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PERFORMANCE COMPARISON WITH ACCESSIBILITY PREDICTION AND LINK BREAKAGE PREDICTION IN MANETS

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Abstract - Ad Hoc Networks face a lot of problems due to issues like mobility, power level, load of the network, bandwidth constraints, dynamic topology which lead to link breaks, node break down and increase in overhead. As nodes are changing their position consistently, routes are rapidly being disturbed, thereby generating route errors and new route discoveries. The need for mobility awareness is widely proclaimed. In our dissertation we present a scheme AOMDV-APLP that makes AOMDV aware of accessibility of neighbor nodes in the network. Nodes acquire the accessibility information of other nodes through routine routing operations and keep in their routing table. Based on this information route discovery is restricted to only "accessible" and "start" nodes. Further route with the strongest signal strength is selected from multiple routes using Link life value predicted by Link Breakage prediction technique. Simulation result shows that using accessibility and link life knowledge in route discovery process MAC overhead, routing overhead and average delay is reduced **3** times, and improve the Packet delivery ratio to a large extent than standard AOMDV which reflects effective use of network resources.

Keywords*- Ad hoc networks; Routing protocols; ; QoS,link breakage, accessibility prediction.*

I. INTRODUCTION

Wireless technologies are unequivocally among the most rapidly progressing technology sectors. There is a vast range of wireless technologies, applications and devices, which are either already a substantial part of our daily life or could play this role in future. Wireless ad hoc networking is one of these applications, which can potentially enhance our abilities to solve real life challenges.

Wireless ad hoc networking or Infrastructure-less networking can be considered as an extension to the autonomy that was anticipated with the introduction of wireless networking. Wireless ad hoc networking makes those real life scenarios possible where there is a need of instantaneous and prompt communication. There is a widespread range of scenarios, from conventions or meetings with people quickly sharing information to the emergency search-and-rescue operations, where such networks are well suited. A wireless ad hoc network is a random collection of devices with radio transceivers that accompany each other without any prior infrastructure in a temporary manner to collaboratively accomplish a task.

- The participants i.e. the devices or the nodes can be stationary, mobile, or both, and they can join or leave the network as per their requirement. Similarly, wireless ad hoc networks have technically no geographical limitations on their size; a wireless ad hoc network can be as large as possible provided that all the nodes are able to communicate with each other, though the commonly available range is restricted from the body area to the local area. The concept of wireless ad hoc networking has numerous real life applications as it provides a simple, flexible, effortless, and instant approach to communicate in a cooperative scenario.

- Efficient communication
- Technological limitations
- Resource limitations
- Security
- Quality of service

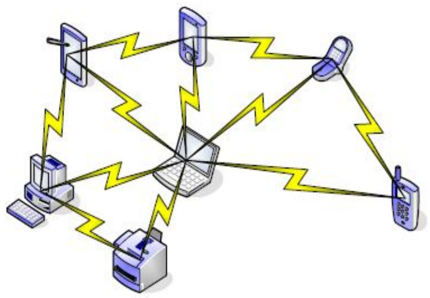

Fig 1-1: A typical wireless ad hoc networks

II. ROUTING PROTOCOL

AODV [11] is an improvement on DSDV. AODV makes use of the on-demand approach for finding routes. A route is established only when it is required by a source node for transmitting data packets and it maintains these routes as long as they are needed by the sources. AODV performs hop-by-hop routing by maintaining routing table entries at intermediate nodes. A node updates its route information only if the destination sequence number of the current received packet is greater than the destination sequence number stored at the node. This indicates freshness of the route and prevents multiple broadcast of the same packet. AODV makes use of the broadcast identifier number that ensures loop freedom since intermediate nodes only forward the first copy of the same packet and discard the duplicate copies. There are three phases of the AODV

Routing Protocol. First is the Route Request, Route Reply and Route Maintenance phase. The Figure 2.1 displays a Wireless Ad Hoc scenario, which consists of 9 mobile nodes where the route has to be set from source (S) to destination (D).

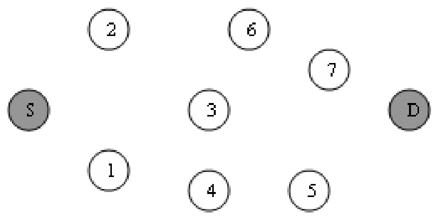

Fig. 2-2 : Wireless Ad Hoc Network Scenario

- **Route Request Phase:**

The route discovery process is initiated when a source needs route to a destination and it does not have a route in its routing table it floods the network with RREQ packet specifying the destination for which the route is requested.

