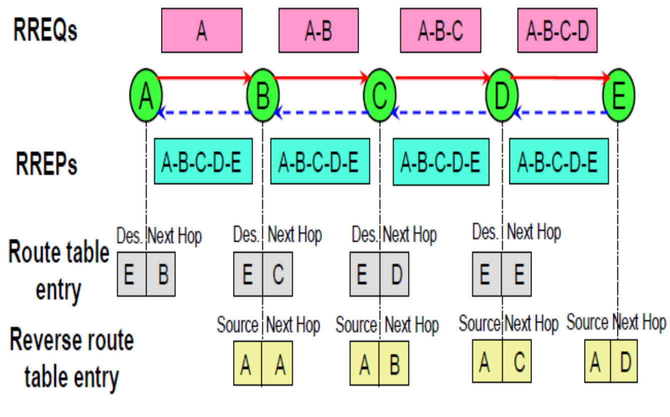

Fig (xii): path accumulation in AODV_Multipath

Decreasing Routing Overhead

When a node receives a RREQ packet for the first time, it checks the path accumulation list from the packet and calculates the number of hops from the source to itself and records the number as the shortest number of hops in its reverse route table entry. If the node receives the RREQ duplicate again it computes the number of hops from the source to itself and compares it to the number of the shortest hops recorded in its reverse route table entry. If the number of hops is larger than the shortest number of hops, the node drops the RREQ packet. After the RREQ packets have arrived at the destination node, the destination node decides which routes are node-disjoint (Fig (xiii)), adds them in the reverse routing table and replies with a RREP.

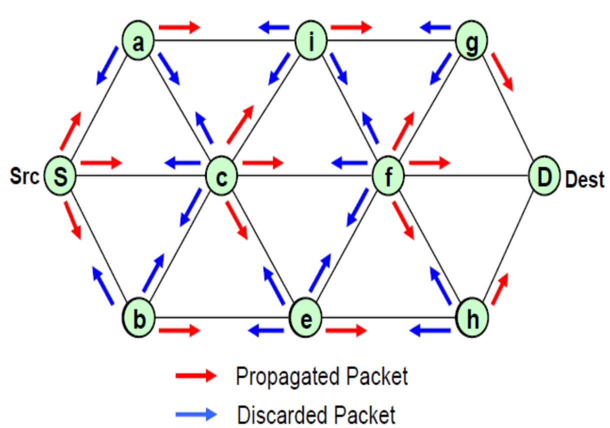

Fig (xiii): Route Request process with low overhead

Fig. (xii) illustrates the route request process with low routing overhead in the entire network. Source S broadcasts a route request packet. Each intermediate node uses the approach with low routing overhead to propagate and discard packets. Therefore, only seven packets (S-c-f- D, S-a-i-g-D, S-b-e-h-D, S-c-i-g-D, S-c- e-h-D, S-c-f-g-D, S-c-f-h-D) can reach the destination D. However, not all of paths packets that arrive in destination are node-disjoint. In next section we discuss how to choose node-disjoint paths.

Selecting Node Disjoint Paths

In AODV_Multipath, the destination is responsible for selecting and recording multiple node-disjoint route paths. In Fig(xiii), its three node-disjoint route paths are: S-a-i-g-D, S-c-f-D, S-b-e-h-D. When receiving the first RREQ packet (the shortest route path: S-c-f-D), the destination records the list of node IDs for the entire route path in its reverse route table and sends a RREP that includes the route path towards the source along the reverse route. When the destination receives a duplicate RREQ, it will compare the whole route path in the RREQ to all of the existing node disjoint route paths in its route table entry. If there is not a common node (except source and destination) between the route path from the current received RREQ and any node disjoint route path recorded in the destination's reverse route table entry, the route path of the current RREQ (such as S-a-i-g-D or S-b-e-h-D) satisfies the requirement of node-disjointness and is recorded in the reverse route table of the destination.

