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Enhancement Route Maintenance for Routing Protocol in Wireless Mesh Network.

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Abstract: - Route breakage between mesh clients is one of the research issues in hybrid wireless mesh network, especially if the traffic comes from internet to mesh clients. To ensure the robustness of the network, the routing protocol should be able to repair the route as fast as possible. In this paper, we propose a mechanism to enhance route repair in the well-known AODV routing protocol. The proposed mechanism uses mesh routers that part of the route for repairing the route break between gateway(i.e. source node) and mesh clients(i.e. destination node). The mesh routers have capabilities in terms of minimal mobility (i.e. most of the time are static) and have no constraint in power consumption. The Simulation results show that the proposed approach outperforms the AODV for routing overhead, end-to-end delay, throughput and number of packet delivery ratio.

1. Introduction

In wireless mesh network, routing protocols suffer from scalability issues. The increase in network size causes to degradation in the performance of the network significantly. Most of the traffic in wireless mesh network travels from gateway to mesh clients and vice versa. The path length between gateway and client mesh is very long and size of network is large, it takes long time and consumes a lot of bandwidth for transmitting a control packets in cases of route discovery, route maintain and route repair. The overhead increasing in wireless mesh network has significant impact than in ad-hoc network, because the wireless mesh network supplies a backhaul connectivity to different technology, thus, the routing overhead should reduce in wireless mesh network for utilizing a bandwidth for data traffic[1][2].

In ad-hoc on demand routing protocol (i.e. AODV)[3], when the link is broken between any mesh nodes in active route, the upstream mesh node mark up this route as invalid and finds a distance from the destination. If the determined distance is less than or equal to the value of MAX_REPAIR_TTL than hops away from destination (MAX_REPAIR_TTL=0.3*NET_DIAMETER), where NET_DIAMETER measures the maximum possible number of hops between two sources-destination pairs in the network, then upstream node will try to find alternate route by broadcasting RREQ packet. At the same time the upstream mesh node buffers data packets for unreachable destination and waits for receiving the route reply (i.e. RREP) packet. On the other hand, if upstream finds a distance from destination greater than MAX_REPAIR_TTL or if does not receive a RREP within discovery period time then the upstream mesh node sends route error(i.e. RERR) message for unreachable destination. The route maintenance process is described in figure 1 as follows:

A mesh node S sends data packets to mesh node D. When mesh node C receives data packets and finds that a route to destination D is broken, then mesh node C will check the distance between mesh node D and itself. If the distance is less than MAX_REPAIR_TTL hops away distance from source mesh node S to mesh node D, mesh node C broadcasts RREQ packet to find alternate route. Mesh node C also buffers data packets that come from source node S during local repair route process. If node C gets the route

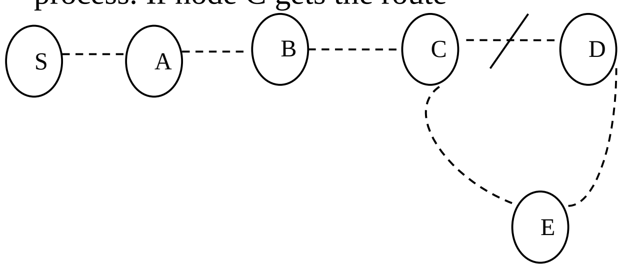

Figure 1: Local Route Repair in AODV.

reply packet RREP from mesh node E then it will be forward data packets to destination D. If mesh node C is unable to receive route reply packet, or it is far away from the destination, then node C issues route error packet towards the source node. When gateway receives data traffic from internet or external network for mesh clients; it is acting as source node and mesh client acts as destination node. There may not be a route between a source and destination, because of client mobility.

Most of the routes in hybrid wireless mesh network consist of gateway, mesh routers and mesh client. The movement of mesh clients causes frequent route breakage, thus multiple control packets (i.e. RERR packets) are generated towards gateway. These control packets might create bottleneck at gateway and at backbone mesh, (i.e. it is the mesh router that received packets from gateway or other border mesh routers, and it has no communication with mesh clients). This will also increase the routing overhead and capacity of a hybrid wireless mesh network will significantly reduce. The route break at mesh routers is rare. For route break repair, AODV uses local repair mechanism through intermediate node that is close to destination. In case of local repair failure, the intermediate mesh node generates error packets and then propagates it. Hybrid wireless mesh network is wide, scalable and multi hop in nature. Error packets travel from one mesh node to another mesh node (i.e. from mesh client to mesh routers or from mesh routers to another mesh router). Because, route length between gateway and mesh client is long, where time taken by error packets to travel from intermediate node (that generates error packets) to gateway will be high. When the error packets move from one mesh node to another, these packets may not be forwarded directly by receiving mesh node, instead these may be placed in a queue of mesh interface and wait for transmission. This waiting time will cause a delay in the arriving time of route error packets to gateway and in turn the total end to end delay will rise. Once the route error packets (i.e. RERR packet) reach gateway, the gateway starts setting up the route again between gateway and mesh client, which may take long time. If time taken by error packets to reach the gateway is high total end to end delay will also be high. Moreover, before error packets reach gateway, the gateway might be busy in sending data packets to unreachable mesh clients, without knowing that the route is broken and so those data packets might be lost. Unless well addressed, this causes significant performance degradation. Figure 2 describes a situation when the link breaks between mesh clients B and C and also between mesh clients E and F. Mesh clients B and F detect that the links are down and both fail to recover the links locally. In such a situation, these issue route error (i.e.

RERR) packets to inform gateway A about routes breaks. RERR packets travel from hop to hop until it reach internet gateway A and internet gateway issue RREQ packets for new routes for both destinations mesh clients G and D.

In this paper, a mechanism for enhancement of route maintenance features of AODV in hybrid wireless mesh networks has been proposed as, following contributions:

- The proposed mechanism uses the mesh router to find out the alternative route, when the main route is broken between mesh clients, further, the local repair is failed. The mesh routers have capabilities in terms of minimal mobility (i.e. static for most of the time) and no constraint in power consumption.
- We implement the proposed M-AODV routing protocol based on AODV[3] in NS-2 simulator. Extensive simulation experiments demonstrate that the M-AODV outperforms single radio AODV, with QoS in terms of network aggregate throughput, end-to-end packet delivery ratio, end-to-end delay and routing overhead. The primary version of this work has been appeared in RAIT[19]. The paper is organized as follows. Section 2 discusses the related work. Section 3 presents proposed work.section4 describes the simulation environment for the proposed work. The detailed analysis for results and discussions are given in section5, followed by conclusion and references.