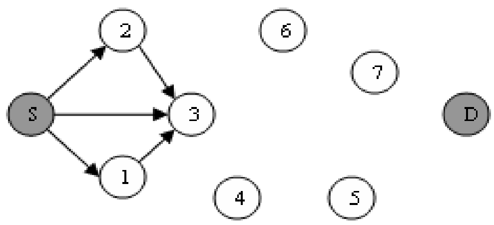

Fig. 2-3 : Route Request Broadcast

The figure 2.2 shows the broadcast of Route Request to the neighboring nodes. Here if node 3 has already received request from node S then it will discard the request that will come from node 1 and node 2. The nodes 1 and 2 will further broadcast it to their neighboring nodes 6 and 4 and if all the intermediate nodes do not have a route to the destination then the request is further broadcast to node 7 and 5 and thus it reaches the destination node D.

- **Route Reply Phase:**

The second phase is the Route Reply phase if the neighboring nodes have route to the destination then the node generates a RREP and sends back to the source along the reverse path and if it does not have the route then the request is forwarded to other nodes. Once the source node receives the RREP it can start using the route to send data packets. The source node rebroadcasts the RREQ if it does not receive a RREP before the timer expires, it attempts discovery up to maximum number of attempts or else aborts the session. It also makes a reverse route entry in its routing table and then forwards the packet. S starts sending the data from whichever route it receives the RREP and then changes the route if it receives the route with a less hop count.

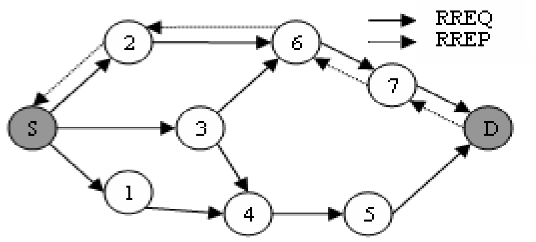

Fig. 2-4 : Route Reply Phase

The table 2.1 shows the routing table of AODV maintained by each node. The table consists of 5 fields the address of the destination node, sequence number, hop count, next hop and expiration time out. As each node just contains a single route to the destination if this route fails then a new route discovery has to be run by the source node. The Destination entry of the routing table specifies the node D where the source has destined the packet. The Sequence Number helps in maintains the freshness of the route. The Hop Count specifies the number of hops required by the source to reach the destination. The Next Hop specifies the next hop taken by the data to reach the destination D.

Table 2-1 Routing Table of AODV

Destination	Sequence Number	Hop Count	Next Hop	Expiration Timeout
D	1234	4	2	…..

- **Route Maintenance phase:**

If one of the intermediate nodes changes its position or fails then the neighboring node realizes the link failure and sends a link failure notification to its upstream neighbors. After the link failure notification has reached the source it will reinitiate a route discovery if needed. The HELLO messages are sent at regular intervals by the intermediate nodes to find the correct information of the neighboring node. Here if the link between node 2 and node 6 goes down then a new route discovery is run and a path is set up between node S and node D.

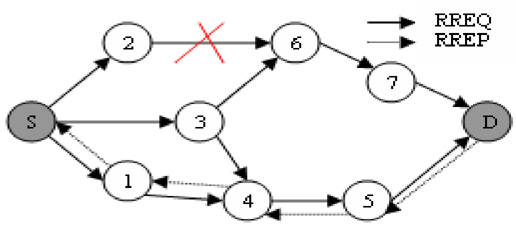

Fig. 2-5 : Route Maintenance Phase

The routing table2.2 displays the modified table of AODV protocol after the link failure.

Table 2-2 Modified Routing Table of AODV

Destin ation	Sequence Number	Hop Count	Next Hop	Expiration Timeout
D	1234	4	1	…..

The biggest drawback of AODV is with respect to its route maintenance. If a node detects a broken link while attempting to forward the packet to the next hop then it generates a RERR packet that is sent to all sources using the broken link. The source runs a new route discovery after receiving RERR packet. The frequent route breaks cause intermediate nodes to drop packets because no alternate path to destination is available. This reduces overall throughput, packet delivery ratio and increases average end-to-end delay if there is high mobility. The other drawback is that multiple RREP packets are received in response to a single RREQ packet and can lead to heavy control overhead. The HELLO message leads to unnecessary bandwidth consumption. Let us have a look at the already existing AODV protocol.

