IMAODV: A Reliable and Multicast AODV Protocol for MANET

Srinivas Sethi
Department of Computer Science and Engineering
Indira Gandhi Institute of Technology, Sarang
Orissa, India
Email: srinivas_sethi@igitsarang.ac.in

Siba K. Udgata
Department of Computer and Information Sciences
University of Hyderabad
Hyderabad, India
Email: udgatacs@uohyd.ernet.in

***Abstract* – A Mobile Ad hoc Network (MANET) can allow mobile nodes to setup a temporary network for instant communication without any fixed infrastructure. Mobile nodes dynamically exchange data/ information among themselves without any fixed base station. Many networking applications such as video conferencing, video-on-demand services, and distributed database replications require multicast communications. Providing reliable multicast is one of the basic requirements to develop better routing protocols which is used for disaster management, emergency relief, mobile conferencing among many other applications. As mobile host changes its access point over a time interval, multicast routes have to be updated frequently. This poses several challenges to provide an efficient multicast routing. In this paper, we propose an Improved Multicast Ad hoc On Demand Distance Vector (IMAODV) protocol based on Ad hoc On Demand Distance Vector (AODV) and Multicast AODV (MAODV) protocol to support reliability and multicasting for on-line routing of delivery-guaranteed multicasts. Exhaustive simulation experiments reveal that, proposed IMAODV performs better in terms of Packet Delivery Ratio (PDR), average End-to-End delay and Network Routing Load (NRL) compared to both AODV and MAODV for high mobility rate and large network grid size.**

Keywords: Mobile Ad hoc Network, Multicasting, Reliable, AODV, MAODV.

I INTRODUCTION

A MANET can be defined as a set of mobile nodes that communicate using the wireless medium, and do not require any pre-existent infrastructure. All nodes behave as router and take part in discovery and maintenance of the route to other node(s) in network. Without the fixed base station the mobile nodes dynamically exchange data among themselves. Traditional routing protocols in static networks are not efficient for Ad hoc networks, because the network topology is unstable and changes frequently with node mobility. Ad hoc network can be used in rescue operation, video conferencing, meeting conventions to share information quickly and timely. In Ad hoc networks, nodes are not familiar with the topology of their networks and are required to discover the topology. A new node may announce its presence and should listen for announcements broadcasted by its neighbors. Each node learns about neighboring nodes and the route to reach them. Multicasting has more benefits as compared to unicasting. It reduces communication cost for applications which need to send the same data packets to multiple destinations instead of sending via multiple unicast. It also reduces the channel bandwidth, sender and router processing and delivery delay. However, to an extent multicast can utilize the wireless link efficiently by exploiting the inherent nature of broadcast property. A number of multicast routing protocols like Multicast Ad hoc On-demand Distance Vector (MAODV) [4][10], On Demand Multicast Routing Protocol (ODMRP)[3] among many others are proposed and normally used in Ad hoc network.

AODV [9] is uniform and destination based reactive routing protocol. It uses table driven routing framework and destination sequence numbers for an on demand protocol. It uses traditional routing tables with one entry per destination. It minimizes the number of required broadcasts, by creating routes on demand basis. For nodes which are not selected in the path, AODV do not maintain any routing information or do not take part in the routing table exchanges. AODV prepares loop free routes. It provides unicast, multicast and broadcast capabilities to all nodes. It disseminates information about link breakage to its neighboring nodes.

It uses this information to minimize the broadcast of control packets. A routing table expires if not used recently. AODV uses destination sequence numbers to ensure that all routes are loop-free and it contains the most recent information. Each node has its own sequence number and broadcast-id. The sequence number is used to indicate the freshness of routing information and to prevent routing loop. All routing packets carry these sequence numbers.

