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FW-AODV : An Optimized AODV Routing Protocol for Wireless Mesh Networks

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Abstract: In this paper we present a new optimized Adhoc on Demand Distance Vector reactive routing approach for Wireless Mesh Networks namely FW-AODV. The algorithm uses fuzzy logic based integrated link cost based cost measure to evaluate route cost. The proposed FW-AODV approach has modified the working of Adhoc on Demand Distance Vector Routing (AODV) routing protocol. The AODV routing protocol becomes unreliable as the mobility of nodes and size of Wireless Mesh Network (WMN) increases. The proposed approach is able to negotiate well with the node mobility and network issues. AODV is one of the most popular and commonly used reactive routing protocols. On the other hand proactive routing techniques increase control traffic of the network and require more bandwidth. The proposed FW-AODV approach has changed the least cost route evaluation process and the maintenance phase of AODV. The proposed approach was implemented in MATLAB and was validated on different network scenarios. The FW-AODV is compared with AODV, BAT and Ant Colony Optimization (ACO) based approaches. The of proposed approach proved to be much superior than the other three approaches.

Keywords*:* Reactive Routing, AODV, FW-AODV, BAT, proactive routing, ACO.

I. INTRODUCTION

Routing in Wireless Mesh Networks (WMNs) is an active research area due to the dynamic nature of the networks. The routing protocols of WMNs fall into three categories i.e. proactive, reactive and hybrid routing protocols [1][2]. Reactive routing protocols are also called on demand routing protocols. In a reactive routing protocol nodes discover routes only when communication is required. These types of protocols reduce the control traffic on the network but these need the extra time to establish the route at the time of communication. The reactive routing protocols or on demand protocols include protocols like Adhoc on Demand distance vector (AODV) [3] and Dynamic Source routing (DSR) [4] protocols. Proactive routing approaches are also called table driven approaches. For proactive routing approaches, every node maintains and discovers the route with every node in the network regardless of whether the route is required or not. These approaches compute the routes with every other node by exchanging the routing tables periodically. The proactive routing approaches increase the more control traffic and require more bandwidth as compared to reactive routing approaches. The proactive routing protocols do no need to discover the route at the time of communication. The routes will be always available. The proactive approaches such as the Destination Sequenced Distance Vector (DSDV) [5] and Optimized Link State Routing (OLSR) [6] use table driven approach. The hybrid routing protocol is the combination of both on demand and table driven approaches. It takes the benefits of both techniques. The Zone Routing protocol (ZRP) [7] and Zone Hierarchical Link State (ZHLS) [8] are the examples of hybrid routing approach. Some nature inspired computing based approaches also have been applied in the area of routing in WMNs. [9][10][11].

The AODV approach is the standard routing protocol of WMNs. To initiate the path discovery from source to destination it uses reactive routing approach. For route discovery the source node sends the route request (RREQ) control message to its all neighbors. If any of the neighbor node is the required destination node then the neighbor which is also the destination will send the route reply (RREP) control message back to the source node otherwise, all the neighbors will send the RREQ control message to there neighbor nodes and so on until the destination node is found. To eliminate the loops and to maintain the freshness of the RREQ message AODV uses the concept of sequence numbers [3].

During the communication phase if any node moves out from the active path, then there is a need to maintain or recover the path. If source node moves out from the active path then the source node will again discover the path. If any other node moves out from the active route then the Last Connected node (LCN) will send the route error (RERR) control message towards the source node. Here Last Connected Node (LCN) is the last connected to the source from where a link of the given route has broken. After receiving the RERR message the source node will rediscover the path. The LCN could detect the link breakage by sending a special hello control message to the neighbor nodes. If the node does not receive the acknowledgement of the sent hello messages within the specified threshold time then the link is assumed to be failed or broken.

The figure 1 illustrates the route maintenance approach followed by AODV. In the given figure if node C moves out from the active path then the node B (LCN) will detect the link breakage by making the use of hello control messages. Further the node B will also send the RERR message towards the source node “SN”. Once the source node receives RERR message it will again start the route discovery process. Hence, the route is rediscovered by the source node only.

In AODV if any node in WMN encounters the link breakage then it must send RERR control message to source node and source node will again discover the path. This approach of AODV route maintenance slows down the route repair process and hence, not suitable for the highly dynamic networks because the link needs to be re-established within the given timing constraints.