AOMDV

Adhoc On-demand Multi-path Distance Vector (AOMDV) [12] is an extension to the AODV. The main difference lies in the number of routes found in each route discovery. A little additional overhead is required for the computation of multiple paths. This protocol does not require any special type of control packets but makes use of AODV control packets with a few extra fields in the packet headers. The AOMDV protocol computes multiple loop-free and link-disjoint paths. There are three phases of the AOMDV protocol. The first phase is the Route Request, second is the Route Reply and the third phase is the Route Maintenance phase.

- **Route Request:**

The protocol propagates RREQ from source towards the destination. The figure 2.5 will show the working of AOMDV, which allows multiple RREQ to propagate. The node S as shown in Figure 2.5 has to set a path to the destination node D. So node S as in AODV broadcasts multiple requests to its neighboring nodes 1 and 2. This means that request with same sequence numbers are sent to the destination node. They further broadcast the request to the other neighboring nodes, which are further sent to the destination node D.

- **Route Reply:**

The protocol establishes multiple reverse paths both at intermediate nodes as well as destination. Multiple RREPs traverse these reverse paths back to form multiple forward paths to the destination at the source and intermediate nodes. If the intermediate nodes have the route defined for the destination then they send the RREP to the source node S. The protocol is designed to keep track of multiple routes where the routing entries for each destination contain a list of next hops together with the corresponding hop counts. All the hop counts have the same sequence number then the path with the minimum hop count is selected and all the other paths are discarded. The protocol computes multiple loop-free and link-disjoint paths. Loop-freedom is guaranteed by using a notion of "advertised hop count". Each duplicate route advertisement received by a node defines an alternative path to the destination. To ensure loop freedom, a node only accepts an alternative path to the destination if it has a lower hop count than the advertised hop count for that destination. The advertised hop count is generally the maximum hop count value possible for a node S to reach a node D. If any value that is received by the source S is greater than the advertised hop count value then a loop is formed so this RREP is discarded. The multiple RREPs are received by the source via multiple paths and a minimum hop count route is selected, the other routes carrying a higher hop count value are discarded.

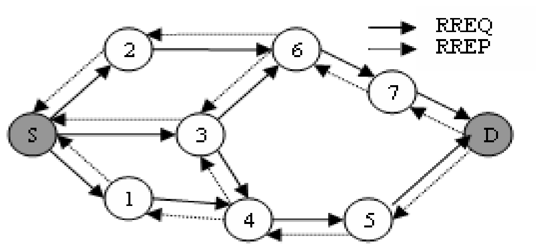

Fig. 2-6 : Working of AOMDV

Destination is the node where the packet is destined to, the sequence number to maintain the freshness of the routes, the advertised hop count that avoids the formation of loops. The route list consists of Hop Count required to reach a particular destination, Next Hop is the next hop the packet is supposed to take to reach the required destination, Last Hop is the last hop taken to reach the destination. If the packet is following the same path then this value is same as the Next Hop or else it changes and Expiration Timeout is the time for which the path will exist. There are multiple entries for a single destination but the routes that contain the lowest hop count are only recorded in the routing table and the other routes are discarded.

- **Route Maintenance Phase:**

The third phase is the Route Maintenance Phase. This phase works in exactly same as AODV. If the intermediate nodes are not able to receive a response of the HELLO message then they broadcast a Route Error message. After receiving this message all the nodes that use the particular route to reach the destination make this particular route as infinity and inform the source node to run a fresh route discovery. The routing table after a link break will appear as follows:

As node 3 has gone down the modified routing table of S will appear as above. When node 7 or node 5 goes down and there are no routes left in the routing table of S then the route discovery will be run. So it surely provides an improvement over AODV.

The above mechanism establishes loop free paths at every node but these paths have to be made disjoint. There are two types of disjoint paths, one is the node disjoint and the other is the link disjoint. Node-disjoint paths do not have any nodes in common, except the source and destination. The link disjoint paths do not have any common link.

An AODV protocol is been developed which develops route on-demand. The biggest drawback of AODV is with respect to its route maintenance. If a node detects a broken link while attempting to forward the packet to the next hop then it generates a RERR packet that is sent to all sources using the broken link. The source runs a new route discovery after receiving RERR packet. The frequent route breaks cause intermediate nodes to drop packets because no alternate path to destination is available. This reduces overall throughput, packet delivery ratio and increases average end-to-end delay if there is high mobility. The other drawback is that multiple RREP packets are received in response to a single RREQ packet and can lead to heavy control overhead. The HELLO message leads to unnecessary bandwidth consumption.