The broadcast-id is incremented whenever nodes initiate a route request and the protocol identifies the route request together with node IP address. The source node includes its own sequence number and broadcast-id in the route request and the most recent sequence number for the destination. Intermediate nodes do reply only if they have a route to the destination, whose corresponding destination sequence number is equal to or greater than that contained in the route request. A set of preprocessor nodes are maintained for each routing table entry, indicating a set of neighboring nodes which used to entry to route data packets. These nodes are notified with Route Error (RERR) packets when the next hop link breaks. MAODV [4][10] is multicast extension of AODV. It discovers Multicast routes on demand. The multicast is similar to unicast route request and route reply propagates back from nodes that are members of multicast group. In MAODV, every node maintains two routing tables. One routing table is used for unicast operation of AODV and is used for unicast route discovery. The other one is used for Multicast routing information storage. Every node, that is a router for a multicast group maintains a multicast route table entry for that group. A bidirectional shared tree is formed which consist of members of the multicast group and intermediate nodes for every multicast group. Each multicast group has a group leader associated with it, where as the group leader maintains and disseminates the multicast group sequence number. Here also the sequence number is used to indicate the freshness of routing information for the multicast group

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and to prevent routing loop. MAODV offers quick adaptation to dynamic link conditions, low processing and memory overhead, and low network utilization.

Xie et. al. extended IEEE 802.11 a Round Robin Acknowledgement and Retransmit (RRAR) [1] protocol to improve the reliability of broadcasting. They test the reliability with PDR and throughput. They introduced the RRAR with ODMRP and shown the improved performance of their protocol. But, the performance of MAODV can still be improved by introducing the acknowledgement from receiver to sender. The sender can resend the data packet if it failed to be delivered correctly. The different performance evaluation parameters can be compared with AODV, MAODV.

Pbcast protocol [2] is a new option in scalable reliable multicast protocols that offers throughput stability, scalability and a bimodal delivery guarantee as the key features. The authors discuss the throughput stability of reliable multicast protocol. But, they have not discussed about reliability in terms of PDR.

In [7], authors studied the MAODV based on mobility prediction. According to their simulation results, MAODV reduces the end-to-end delay effectively and enhances the real time characteristics. By estimating neighbor node's distance, the sender node can control its route. By predicting the neighbor node's mobility, it can also adjust to the fast changing network topology. This mechanism reduces the end-to-end delay effectively. But this paper does not discuss about the guaranteed packet delivery.

RMAODV [6] describes the reliable use of packet delivery ratio for multicast routing protocol. But it ignored important performance evaluation parameters like NRL and end-to-end delay by increasing the PDR. Further it may increase the end-to-end delay if nodes, which are far away from the existing tree root node, wish to send packets to its multicast group. In the high mobility and large area grid size, the RMAODV also encounters low packet delivery ratio with more end-to-end delay due to the frequent network topological change. Our goal in this work is to overcome such disadvantages and to make it more robust for high mobility ad hoc networks.

In this paper, MAODV and AODV are considered for comparison with proposed IMAODV. Communication link that exists between sender node, or some intermediate router node, with other multicast tree nodes, but may not belong to multicast tree edges are known as "potential communication links" [8]. If "potential communication links" are used to deliver packets, the packet end-to-end delay can be reduced for some of the multicast group receivers. It is also possible to use "potential communication links" to retransmit the same packets after receiving negative acknowledgements from the receivers. Since the packet delivery ratio which is an important measure of reliability for IMAODV, the source node retransmits the same packet again, if the data packet is not delivered correctly. By using this and potential communication links, the packet delivery ratio is significantly improved along with end-to-end delay and NRL. In this paper, all important performance evaluation parameters like NRL and End-to-End delay with different expected PDR range has been considered. It is observed that, the IMAODV performs better as compared to AODV and MAODV.

This paper is organized as follows: Section II has a detailed discussion on proposed work. In Section III, we describe the performance evaluations parameters followed by experiment and simulation in Section-IV. Observations and discussions are discussed in Section-V followed by conclusions in Section VI.

II PROPOSED IMPROVED-MAODV (IMAODV)