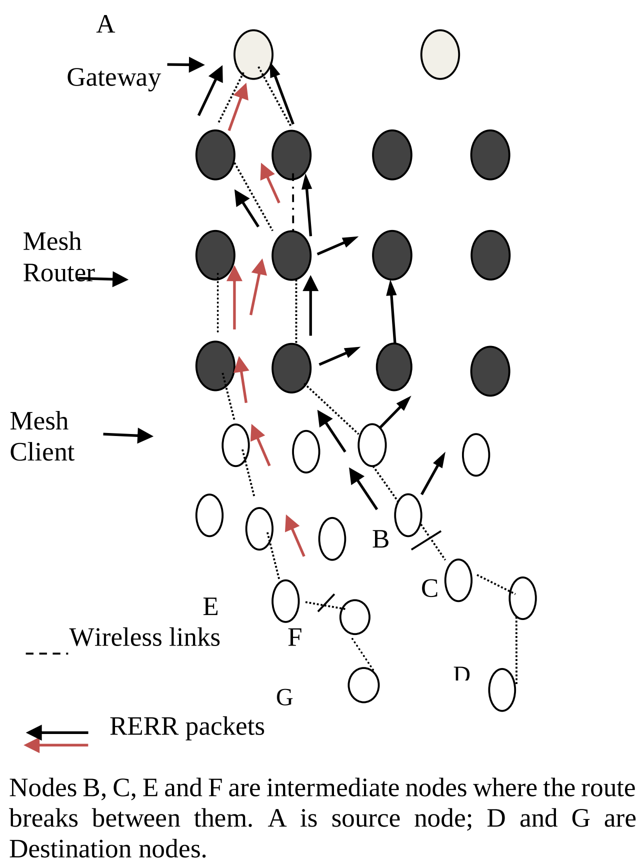

Figure 2: Route Break Situation in AODV over Hybrid Wireless Mesh Network.

2. Related work

A number of proposed works have been suggested to address the route break problem. In [4], the authors have discussed about the link breaks in the path. They argue that, noise or interference factors might cause to transmission fail. The authors have considered multiple factors to differentiate between links with transient transmission problems from those links, which have permanent transmission problems. The proposed mechanism aims to reduce false route breakage. MAC and physical information have been exploited to estimate the long-term performance of the link. In [5], the authors address the problem of route weakness in backhaul wireless mesh networks. They have proposed a route maintenance mechanism called congestion aware routing; this proposal keeps monitoring the medium and the transmission failures. It use an estimation of medium congestion, frequency and distribution of link failures to distinguish between broken (or poor quality) links from those experiencing temporary losses. The proposed work has been integrated with DSR without modifications.

The problem of route instability in multi-hop wireless networks has been presented in [6], the authors describe route flapping i.e. frequent route switching due to changing route metrics as the main cause of route instability. The authors in [7-13], suggested to use overhearing concept to build up backup routes. The suggested to use if the main route is fail. In [14], authors suggested to maintain multiple links between any two adjacent nodes in the route, the multiple links are created during a route discovery phase. If the primary link fails, an alternative link can be used. Even though this approach might reduce the time to locate the new route, when link is broken between mesh nodes itself, it might not be efficient because there is no guarantee that an alternate link is not down or also has bad quality due to changes in network conditions. A numerous of proposed works have been suggested for choosing a route based on route metrics [15, 16 and 17], the purpose of that is to mitigate route break, which might be results from bad quality of the link in the path.

3. Proposed Methodology for Enhancement of Route Maintenance in AODV over Hybrid Wireless Mesh Network

Route link failure in hybrid wireless mesh network, is one of the problems that AODV suffers. In such a network, the time taken to repair route by source node is high. If traffic is from gateway to the mesh client then this issue can degrade the network performance. The proposed technique applies mainly in the situation where route is broken between mesh clients and the local repair is not successful. We have proposed to use mesh routers to find out the new alternative route because the mesh routers have capability to buffer the data packets arriving from gateway. Further, mesh routers do not suffer from power problem as these have sufficient high capacity battery backup or use plug-on power supply and have minimum mobility, whilst mesh clients are equipped with limited capacity batteries.

The objective of our proposed work is to enhance route maintenance mechanism of AODV in hybrid wireless mesh networks. Mesh routers have more resources as compared to mesh clients. The proposed work is based on exploitation of these features of mesh router and is applied if local repair fails and border mesh router (i.e. the first backbone mesh routers that receive packets from mesh clients and same time is the last backbone mesh router that receives packets from the precursor's backbone mesh routers) receives error packets. When border mesh router receives an error packet from mesh client, it checks whether it is part of the route or not, by looking to destination address in the route table. If it is not a part of the route table, then error packets are discarded, otherwise, it checks a next hop. If the next hop is another border mesh router, it will drop RERR packet, but it will not mark the route as invalid, hence it continues to forward data packets to next border mesh router. Next border mesh router will buffer data packets, and start route discovery process, which is only exception from AODV. In AODV, an intermediate node will mark a route break as invalid in its route table. Figure.3 illustrates an example of this situation.

As shown in figure 3, border mesh router A receives RERR packet form mesh client C and finds that the next hop of route break is border mesh router B. As the next hop is a border mesh router, it suppresses RERR packet. In the meantime A forwards data packets to B, which will queue these data packets and start finding new route for unreachable destination. Other situations, which are handled by proposed methodology, are as follows:

- In case a border mesh router receives RERR packet (here we consider RERR packet is also broadcasting packet), and finds destination is mesh gateway and realizes that the link is broken in between intermediate mesh clients; the border mesh router will drop the RERR packet and mark this route entry in its route table as invalid. The purpose of dropping the RERR packet is to reduce the number of RERR packet from reaching backbone mesh routers as well as gateway. Hence routing overhead will reduce.
- In case a border mesh router finds that next hop is mesh client and realizes that the link is broken in between intermediate mesh clients and destination mesh clients, then it starts route discovery, then it starts route discovery process on behalf of the actual source node (i.e. gateway). It increments the sequence number for the destination and marks a route entry as invalid in rout table, and starts broadcasting RREQ packets for that destination (i.e. Mesh client). Border mesh router buffers data packets that came from gateway through predecessor mesh routers, which are involved in the route.