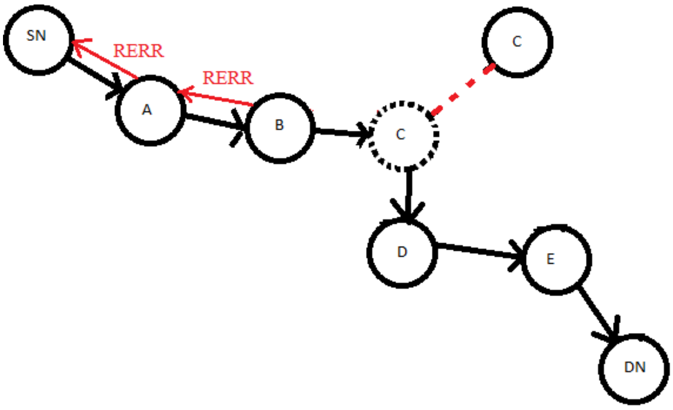

Figure 1: Route Maintenance using AODV

The figure 1 shows that the source node "SN" is communicating with the destination node "DN". Due to any reason if route between node B and node C fails, the node B (LCN) would detect the link failure by making the use of hello control messages. Node B will also send this link failure information to "SN". To send this information the node "B" will unicast a route error (RERR) control message to node "A" and node "A" will send this RERR control message to "SN". After receiving the RERR control message the "SN" will again discover the route.

This type of route maintenance approach could slow down the route repair task due to increased control traffic on the WMNs. Thus, there is a need of an efficient route maintenance/ route recovery approach that will repair the route from LCN onwards before sending RERR message to source. This route repair maintenance approach is expected to be faster than the prevalent methods. This paper incorporates this route maintenance and least cost route evaluation process in AODV routing protocol. Thus, transforming AODV to FW-AODV approach.

Section II of the paper proposes FW-AODV approach. Section III presents simulation results to validate our approach under different WMN scenarios. Section IV concludes the paper.

II.PROPOSED FW-AODV APPROACH

As shown in Algorithm the proposed FW-AODV approach works in two phases i.e. route discovery and route maintenance. The proposed routing protocol extends the performance of AODV routing protocol by introducing new fuzzy based least cost route evaluation method and a new route maintenance approach. The algorithm uses fuzzy logic based integrated link cost based cost measure to evaluate route cost.

A. Route Discovery

In case a node wants to communicate with a destination node; it starts it by initiating a route discovery process. The proposed approach discovers the route from source to destination same way as described in [3]. The source node may discover more than one routes from source to destination. If multiple routes are discovered by the "SN", then it selects the least cost path for further communication. There are number of route cost evaluation metrics available in the literature. Some of these are minimum hop count, per hop Round Trip Time (RTT) [14], Per-Hop Packet Pair Delay (PktPair) [15], Expected Transmission Count (ETX) [16], Expected Transmission Time (ETT), Weighted Cumulative ETT (WCETT) [17], Expected Transmission on a Path (ETOP) [18], Effective Number of Transmission (ENT) and Modified Expected Number of Transmissions (mETX) [19], Metric of Interference and Channel Switching (MIC) [20], Bottleneck Link Capacity (BLC) path metric [21] , cross layer link quality and congestion aware (LQCA) metric[22]. A novel interference aware low overhead routing metric was proposed by Liran Ma et al. [23].

In this paper we propose an integrated cost measure to evaluate the route cost. The proposed integrated link cost (ILC) measure is a function of 5 parameters as defined below:

ILC = $f(T, J, RE, D, M)$

Where we use parameters as defined below :

T: throughput, J: Average jitter, RE: Residual Energy, D: End to End Delay and M: node mobility/node speed.

We use a fuzzy logic based system as given in figure 2 to compute the ILC. This cost evaluation approach is similar to the one given in [9].