MAODV [4] [10] has multicasting capability where as proposed IMAODV (Improved Multicast Ad-hoc On Demand Distance Vector) has multicasting and reliability capability in high mobility rate and large network area. It is a shared tree based protocol. It builds multicast trees on demand to connect group members. As nodes join the group, a multicast tree composed of group members is created. Multicast group membership is dynamic and group members are routers in the multicast tree. Link breakage is repaired by downstream node broadcasting a route request message. It offers quick adaptation to dynamic link conditions, has low processing and memory overhead, and low network utilization. IMAODV creates bi-directional shared multicast trees and these trees are maintained as long as group members exist within the connected portion of the network. Each multicast group has a group leader that maintains the group sequence number, which is used to ensure freshness of routing information [10]. It enables dynamic, self-starting, multi-hop routing between participating mobile nodes in wishing to join or participate in a multicast group within an ad hoc network. IMAODV enables mobile nodes to establish a tree connecting multicast group members. It responds quickly to link breaks in multicast trees by repairing in time. Multicast trees are established independently in each partition, and trees for the same multicast group are quickly connected if required. Many of the configuration parameters used by IMAODV are based on AODV [9] and MAODV [10]. It discovers the route only when required. Every multicast group is identified by its own unique address and group sequence number. If node is not a tree member, it will check its Unicast Route Table to find the next hop for the multicast address. If it has the information, the data packets are forwarded towards the next hop; otherwise, it will send an unsolicited Route Reply (RREP) back to the source node. If the node itself is a tree member, it will follow its Multicast Route Table to forward the packets. Group-Hello message (GRPH) broadcasted throughout the whole network, to indicate the existence of group. When a non-member node receives GRPH first time, it tries to join the group. A new group leader is selected for partitioned tree or when the group leader revokes its group membership. In the event of selection of a new group leader, each node must update its Group Leader Table to indicate newly elected/ selected group leader.

If a node wishes to send multicast data packets to its multicast group and this node is close to the existing shared-tree root node, it delivers its data packets along the original shared-tree; If a node wishes to send multicast data packets to its multicast group and this node is far away from the existing shared-tree root node, it initiates a new route discovery. If there exist some potential communication links [8] between any pair of existing nodes which are on the existing tree, and these potential communication links can be used to deliver data from the new source node, they are called forwarding path with respect to the new source node.

When a source node that is far away from the group leader, it initiates the new forwarding route discovery; forwarding table will be set up for the nodes that are involved in new route discovery and forwarding path establishment. The new forwarding table will contain Source Node IP Address; Next Hops; Group Leader IP Address; Hop Count to Source Node. In the defined forwarding table, source node is the node that initiates a new send and next hops are a list of both the upstream and downstream link nodes. Each next hop contains two fields: next hop IP address and link direction. Link direction is determined upon whether a Forwarding Query Message is received from a requesting node. UPSTREAM indicates receiving and DOWNSTREAM indicates forwarding. Hop Count to Source Node is the number of hops away from source node. If a node is involved in forwarding new data, this forwarding table will be maintained as long as the sending session of the source node continues. After the source node completes its own sending, the forwarding table will be invalidated.

The Query Message consist of dest_addr, hop_cnt, hop_cnt_diff, broadcast_ID, mgroupLeader_addr and the Forwarding Reply Message that contains information like dest_addr, lastHop_addr, source_addr, mgroupLeader_addr. Where dest_addr is the IP address of multicast group and the hop_cnt is the number of hops that current node is away from the source node. hop_cnt_diff is the distance of the responding node from the last node on the shared multicast tree. Broadcast_ID is used to identify the RREQ each time it is generated by a source node. mgroupLeader_addr is the address of the multicast group leader. The source_addr is the address of the initiating source node and lastHop_addr is the address of last hop node.

To establish new forwarding path within the vicinity of the existing shared tree to reduce the average end-to-end delay. Hence, the new route discovery will be exploited when a node that is far away from the group leader wishes to send data. In our proposed protocol, the existing shared tree established by the group leader is maintained for use such as grafting a new branch, pruning an existing branch, forwarding data packets that originated from the group leader or nodes close to group leader, and repairing a broken link. When a link along the forwarding path breaks, the node downstream of the break is responsible for repairing the link. This is similar to repair in MAODV. The downstream node initiates the repair by broadcasting a RREQ with source_addr set to the new source node. When a node on the new forwarding tree receives the RREQ, it can reply to the RREQ by unicasting a RREP back to the initiating node. RREP forwarding and subsequent route activation with the MACT message are handled similarly as in MAODV.

It will test for reliability of packet delivery (i.e. verify weather packet is received correctly or not by the receiver). The reliability in terms of the packet delivery ratio has been measured. We consider that more the PDR more is the reliability. We implement an Acknowledgement-Retransmit mechanism to ensure correct delivery of the data packets at the receiver node. If the data packet could not be delivered or get delayed, the sender node will not get the acknowledgement from the receiver within a pre-specified time quantum and will be retransmitted again. In case of failure in the transmission, the data packet will be retransmitted once again and this approach improves the packet delivery ratio and reliability as compared with MAODV. The detailed procedures in our work are described below.