During route discovery process, other backbone mesh router might receive RREQ, in this situation, this backbone mesh router will drop RREQ packet, since, and we try to make the route discovery process by border mesh router invisible to the gateway, as reducing in the number of RREQ messages would significantly improve the overall performance. Although, it is possible that the backbone mesh router which is a member in the route, receives RREQ packets from border mesh router for new route and detects that the route break has occurred. But it will neither drop data packets nor mark the route as invalid and keeps forwarding data packets to next hop as shown in figure 4, which shows behavior of backbone mesh router A, when it receives RREQ packet from border mesh router B and detects that the link is down between mesh clients.

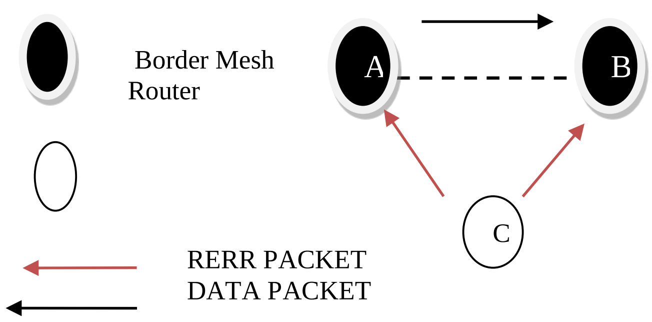

Figure 3: An Example of Our Work.

- The border mesh router might not be able to find the new route, and then it will generate RERR and send it to precursor backbone mesh routers towards gateway. Once the backbone mesh router receives RERR packets from border mesh router it marks up the route entry as invalid and make hop count as infinite, like in AODV Figure 5 gives a full picture for the process of route maintenance, where border mesh router stops error packets to be retransmitted again between mesh routers.

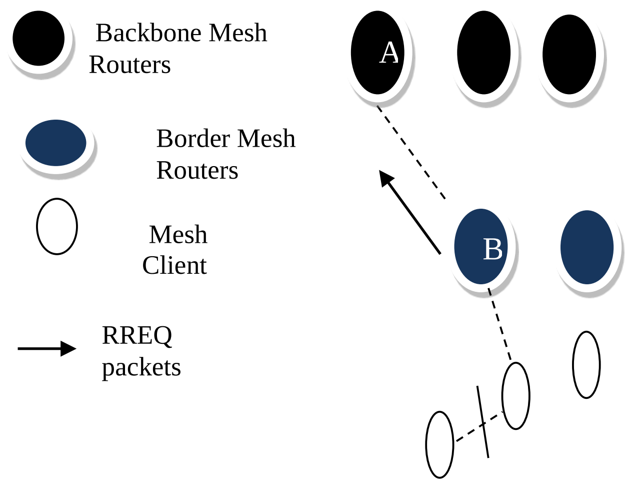

Figure 4: Behavior of Backbone Mesh Routers during Route Break Detection.

This approach helps in following:

- Reduction of number of RREQ packets that are generated by gateway to find out an alternative route. Thus routing overhead will be reduced in overall network.

- Alleviates the traffic at gateway and backbone mesh routers by reducing the number of RERR and RREQ packets which will subsequently reduce the possibility of congestion at gateway.

By using the proposed modifications, the mesh routers can utilize channel bandwidth to send data packets instead of error packets. Consequently the throughput will increase.
At the gateway, unicast and broadcasting control packets will decrease. This will also help to decrease, the probability of bottleneck incidence.
Total time taken to detect a route break and starting of the process of finding out new alternate route to the same destination by border mesh router is less than time taken by actual source node (i.e. gateway). Consequently, the total end-to-end delay will decrease. Border mesh router buffers data packets that come from gateway during the route discovery process.

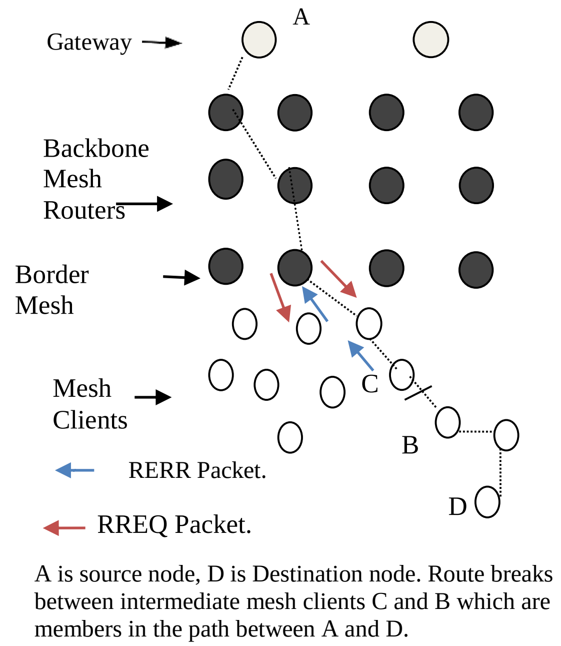

Figure 5: Route Maintenance in Proposed Work.

This approach avoids the drop in data packets; hence the number of lost data packets will decrease in overall network. Figure 6 shows a pseudo code implementation and Figure 7 illustrates flowchart of the proposed methodology.

4. Simulation Parameters

Our proposed work has been simulated by using network simulator version 2.33 [18] for evaluating the performance scenarios as shown in Figure11.