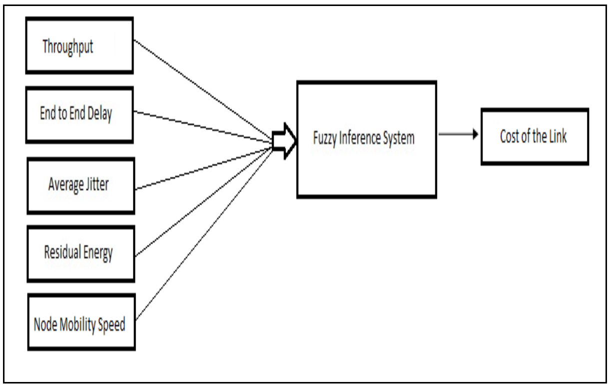

Figure 2: ILC function evaluation using Fuzzy Logic Based System

B. Route Maintenance

In FW-AODV the link is repaired by the Last Connected Node (LCN). During the route maintenance phase, if an LCN encounters/detects the link breakage, it discovers the route from LCN onwards.

Algorithm: Proposed FW-AODV Approach

BEGIN

// Last Connected Node (LCN): LCN is the last connected to the source from where a link of the given route has broken.

//Source Node (SN): SN is the source node.

//Destination Node (DN): DN is the destination node.

Step 1 Discover the route from SN to DN using basic AODV route discovery mechanism.

Step 2 if more than one routes are discovered by SN then compute least cost path using ILC as proposed in secton II of this paper.

Step 3 Use the new least cost path for further communication.

Step 4 if an LCN encounters/detects the link breakage then:

(a) check the route nodes after broken link with the neighbor nodes of the LCN of broken link.

(b) if any node of route after broken link lies in the neighborhood of LCN then use the path through that particular neighbor node.

(c) Else discover the route from the LCN onwards.

(d) Send this new route and route repaired message to source node.

End

In our proposed approach, if LCN encounters the link failure then LCN makes an attempt to discover the route by checking its neighborhood nodes. If any node amongst the neighbors of LCN lies on the path after link breakage, then the LCN will create the path to destination node through that particular neighborhood node. If LCN fails to create the route by using old route then it will rediscover the path from itself (LCN) onwards by sending the RREQ control messages to its neighbor nodes rather than sending the RERR control message to source node. Unlike basic maintenance phase of AODV the route will be discovered by the node that detected the link failure (LCN). After route discovery the LCN has the responsibility to send this route repair information to source node.

Figure 3 illustrates an active route from source node “SN” to destination node “DN”. The complete route from “SN” to “DN” is: SN, A, B, C, D, E and DN. Suppose the link between node B and node C has broken. The node C has moved out from the range of node B. In this case, the LCN is node B. Hence the node B will check that whether any node from the route after broken link lies in its neighborhood.

if any node of route after broken link lies in the neighbor-hood of B node (LCN) then use the path through that particular neighbor node. Alternatively, node B (LCN) will try to rediscover a path from node B to node “DN”. The figure 3 describes that node B discovers that new path from its point onwards by checking its neighbors and route nodes after broken link. The new path from LCN node B to destination node DN would be B, D, E and “DN”. Further this new route information is also unicasted to node “SN”, so that “SN” could update its routing table. The new recovered route will be: SN, A, B, D, E and DN.

If the LCN/current node fails to find any neighbor node which lies in the active path after LCN, then LCN will rediscover the path from LCN onward. After discovering the route this new route information will be sent to source node.

III.SIMULATION, RESULT AND DISCUSSION

We have implemented and simulated the proposed FW-AODV routing protocol along with other 3 approaches in MATLAB. We have tested the performance of FW-AODV protocol on 100, 500 and 1000 node client WMNs with different timing constraints. The radio range of each node is 250 meters. We have conducted 20 trials for each timing constraint.

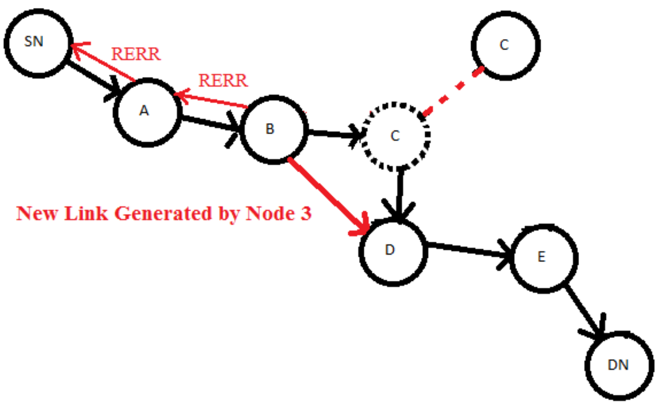

Figure 3: Route Repair by FW-AODV

Table 1: Simulation parameters for different WMN scenarios

No. of Nodes	Area (m×m)	Radio Range	Timing Limits (in Seconds)
100	500× 500	250	1.0, 2.0, 3.0, 4.0, 5.0
500	500× 500	250	5.0, 6.0, 7.0, 8.0
1000	1000× 1000	250	6.0, 7.0, 8.0, 9.0, 10.0