<u>Procedure: local search</u>

```
Begin
 If (hop_count > p_value)
   Begin
      Call Query_Message( Source_addr, Cente_ add, lastHo_ addr, Dest_addr,Hop_cnt, Hop_cnt_diff);
      Call Forwarding_Table( Source_Node_IP_Address, Group_Leader_IP, Hop_count);
      Call Broadcast(Forwarding_Query_Message);
   End
Else
Deliver_data();
End
```

<u>Procedure : Forwarding Query Message</u>

```
Begin
If(recv_ time_FQM=1 and Ho_ cn_ diff<local_radius)
    Begin
       Call Update_Forwarding_Query_Message( Hop_ cnt, hpp_ cnt_ diff);
       Call Forwarding table( Source_Node_IP_Address, Group_Leader_IP, Hop_count);
       Call Broadcast(Forwarding_Query_Message);
    End
Else
    Call Discard_Forward_Query_Message();
End
```

<u>Procedure: Forwarding Query Message</u>

```
Begin
If (hop_ cnt_ diff<=local_radius and  node_in_shared tree==”True”)
      Begin
          Call Forwarding_Table( Source_Node_IP_Address, Group_Leader_IP, Hop_count);
          Call Unicast_ Forwarding_Reply_Message();
Update_Forwarding_Query_Message( Hop_ cnt, hop_ cnt_ diff);
          Call Broadcast(Forwarding Query Message)
      End
```

```
Else if(  Hop_ cnt_ diff<=local_radius and
node_in_shared tree==”False”)
        Call Broadcast(Forwarding_Query_Message);
Else
        Call Discard_Forward_Query_Message();
End
```

Procedure: Forwarding Reply Message

```
Begin
    If( source_address <> dest_ addr)
    Begin
        Call Update_Forwarding_Reply_Message(
lastHop addr, source_address);
       Call Unicast_Forwarding_Reply_Message();
     End
Else
  Call Discard_Forwarding_Reply_Message;
End
```

Procedure: RREQ

```
Begin
    If(recv_ time_RREQ==1)
       Call Establish_ MRT (Source_Address,
Group_Leader_Address, Hop_Count);
    If(lastHop addr== group_member);
      Begin
       Call Sends_RREP(source node);
       Call Broadcast(RREQ);
     End
Else
   Call Discard RREQ;
End
```

Procedure: RREP

```
Begin
If(recv_ time_RREQ==1)
     Begin
         Call activates_ MRT(Last_hop_addrs);
         If( dest addr_RREP<> node_addres)
           Call  Relay_RREP();
         Else
          call  Discard_RREP();
         End if
Else
   Call Discard_RREP();
End
```

Procedure : packet_retransmission

```
Begin
  Call Delete_link()
  If(pkt_type =data_pkt Or pkt_id=Bcast_id)
            call drop(Pkt);
 call link_break(Pkt);
  if (route_not_down)
          call   Send(Pkt);
  call local_repair()
    if  (route_flag_not_down  Or  route_retry_time  =  0)
 Route_retry_time=1
            call Send(Pkt)
 End
```

III PERFORMANCE EVALUATION

In this paper, Packet Delivery Ratio, End-to-End delay and Normalized Routing Load are considered to compare the performance of IMAODV, a multicast and reliable routing protocol with AODV and MAODV.

Packet Delivery Ratio (PDR): PDR is used to measure the reliability. It is defined as a percentage of data packets delivered to that of no. of data packets sent for that node. The Average PDR is calculated by considering all the nodes in the network.

$$PDR = \frac{\sum \text{No. of received packet by CBR sink}_i}{\sum \text{No. packets sent by CBR source}_i} * 100$$

This performance evaluation parameter measures effectiveness, reliability and efficiency of a protocol.

End-to-End delay: Average End-to-End delay includes all possible delays caused by buffering during route discovery latency, queuing at the interface queuing transmission delays at MAC, and propagation and transfer times of data packets. It is measured as the time elapsed from the time when a multicast data packet is originated from a source and it is successfully received by all multicast receiver.

Normalized Routing Load (NRL): The number of route control packets per data packet delivered at destinations. Normalized Routing Load is important to compare the scalability of the routing protocols, the adaption to low bandwidth environments and its efficiency in relation to node battery power (in that sending more routing packets consumes more power). Sending more routing packets also increases the probability of packet collision and can delay data packets in the queues.