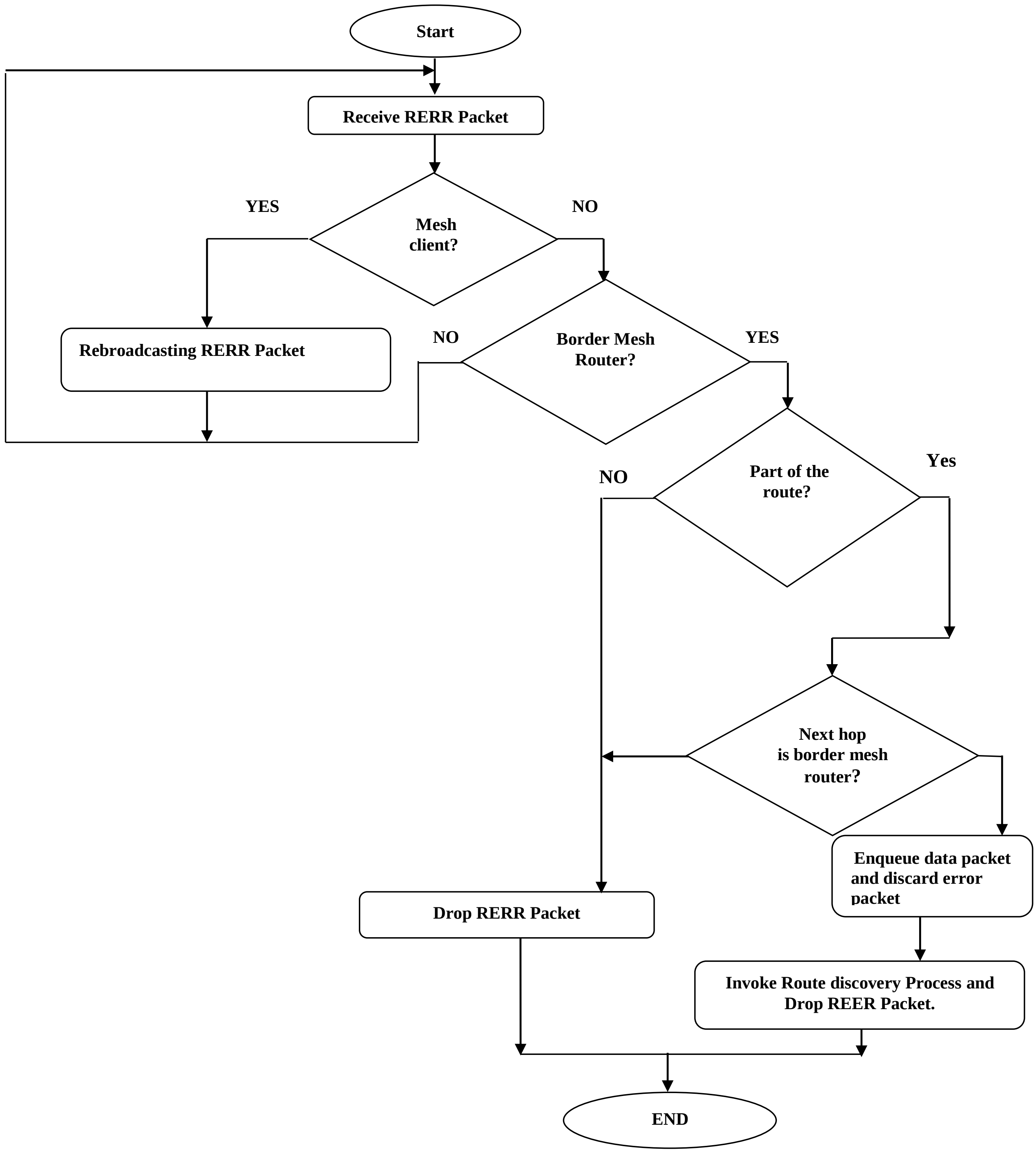

Figure 6: Flowchart of Modified Work.

```
// Initialization
Start
Receive RERR Packet
IF Mesh_Client  Then
{
Rebroadcast RERR packet.
}
ELSE
{
Look up rout table
if( destination is gateway )  Exist
    {
  if  next_hope is border mesh router then
    {
     drop RERR Packet()
     }
   ELSE
     {
      invoke Route Discovery Process
        enqueue Data Packet
      }
       ELSE
        {
     Drop RERR Packet ()
        }
     End
```

Figure 7: Pseudo code for Proposed work.

4.1 Assumptions of the Simulation:

While conducting simulation, following assumptions have been made:-

- Number of static mesh nodes has been fixed in all simulation scenarios as mentioned in table 1
- Flat topology has been used in all simulation.
- Number of mobile mesh clients have been considered as variant while studying the effect of network size and mentioned in table 1. It has been fixed, when we study the effect of pause time and mobile speed for mesh clients. The number of mesh clients has been chosen as 35 nodes.
- While studying the effect of network density and speed mobility, Pause time for mobile mesh client was fixed and kept as 0 second. It has been varied, while studying the effect of pause time, whose values are given in Table 1.
- Speed of mesh client has been fixed at 10m/s while studying pause time and network size. But, while studying the effect of mobility speed in mesh clients it has been varied as mentioned in Table 1.
- Most of the traffics are considering from gateway to the mobile mesh clients and from mobile mesh clients to gateway and also among mobiles mesh clients itself.

All simulation parameters which have been applied in this simulation environment are given in the table 1 and the simulation topology is illustrated in figure8.

Parameter	Value
Application Type	Constant bit rate (CBR).
Transport Type	User Datagram Protocol (udp).
Number of CBR connection	10.
Routing Protocols	AODV,our propsal work .
Simulation time	350 seconds.
Packet Size	128 bytes.
Packet sending Rate	1 Packets/Second.
Simulation area	1200m × 1200m.
Speed of mesh clients	5,10,15,20,25 (m/s)
Pause Time	0,10,20,30,40.
Number of gatewayes (i.e. assumed).	2.
Number of static mesh routers (i.e assumed).	16.
Number of mobility mesh clients .(i.e in case of network size scinario).	5,15,25,35,45,55,65.
Mobility model.	Random way point.
Propagation model.	TwoRayGround.
Transsmission Range.	250m.
MAC layer.	IEEE 802.11.
Antenna model.	Omni Antenna.

Table1. Simulation parameters.

4.2 Performance Metrics:

Following performance metrics have been considered in case of different number of mobile mesh client, varying speed mobility and different pause time.

1) Packet Delivery Ratio (PDR): it is defined as fraction between total amounts of data packets received successfully to total number of data packets generated.

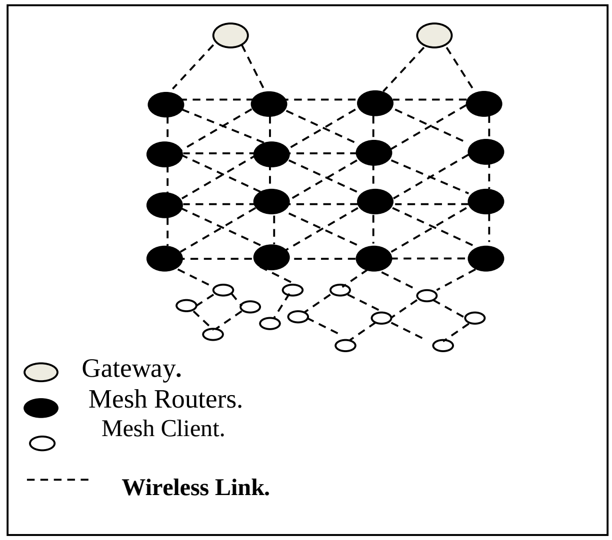

Figure 8: **Simulation Topology**

This metrics represents the span of reliability and efficiency of each routing Protocol. It can be expressed by following equation:

$$PDR = \frac{\sum_{i=1}^{n} P_r[i]}{\sum_{j=1}^{n} P_t[j]} \times 100 \qquad 1)$$

Where n is total number of nodes in path $P_r[i]$ is the total number of data packets, successfully received by the node i during simulation experiment. $P_t[j]$ is the total number of data packets has been generated and sent by the node j during simulation experiment.