On 100 nodes client WMNs we have compared the performance of 4 approaches i.e ACO, BAT, AODV and FW-AODV with the timing limits of 1.0, 2.0, 3.0, 4.0 and 5.0 seconds. The performance results are shown in the form of histogram in figure 4. From the results, we have observed that for the timing constraint of 1.0 second AODV produced minimum cost path 7 times and FW-AODV produced minimum cost path 10 times. 3 times both AODV and FW-AODV approaches produced same minimum cost path. ACO approach did not be able to discover any route in any of the trial. Being a proactive approach BAT successfully found the path but the cost of every path is much higher. 1 time AODV was failed to discover the route from source to destination node. With 2.0 seconds timing limits, AODV given minimum cost path 9 time and FW-AODV provided minimum cost path 6 times. 5 times both FW-AODV and AODV given same best performance. On 3.0 seconds timing constraints AODV given minimum cost path 4 times and FW-AODV given 8 times. 8 times both AODV and FW-AODV given same performance. With 4.0 seconds timing constraint AODV produced minimum cost path 3 times and FW-AODV 10 times. 7 times both approaches produced same equal paths. For 5.0 seconds timing limits AODV produced minimum cost path 12 times and FW-AODV 8 times. We also observed that ACO was totally failed to discover the path from source to destination in any of the trial and any of the timing constraint. Also, BAT discovered the path for every timing constraint but is failed to provide the minimum cost path in any of the trial.

Table 2: Performance on 100 node client network

	Timing Constraints (in seconds)				
Algorithm	1.0	2.0	3.0	4.0	5.0
BAT	0	0	0	0	0
AODV	7 + A	9 + B	4 + C	3 + D	12
FW-AODV	10 + A	6 + B	8 + C	10 + D	8
ACO	0	0	0	0	0
A = 3, B = 5, C = 8, D = 7					

To evaluate the performance of all 4 approaches on 500 nodes WMNs we have used timing limits 5.0, 6.0, 7.0 and 8.0 seconds. From the results shown in figure 5 and table 4 we have observed that FW-AODV has produced minimum cost path 7, 10, 4 and 9 times on the timing limits of 5.0, 6.0, 7.0 and 8.0 seconds. Whereas AODV produced minimum cost path 1, 3, 3 and 4 times on the timing constraints of 5.0, 6.0, 7.0 and 8.0 seconds. Also BAT successfully produced minimum cost path 3, 1 and 1 times for the timing constraint of 5.0, 6.0 and 7.0 seconds respectively. Hence for given network scenario and timing limits FW-AODV has produced minimum cost route more times as compared to other three approaches.

Table 3: Performance on 500 node client network

	Timing Constraints (in seconds)			
Algorithm	5.0	6.0	7.0	8.0
BAT	3	1	1	0
AODV	1 + A	3 + B	3 + C	4 + D
FW-AODV	7 + A	10 + B	4 + C	9 + D
ACO	0	0	0	0
A = 9, B = 6, C = 12, D= 7				