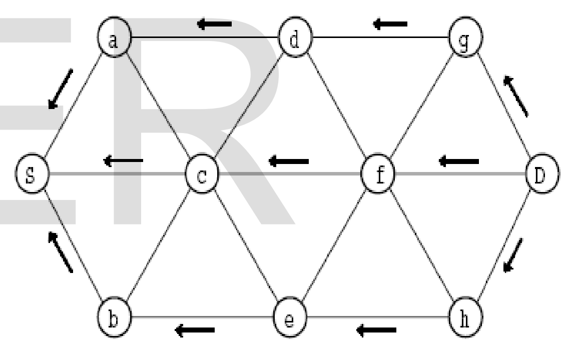

Fig (xiii): Node Disjoint RREP Paths in AODV_Multipath

Route Establishment:

In NDM_AODV protocol when the source node needs to communicate with a destination node, it first lookup in its routing table, if there exists a route to reach the destination node. If the route exists and if it is effective, the source node immediately uses this route to send packets, otherwise, it will place the packet to the sending buffer and start the route discovery process. First the source node sends a route request message RREQ. All nodes within the source node wireless coverage area will receive this routing request. Fig(xiv) and Fig(xv) shows AODV_Multipath RREQ and RREP packet formats respectively.

AODV_Multipath uses the 'F' flag in the RREQ and RREP packets for distinguishes the main route or backup route packet route discovery processes.

Type			……	D		Reserved	Hop

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	J	R			F		Count
RREQ ID							
Destination IP Address							
Destination Sequence Number							
Originator IP Address							
Originator Sequence Number							

Fig: (xiv): AODV_Multiapth RREQ packet

Type	R	A	**F**	Reserved	Prefix size	Hop Count
Destination IP Address						
Destination Sequence Number						
Originator IP Address						
Originator Sequence Number						

Fig: (xv): AODV_Multiapth RREP packet

When intermediate nodes receive the RREQ packet, they will carry out the processing as follows:
(i)If the node has received the message for the first time, the node will take the hop count in the RREQ message as the minimum hops of reverse routing from the source node to the node, denoted by Hop_min, or else turn to (ii).
(ii) Compare Hop_min with the reverse routing hops Hop in the RREQ message from the source node to the node. If Hop>Hop_min, discard the RREQ message, or else turn to (iii).
(iii) Establish or update reverse path according to the RREQ message content, and add its own address to "source routing node address sequence" domain and broadcasts the RREQ message to its neighbouring nodes.

When destination node receives a RREQ message, it performs the following procedure:
(i) If the node receives the RREQ message for the first time, it will copy the source routing node address sequence in the RREQ message to the corresponding field in the Reverse Routing table. The source routing node address sequence will be taken as first node-disjoint paths from the same source node to the destination. The value of the MAX _AODV_Multipath is minus 1. Then the node forms a RREP message, and copy the reversed order of paths sequence to "the destination routing node address sequence" domain in the Reverse Routing table. The RREP message is sent to the source node along reverse path, or else turn to (ii).
(ii) Comparing the source routing node address sequence in the RREQ message and the node address sequence of all paths saved in the Reverse Routing table from the same source to destination node, if there is common node, the destination node will directly discard the RREQ message, or else turn to (iii).
(iii) If MAX_ AODV_Multipath ≥ 0, copy the source routing node address sequence to Reverse Routing table as a new node disjoint paths and MAX_ AODV_Multipath minus 1.

Once received a RREP message, an intermediate node judges if the RREP message is repeated. If it is repeated, an intermediate node directly discards it, or else according to destination routing node address sequence in the message, establishes the forward routing from the node to the destination node, that is, it determines the destination node that initiated RREP message and the next hop to send RREP message to the node, and establishes the reverse routing from the node to the source node, that is, determines the destination node that the RREP message finally should reach to and the next hop that the RREP message will be sent to. Once received a RREP message, the source node establishes the reverse routing from it to the destination node and then performs data transmission.