2) Average Route Overhead: Indicates the ratio between total amounts of generating routing control packets of each successful received data packet to total number of successfully received data packet.

$$\text{Average Routing overhead} = \frac{\sum_{i=1}^{n} P_{Overhead}[i]}{\sum_{j=1}^{n} P_r[j]} \qquad 2)$$

Where $P_{Overhead}[i]$ is total number of routing control packets that generated for data packet by node i. The $P_r[j]$ is total number of successfully received data packet by node j.

3) Average Throughput: The average number of data packets delivered during a session.

Average Throughput= $\frac{\sum_{i=1}^{n} P_r[i]}{T_r - T_s}$ 3)

, where T_r is time at which packet is received by receiver T_s. The time at which packet is sent by sender.

4) Average end To end Delay (AEED) Total time takes by all data packets that travels from source to destination, to total number of successful received data packets (N).

AEED=End_to_End_delay $\times$1000(ms) 4)

Where

End_to_End_delay= $\frac{TDT}{\sum_{i=1}^{N} P_r}$ 5)

TDT=TDT+ $\sum_{i=0}^{N} delay[i]$ and

Delay[i]= $T_r[i] - T_s[i]$

5. Results and Discussion

The efficiency of our proposed M-AODV is compared with AODV. End to end delay, packet delivery ratio, route overhead and throughput have been considered as performance metrics for evaluation. Total connections between source and destination pairs are 10. Each source node generates and transmits constant bit rate (CBR) traffic. The packet size is 128 bytes with rate of 1 packet/s. All results are calculated from an average of above 100 runs with identical traffic models but randomly generated different mobility scenarios. Identical traffic and mobility scenarios are used across AODV and our scheme. We have used same assumptions and simulation parameters as mentioned in previous chapter.

The following three tests were conducted to evaluate the performance of the M-AODV with AODV:

1) Test 1: Impact of varying density of mesh clients.

2) Test 2: Impact of varying speed of mesh clients.

3) Test 3: Impact of varying pause time of mesh clients.

5.1 Test 1: Impact of Varying Density of Mesh Clients

To investigate the impact of network density, the number of mesh clients has been varied from 5 to 65. The maximum speed of mobility of mesh clients are 10 m/s and pause time is 0. The results of this scenario are shown in figures 9 to 13.

It is observed from figure 9, that with the increase in number of mesh clients, the end to end delay also increases. This increase is due to the fact that with the increase in number of mesh clients, the length of route from gateway to the mesh clients will also increase resulting in more number of hops. Hence due to the mobility of mesh clients, number of route breaks is high, which in turn increases the number of dropped data packets. Further, more number of error packets will be generated and time of retransmission of the dropped packets will also increase. The proposed modifications will reduce the delay time in comparison with the AODV. It is clear that when number of mesh client is 55, time delay is 73.985 millisecond for AODV, whereas it is 45.8136 millisecond with the proposed modifications, because time taken by error packets to reach gateway and repair is greater than time taken by error packets to reach border mesh routers. Our proposed work outperforms the AODV. The average reduction in end-to-end delay is by 13.395%.

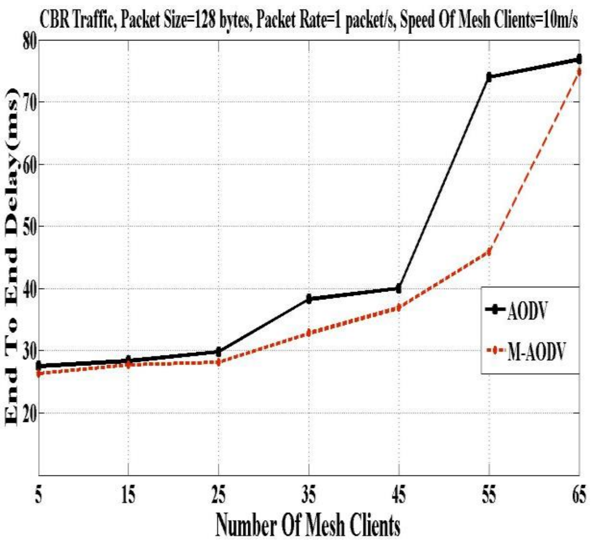

Figure 9: End- to-End Delay vs. Density of Mesh Clients.

It can be observed from figure 10, that as compared to AODV, the proposed modifications exhibit improvement in packet delivery ratio for varying number of mesh clients. With the increase in number of mesh clients, the packet delivery ratio decreases. Packet delivery ratio is also affected by number of lost packets in the network. The relationship between packet delivery ratio and lost packets is inversely proportional. One of the reasons for packet loss is route break, and the possibility of route break depends on number of hops in the route.

The 99.54 % packet delivery ratio is achieved in our experiments when number of mesh clients are 15, while in AODV it is 98.48%. Further, with 65 mesh clients, 98.39 % packet delivery ratio is achieved in our experiments, while in AODV it is 98.016%.The average improvement in PDR is by 0.1777%.

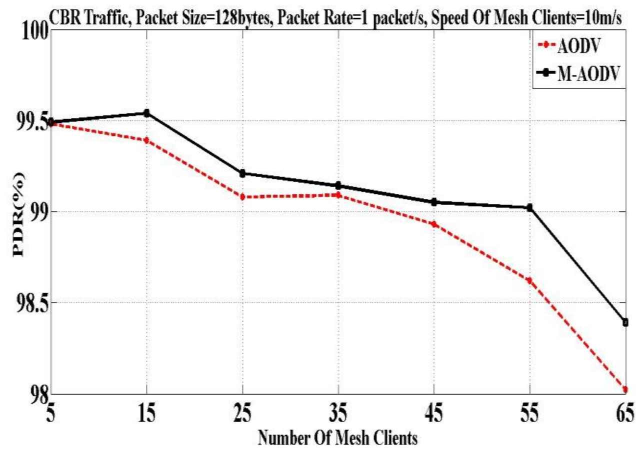

Figure 10: Packet Delivery Ratio vs. Density of Mesh Clients.