The AOMDV is an extension to the AODV protocol for computing multiple loop-free and link-disjoint paths. The protocol computes multiple loop-free and link-disjoint paths. Loop-freedom is guaranteed by using a notion of “advertised hop count”. Each duplicate route advertisement received by a node defines an alternative path to the destination. To ensure loop freedom, a node only accepts an alternative path to the destination if it has a lower hop count than the advertised hop count for that destination. With multiple redundant paths available, the protocol switches routes to a different path when an earlier path 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.

In AOMDV RREQs reaching the node may not be from disjoint paths, if RREQ is from one common node one of the RREQ is discarded, this messages implicitly provide knowledge about the mobility and accessibility of their sender and originator. for example, if node A is constantly receiving messages initiated by another node B, this implies that node B is relatively stationary to node A. furthermore a valid route from node A to node B is available either directly or through other nodes. Instead of discarding repeated RREQs messages node can perform additional computation on available routing data and predict accessibility of other nodes. In terms of cost, AOMDV-AP has two additional characteristics. Firstly, repeated RREQs are used for routing table maintenance. Certainly, the additional overhead of performing this action is negligible because this RREQ is already available to the routing agent and all it has to do is to update one or two entries in the routing table. Secondly, routing entries remain permanently in the routing table. As a result, routing tables have more entries (and they also have an additional field in every entry). Use of repeated RREQs further stimulates this issue by adding entries, which were usually discarded. However, in our view, for an ad hoc network with a fair number of nodes such a situation will not cause serious problems. Larger routing tables have a positive role too. During the route discovery process, intermediate nodes can generate RREPs if they have a valid route to the destination; thereby, flooding of RREQ is obstructed. Undoubtedly, flooding has the worst effects on the performance of an ad hoc network.

Now AOMDV[8] 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 will go for link breakage prediction. Prediction will be done only for multiple paths that 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 are MAC frames which gives the transmitted and received power from which distance can be measured. This distance can be used to predict whether the node is moving inward or outward relative to the previous distance value that is it give the signal strength. At any point of time, only the path with the strongest signal strength is used for data transmission.

III. AOMDV WITH ACCESSIBILITY PREDICTION

In AOMDV repeated RREQs are not discarded. All duplicate RREQs arriving at the node are examined but not propagated further as each duplicate defines an alternate route. Thus AOMDV allows for multiple routes to same destination sequence no. With multiple redundant paths available, the protocol switches routes to a different path when an earlier path fails. Thus a new route discovery is avoided. Route discovery is initiated only when all paths to a specific destination fail. Routing table entry has one common expiration timeout regardless of no of paths to the destination. If none of the paths are used until the timeout expires, then all the paths are invalidated and the advertised hop count is reinitialized. While doing all this, routing information such as RREQs,RREP and REER packets collected can be used to predict the accessibility of nodes. This prediction is used to reduce routing overhead, MAC overhead and to enhance packet delivery ratio and connection success ratio.

3.1. Accessibility Prediction algorithm

a) If a node A receives a routing packet from another node B, node B is in A's neighborhood and is accessible to A.

b) If a node A receives a routing packet originated by a node B, node B is accessible to node A and there exists a valid route from node A to node B.

c) If a node A receives a RERR from a node B, all the unreachable nodes mentioned in this RERR are no more accessible to node A through node D.

Routing entries will never be deleted a new field "Accessible" is added to each routing table entry depicts the predicted accessibility information

Possible values

Start = No information

Accessible = A valid route to node exists or would be possible

Inaccessible = A valid route to node would not be possible

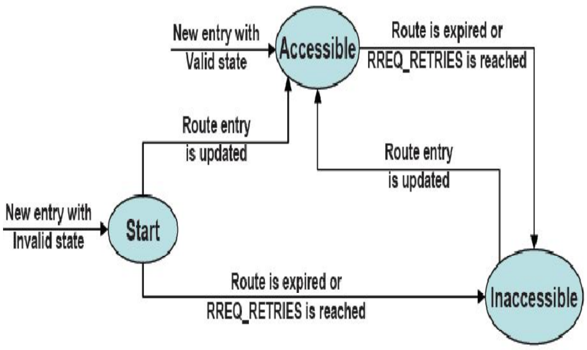

Fig. 3.1: State diagram of AOMDV with accessibility Prediction

Table 3-1 : Routing Table of AOMDV-APLP

Destination
Sequence number
Advertised_hopcount
Expiration _timeout
Route list {(nexthop1,hopcount1),(nexthop2,hopcount2),…
Accessibility

Cost

No extra messaging is required.