Route Maintenance:

AODV_Multipath protocol uses HELLO message to maintain local connectivity. If a node has not received the HELLO message of any other neighbouring node within a HELLO period, the node will consider that the link may be broken. When found a link broken, the node will send a RERR message to the source node. When intermediate nodes received the RERR message it will mark the routing of reaching the destination node as invalid in the routing table, then continue to send the RERR message to its upstream nodes. When source node receives RERR message, it first marks corresponding routes as invalid in the routing table and finds whether there are effective node disjoint route to reach same destination node. If it has an effective route available, it will use this backup routing to continue data transmission. If all backup routings are failure, it will perform the route discovery again.

IV. Proposed system

Single path routing protocols have been heavily discussed and examined in the past. A more recent research topic for MANETs are multi-path routing protocols. Multi-path routing protocols establish multiple disjoint paths from a source to a destination and are thereby improving resilience to network failures and allow for network load balancing. These effects are particularly interesting in networks with high node density and high network load. A comparison of multiple multi-path protocols is therefore particularly interesting in scenarios of highly congested and dense networks.

Up to now, no extensive simulations and quantitative comparison of multipath routing protocols have been published. In the present paper, we fill this gap by presenting an evaluation and comparison of three wireless ad hoc multipath routing protocols, namely SMR [2], and two modifications or extensions of AODV [4]: AOMDV [3] and AODV_ Multipath with the help of fitness function.

The fitness function is used to evaluate the quality of the obtained solution and to find the shortest and feasible path to destination is as given below,

$$F(P_i) = \sum_{l \in p(s,n)} P_l + P_d$$

Where,
P_i= Path fitness value
P_l= cost of the path
P_d= delay experienced by the path

The comparison focuses on the following metrics: data delivery ratio, routing overhead, end-to-end delay of data packets and load balancing.

The contribution of this present paper is three-fold:

i) We show in the comparison that: AODV Multipath performs best in static networks with high node density and high load; AOMDV outperforms the other protocols in highly mobile networks; SMR offers best load balancing in low density, low load scenarios;
ii) We demonstrate that multi-path routing is only advantageous in networks of high node density or high network load; and
iii) We confirm that multi-path routing protocols create less overhead compared to single path routing protocols.

Having the following fundamental properties:

- The routing protocol provides multiple, loop-free, and preferably node-disjoint paths to destination.
- The multiple paths are used simultaneously for data transfer and
- Multiple routes need to be known at the source.

In this work we are trying to focus to improve the routing performance of multipath routing protocols by passing QoS Parameter metrics:

- *Throughput:* Refers to amount of data that can be transferred from sender to receiver in a given amount of time.
- *End-to-End Delay:* The average time taken by a data packet to arrive in the destination. It also includes the delay caused by route discovery process and the queue in data packet transmission. Only the data packets that successfully delivered to destinations that counted.

$$\sum \text{(arrive time – send time)} / \sum \text{Number of connections}$$

The lower value of end to end delay means the better performance of the protocol.

- *Normalized Load:* The total number of routing packet transmitted per data packet.
  Normalized load=Total number of routing packets sent/ total number of data packets received.
- *Routing Overhead:* It is the total number of control packets or routing packets generated in the network.
- *Jitter:* It is the variation in latency as measured in the variability over time of the packet latency across a network. A network with constant latency has no variation (Jitter).

V. Conclusion

The objective of this paper is to provide a quantitative comparison of multi-path routing protocols for mobile wireless ad-hoc networks. At the same time, we examine and validate the advantages and the limitations of multipath versus single path routing in general. Our study shows that the AOMDV protocol is more robust and performs better in most of the simulated scenarios. The AODV Multipath protocol achieves best performance in scenarios with low mobility and higher node density. SMR performs best in networks with low node density, however the immense routing overhead generated in high node density degrades protocol's performance.

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