From figure 11, the number of RERR packets that retransmitted is reduced, due to proposed modifications, such as, the RERR packets travel lesser number of hops than AODV, Hence the total number of route packets overhead for all routes in the network is decreased. On an average, a reduction of 17.5% has been achieved in the total number of RERR packets generated and retransmitted in comparison with AODV.

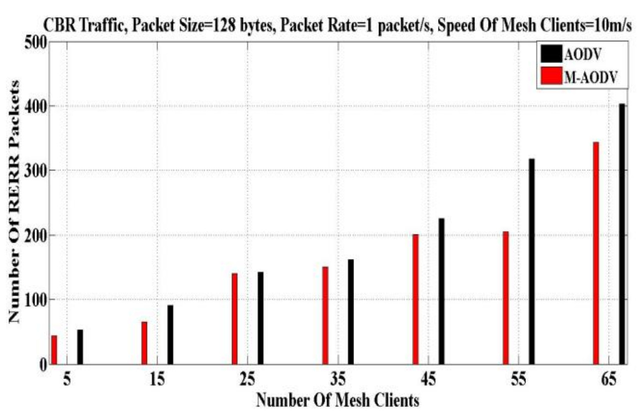

Figure 11: Total Number of RERR Packets Sent vs. Density of Mesh Client.

With the increase in number of mesh clients in the route, there are more hops and the chances of route break is high, when mesh client which is member in the route moves, and becomes out of the transmission range of other mesh nodes of same route. As such, with the increase in number of mesh clients in the route, the route packet overhead also increases. From figure 12, it can be

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observed that with the proposed modifications a slight reduction of 1.3189% has been achieved in routing packet overhead as compared to AODV.

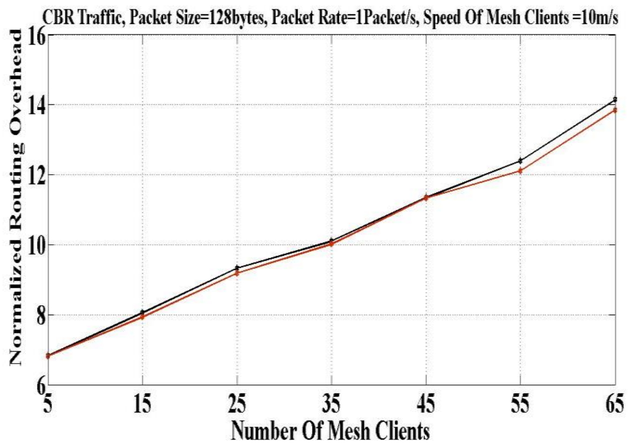

Figure 12: Normalized Routing Overhead vs. Density of Mesh Clients.

The proposed modifications prevent retransmission of error packets between mesh routers during a route break, which saves bandwidth. This bandwidth can be utilized for sending data packets or other control packets. In AODV, the RERR packets travel between mesh routers and the mesh routers use bandwidth for transmitting these packets. Because of the proposed strategy of not transmitting the RERR packets once it reaches border mesh router, a better throughput than AODV has been achieved, as it is evident from figure 13.

It is also observed that as number of mesh clients' increase, the throughput decreases because of the larger number of lost data packets. Even then, our proposed methodology successfully achieves a better throughput than AODV. An average improvement of 0.3915 % has been achieved.

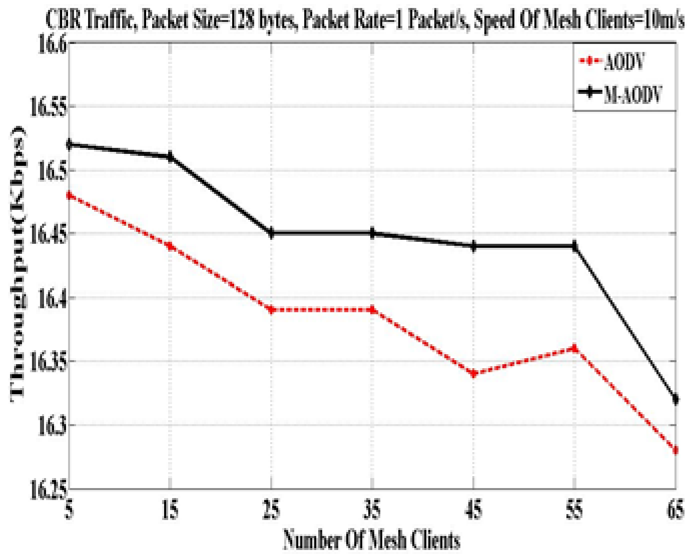

Figure 13: Throughput vs. Density of Mesh Clients.

5.2 Test 2: Impact of Varying Speed of Mesh Clients

In this test, the effect of the speed of mesh clients has been observed by varying the maximum speed from 5 m/s to 25 m/s with increments of 5 m/s. The results are shown in figures 14 to 18.

The end-to-end delay is caused due to frequent movement of mesh clients and loss of original route. The data packets have to wait at queue interface till a new route is established. Simulation results as shown in figure 14 reveal that end-to-end delay increases with the speed of mobility of mesh clients, both in AODV and modified AODV. Further, it can also be observed that the route recovery after route breaks is faster in the proposed scheme than AODV. At low speed (i.e. 5 m/s) end to end delay of 28.09ms has been achieved against 29.44ms of AODV. Further, at high speed (i.e. 25 m/s) end-to-end delay of 51.78 ms has been achieved against 58.55

ms of AODV. The proposed scheme reduces End-to-End delay for all values of speed.

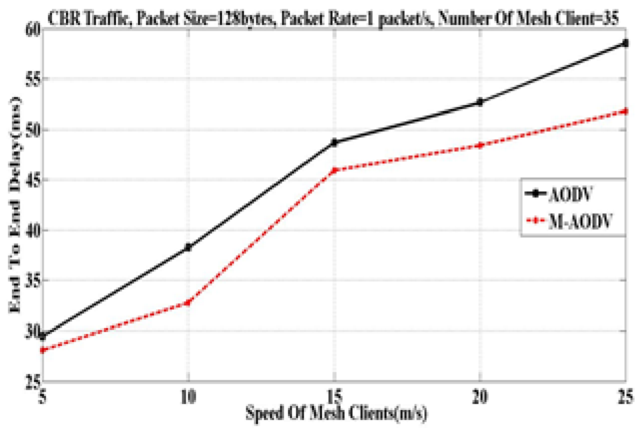

Figure 14: End-To-End Delay vs. Speed of Mesh Clients.