Additional computation due to "Accessibility" field is negligible.

Computation cost of using repeated RREQs is negligible.

Routing table entries are never deleted.

Size of routing table might not be a problem in a reasonable size network.
Relative stationary nodes are good candidate to be included in route

3.2 Modified route discovery with accessibility prediction

There is no route discovery for "Inaccessible" nodes, which reduces overhead. The value of the accessibility field is just a prediction. It is likely that this information gets stale. To assume an "Inaccessible" node "Accessible" is not an issue as in such a situation usual AOMDV procedures will be followed. However, the converse could have serious consequences. For example, nodes can conserve plenty of resources by not performing route discoveries for "Inaccessible" nodes, provided the prediction is correct. However, if this prediction is incorrect, this resource conservation will cost them in the form of connectivity loss and consequently throughput loss. Thus, in such a situation there is a trade-off between overhead reduction (or resource conservation) and connectivity (or throughput).

IV. MODIFIED AOMDV WITH LINK BREAKAGE PREDICTION

Now AOMDV with accessibility prediction routing protocol 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 will go for link breakage prediction. Prediction will be done only for multiple paths that 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 are MAC frames which gives the transmitted and received power from which distance can be measured, this distance can be used to predict whether the node is moving inward or outward relative to the previous distance value that is it give the signal strength. At any point of time, only the path with the strongest signal strength is used for data transmission. Following is the method to calculate link lifetime.

From two ray ground model we get Transmitted power PT and Received power PR using which we can calculate distance 'd' by given formula.

$P_r = k \frac{P_t}{d^4}$ **where k =** $G_t.G_r.(h_t.h_r)^2$ **is a constant**

A link breakage algorithm is used to predict the value of t_{break} using **'d'.**

4.1 Link Breakage Algorithm

Now t_{break} can be calculated by the following algorithm

Always assume nodes moving radially outward. Initially

$$V = V_{prev} = V_{\max}\, m/s, d_{prev} = 0.0m$$

$$v = \left| \frac{d - d_{prev}}{t - t_{prev}} \right|$$

$$V = (w)^* v + (1 - w)^* V_{prev}\,\mathrm{k}$$

w based on ratio of time since last sample (!t = t – t prev) and average sample interval T

Time dependency of w ensures quick adaptation to change

$$t_{break} = \left[\frac{d_{\max} - d}{V} \right]$$

$$V_{prev} = V; d_{prev} = d$$

Thus Accessibility and Link Breakage Prediction (APLP) techniques are implemented in AOMDV protocol the proposed protocol has produced good results. The proposed AOMDV-APLP protocol has reduced MAC overhead, Routing overhead and end-to-end delay. On account of which packet delivery ratio is increased a lot as compared to AODV-AP (accessibility prediction) and standard AOMDV.

V. PERFORMANCE METRICS

- **MAC overhead** – the total number of all kinds of MAC packets generated during the simulation time. The retransmission of data frames are also included in it.
- **Routing overhead** – it includes all kinds of AOMDV packets generated as well as forwarded during simulation.
- **Average Delay** – The average end–to-end delay is defined packets traveling from the source to the destination node. The packets generally sometimes get delayed due to transmission, processing, collision and queuing.
- **Packet Delivery Ratio** – The ratio of total number of data packets successfully received by all the destinations to the total number of data packets generated by all the sources.

VI. CONCLUSION

AODV came up with the advantage of the routes being discovered a single route on-demand but this caused a lot of packet delay, Routing and MAC overhead on node failure as a new route discovery had to be run by the source and RREQs are send to all the nodes. AODV-APLP came up with the solution of above problem but the number of routes to the destination is one. AOMDV came up with the advantage of multiple routes being discovered and the route carrying the minimum hop count value is selected but it suffers from large Routing, MAC overhead and Packet delay on node failure, because RREQs are send to all the nodes neighboring nodes. We proposed and implemented AOMDV-APLP where RREQs or route discovery is initiated only for "Accessible" and 'start" nodes which reduces the MAC overhead, Routing overhead, Packet Delay.

Results show that, our proposed protocol, reduces packet delay by 70%, and increases packet delivery ratio considerably as compared to standard AOMDV protocol. Our protocol also gives stable connectivity as route with the strongest signal strength is selected with the help of Link lifetime.

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