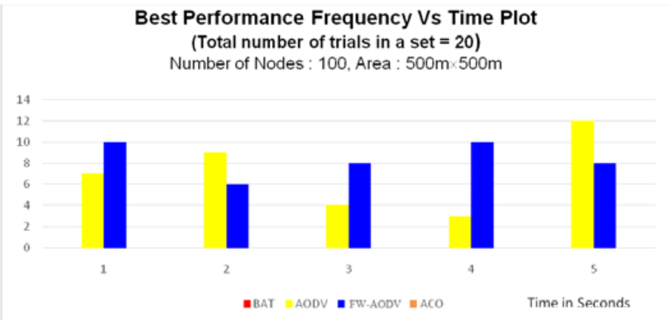

Figure 4: Performance on 100 Nodes Client WMNs

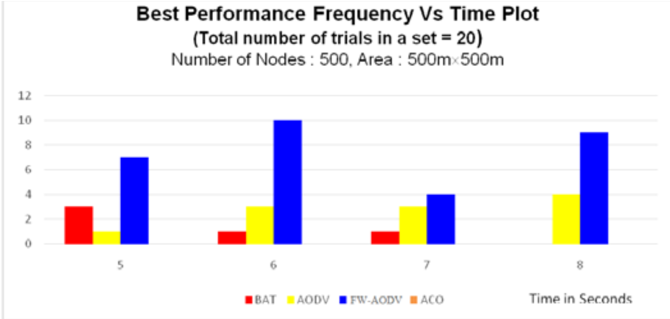

Figure 5: Performance on 500 Nodes Client WMN

To evaluate the performance of 1000 nodes client WMNs we have used the timing limits 6.0, 7.0, 8.0, 9.0, and 10.0 seconds. For every timing constraint, we have conducted 20 trials. The performance results of each approach on the given network scenario is shown in table 5 and figure 6. From the results, we have observed that FW-AODV is giving the much higher performance as compared to other 3 approaches. For the timing constraints of 6.0, 7.0, 8.0, 9.0 and 10.0 seconds FW-AODV produced minimum cost path 13, 15, 18, 11 and 19 times. We also observed that AODV was failed to discover the route from source to destination 5, 15, 19, 8 and 17 times for 6.0, 7.0, 8.0, 9.0 and 10.0 seconds timing constraints respectively. For the same timing constraint FW-AODV was failed to discover the route 1, 1, 2, 3 and 0 times. Hence as the network size grows the performance of AODV degrades. Further the BAT based approach also produced the minimum cost path 1, 2, 2 and 8 times for the timing constraint of 6.0, 7.0, 8.0 And 9.0 seconds. Because BAT belongs to the proactive approach, thus it has successfully discovered all paths from source to destination. Again, ACO did not discovered the path from source to destination in any of the trial and any of the timing constraint. Hence, from the results we have observed that FW-AODV is highly suitable for large networks as compared to other three approaches.

Table 4: Performance on 1000 node client network

	Timing Constraints (in seconds)				
Algorithm	6.0	7.0	8.0	9.0	10.0
BAT	1	2	2	8	0
AODV	A	3	0	1	B
FW-AODV	13 + A	15	18	11	19 + B
ACO	0	0	0	0	0
A = 6, B = 1					

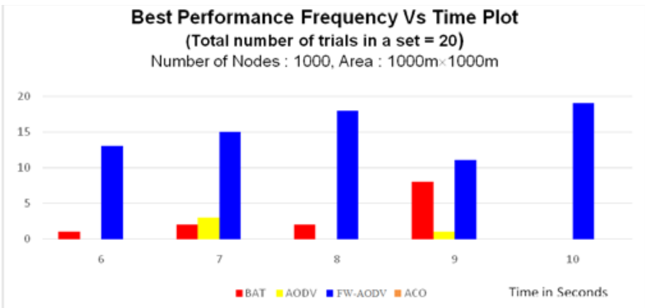

Figure 6 : Performance on 1000 Nodes Client WMN

IV. CONCLUSIONS

This paper has proposed a new optimized AODV based on demand routing technique. The proposed FW-AODV approach has modified the least cost route evaluation approach and route maintenance phase of AODV routing protocol. The algorithm uses fuzzy logic based integrated link cost based cost measure to evaluate route cost. The proposed algorithm was tested on 100, 500 and 1000 node WMNs for various network scenarios and timing constraints. The FW-AODV approach was compared with AODV, ACO and BAT based approaches. The simulation results clearly show that as the network size grows the performance of the proposed FW-AODV approach improves as compared to other approaches. It outperforms ACO, BAT and AODV approaches. AODV and ACO are highly unreliable approaches for large and highly dynamic network. The BAT based approach successfully generates the routes but these discovered routes were found to be very expensive than the ones found by FW-AODV. We observed that the performance of FW-AODV was much better than AODV, ACO and BAT based approaches.

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