The packet delivery ratio (i.e. PDR) directly influences the packet losses. The simulation results in figure 15 reveal drop in packet delivery ratio with increase in the speed of mesh clients, because mesh clients are frequently moving and routes between mesh nodes break. AODV achieves a PDR of around 99.31% at 5 m/s speed of mesh clients, while modified work attains about 99.48%, at a speed of 25m/s. PDF of AODV is 98.07% while in modified work is 98.19%. The average improvement in PDR is by 0.223%.

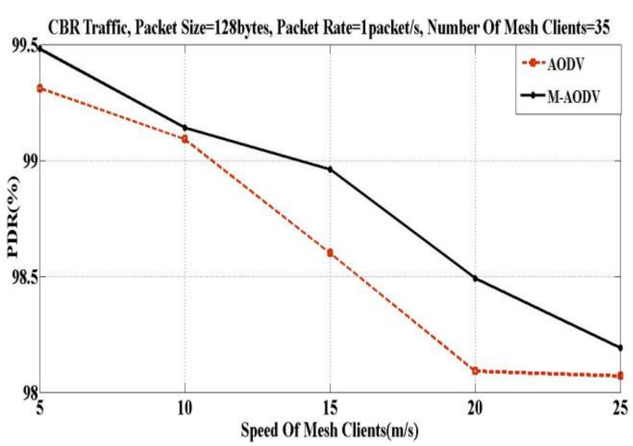

Figure 15: Packet Delivery Ratio vs. varying Speed of Mesh Clients.

Figure 16, summarizes the performances of AODV and the proposed methodology in terms of number of RERR packets sent at different speed of mesh clients. It is observed that with the increase in speed of mesh clients, the total number of RERR packets sent also increases, both in AODV as well as in the proposed approach. But, in spite of it, our scheme shows reduction in number of RERR packets sent in comparison with AODV. At a speed of 5m/s, total number of RERR packets sent in AODV for overall network is near 80 packets, while in the proposed approach it is 55 packets. The total reduction in number of RERR packets sent is about 17.622%, due to the strategy, that border mesh router will not retransmit the RERR packets towards a gateway.

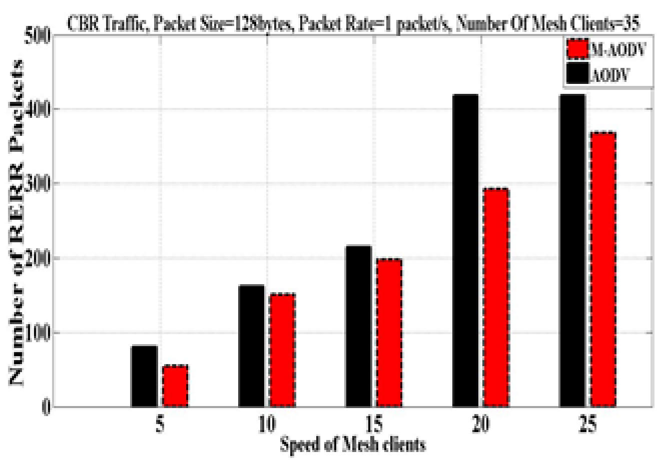

Figure 16: Total Number of RERR Packets That Sent vs. Speed of Mesh Clients.

Frequent movement of mesh clients will result in disconnection in the links between mesh clients in a route. Therefore RERR, RREQ and RREP packets will recall for route repair locally or try to find a new route. The proposed modifications constrict the flooding of RREQ, RERR and RREP packets in the network. Further, the reduction in the number of RREQ and RERR packets would significantly improve the overall performance.

Figure 17 illustrates the amount of normalized routing packet overhead on different speed of mesh clients. It is obvious from the Figure 17 that with an increase in speed of mesh clients normalized routing overhead will also increase. But with the proposed approach an average reduction in overhead of about 1.934% has been achieved.

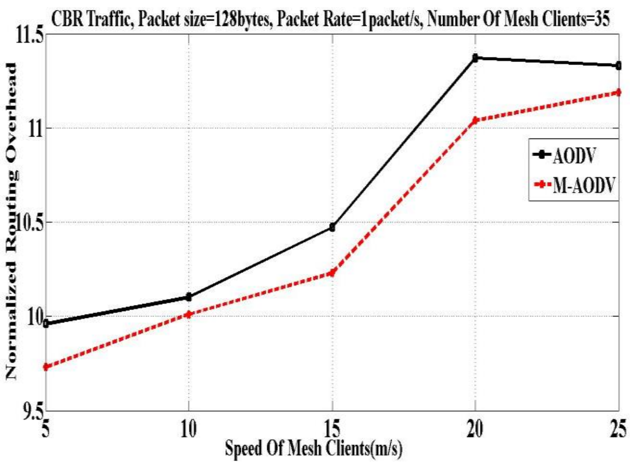

Figure 17: Normalized Routing Overhead vs. Speed of Mesh Clients.

In the proposed approach, an intermediate border mesh router buffers data packets when it searches a new alternative route, and destination mesh clients become unreachable via primary route. Thus, number of data packets lost in the network with the proposed approach is less than the number of packet lost in AODV. The degradation of the throughput in AODV and modified AODV is primarily attributable to speed values of mesh clients, as shown in figure 18. Our proposed approach has better performance for all values of speed. The enhancement of throughput achieved on an average is 0.464%.

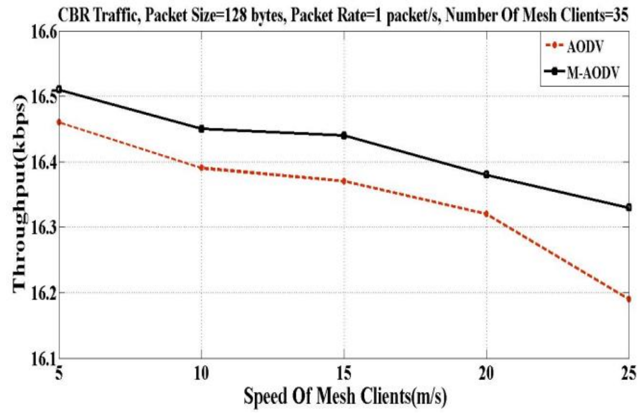

Figure 18: Throughput vs. Speed of Mesh Clients.

5.3 Test 3: Impact of Varying Pause Time of Mesh Clients

In this study, the pause time of mesh clients is varied. The number of mesh clients is 35 and their speed is fixed at 10 m/s. The simulation results are plotted in figures 19 to 23. It has been observed that if pause time is high; routes between sources and destinations are more stable.

From the simulation results of figure 19 it is observed that increase in pause time causes drop in end to end delay. In all cases, the proposed approach demonstrates significantly lower end to end delay than that of AODV. An average reduction of 8.859% in end to end delay has been achieved. Our modification can also find a new route with less hop count than AODV.

International Journal of Computer & Information Technologies (IJOCIT)
Corresponding Author: *M. Meftah Alrayes*
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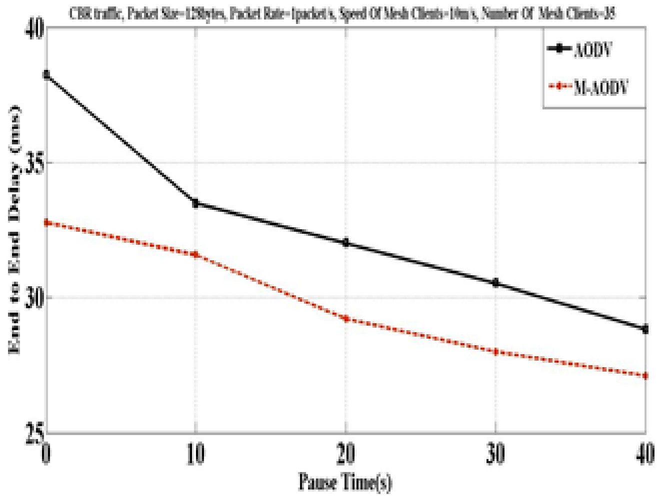

Figure 19: End-to-End Delay vs. Pause Time.

In figure 20, the lower packet loss incurred by modified AODV is able to achieve a slightly higher packet delivery ratio (PDR). An average increase of 0.054% for PDR has been achieved as compared to AODV.

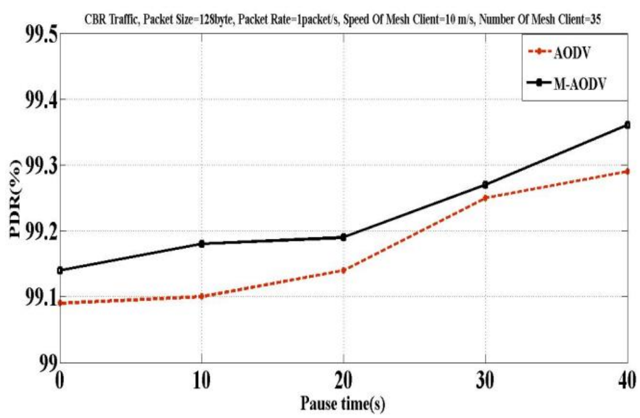

Figure 20: Packet Delivery Ratio vs. Pause Time.

The reduction in RERR packets will significantly affect routing load as shown in figure 21 and routing load in overall network of modified AODV is less than routing load in overall network for AODV. Figure 21 shows the number of RERR packets sent for different pause time and it is observed that with the proposed scheme an average reduction of 7.126% for RERR packets sent has been achieved as compared to AODV.

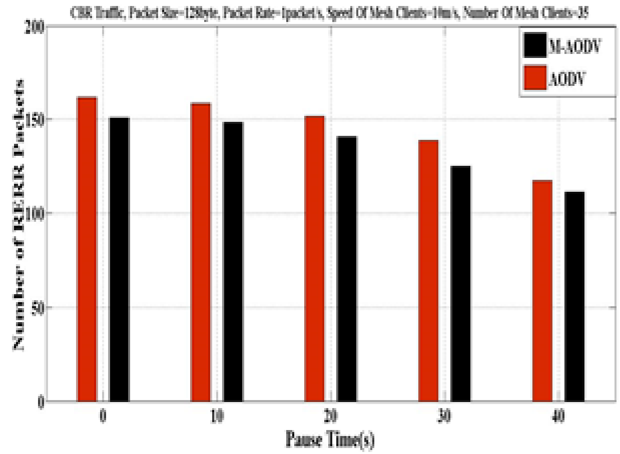

Figure 21: Total Number of RERR Packets Sent vs. Pause Time.

Further the total average of routing overhead is reduced by 0.78%, as shown in figure 22.

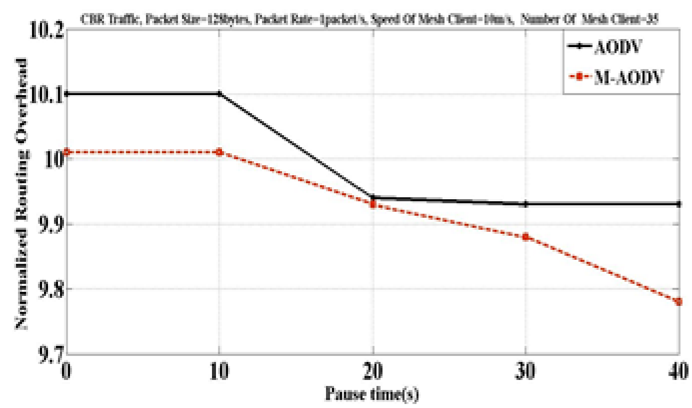

Figure 22: Normalized Routing Overhead vs. Pause Time.

6 Conclusion

The proposed objective to enhance the AODV in hybrid wireless mesh networks for route maintenance capabilities have been achieved by exploiting the following features of mesh router.

- Mesh routers are static and mesh clients are mobile for most of the time.
- Mesh routers do not suffer from power problem as these have sufficient high capacity battery backup or use plug-on power supply, and as such there is no

constraint of power consumption on mesh routers, whilst mesh clients are equipped with limited capacity batteries.

The proposed modifications focuses on the route breaks between mesh clients, where source is gateway, destinations are mesh clients, and path length is high.

Further, the proposed modifications help in preventing the bottleneck problem at internet gateway and backbone mesh routers. The prevention is done by reducing the number of RERR and RREQ packets that are being forwarded via border mesh routers. Reducing the number of RREQ messages and RERR packets would significantly improve the overall performance. Border mesh router has capability to buffer data packets that are incoming from gateway instead of dropping it, so that, the number of lost packets will be reduced in overall network. Also, in the event of link break between two mesh clients, the number of hops that RERR and RREQ packets are crossing in the proposed modification is lesser than the number of hops being crossed by RERR and RREQ packets in AODV. Also an alternative route is being created by border mesh routers to reduce the average route acquisition latency, and subsequently the end to end delay in overall network.

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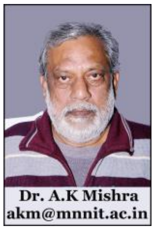

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