In this paper, through simulation we measured all these parameters for performance comparison purpose. Exhaustive simulation experiments are carried out with different mobility rates, varying the area of operation i.e. the grid size in the MANET.

The improved reliability in broadcasting or multicasting ensures better performance of the proposed IMAODV protocol in terms of improved PDR. For time sensitive application such as audio or video conferencing, time delay cannot be neglected. So we tried to improve the performance with respect to end-to-end delay. We also examined on scalability by calculating the NRL. Except few cases, the IMAODV is better with respect to NRL. We simulated all three protocols viz. AODV, MAODV and IMAODV with different combinations of mobility rate; varying grid size. It evaluates the performance improvement achieved with IMAODV in comparison to AODV and MAODV protocol.

IV SIMULATION EXPERIMENTS

Exhaustive simulations are carried out for performance evaluation and comparison using NS-2 simulator [11] under Linux operating system. The simulation parameters are mentioned in Table-1. The NS-2 instructions are used to define the topology of the network, movement of nodes and to configure source and receiver. Continuous Bit Rate (CBR) traffic sources are used with fixed 512-byte data packets. The source-destination pairs are spread randomly over the network.

Table -1: Simulation Parameters

S. No.	Parameters	Values
1	Area size	500x500 m, 1000x1000 m, 1500x1500 m, 2000x2000 m.
2	Transmission range	250 meters.
3	Nodes	50 Nos.
4	Simulation time	900 secs.
5	Nodes speed	1,5,10,15,20 m/s
6	Pause times	10 s
7	Data rate	1 Kbps
8	No. of experiments	5 times.

V OBSERVATIONS AND DISCUSSIONS

With respect to End-to-End delay, it observed that, AODV performs better than both MAODV and IMAODV. Since multicast protocol deals with number of receivers, the end-to-end delay is expected to be more in comparison to simple unicast. IMAODV perform better than MAODV in terms of end-to-end delay as the new route discovery and forwarding path minimize the hop between source and root. Fig. 1(a) shows that increase in the end-to-end delay is not significant for the grid size up to 1500 X 1500. But the end-to-end delay is significantly more in MAODV compared to IMAODV from the grid size 1500 X 1500 which is considered as very large area. From Fig. 1(b) it is observed that, AODV is better than others and MAODV takes more delay to deliver the data packet as compared to IMAODV. In case of different node mobility rate, AODV performs better than two multicast routing protocols (MAODV and IMAODV) but AODV does not support multicasting as it is. But, Comparison of MAODV and IMAODV reveals that IMAODV perform marginally better than MAODV.

From Fig. 2(a), it is observed that Normalized Routing Load (NRL) of MAODV is low only up to 1000x1000 grid sizes. But the IMAODV is better than MAODV 1500x1500 onwards in term of NRL. Fig. 2(b) reveals that the performance of IMAODV in respect to NRL is better than others except 5 m/s and 20 m/s of mobility rate. In the case of 5 m/s MAODV is better than others (AODV as well as IMAODV) and AODV is better than other multicast routers (MAODV as well as IMAODV) at 20 m/s mobility rate. But AODV does not support multicasting. The performance of IMAODV is better in all case except 5 m/s as compared to MAODV.

For reliability in multicasting, we used PDR as the performance evaluation parameter. It is observed that, the packet delivery ratio of IMAODV is much better than AODV and MAODV in all possible combination of grid size and mobility rate. This shows that the proposed IMAODV protocol is considered to be more reliable in compared to MAODV and AODV. Fig. 3(a) shows that IMAODV performs better in case of all grid sizes as compared with AODV and MAODV. As per Fig. 3(b), for all mobility rates, the PDR of IMAODV is better than both AODV and MAODV.

Thus the performance of IMAODV in term of PDR is significantly better corresponding to every grid size and mobility rate, particularly in high mobility rate and large network.

VI CONCLUSIONS

The guaranteed data delivery services are important for reliability of a MANET. This problem is more challenging in case of multicasting. In this paper, the reliability of Multicast Ad hoc On Demand Distance Vector in term of Packet Delivery Ratio has been discussed. Comparison of the IMAODV with AODV and MAODV routing protocols under different mobility rates, and area size, reveals that PDR is much better in case of proposed IMAODV with better end-to-end delay and network routing load. Thus, it can be concluded that IMAODV protocol is suitable for reliable and time sensitive multicasting in MANET environment.

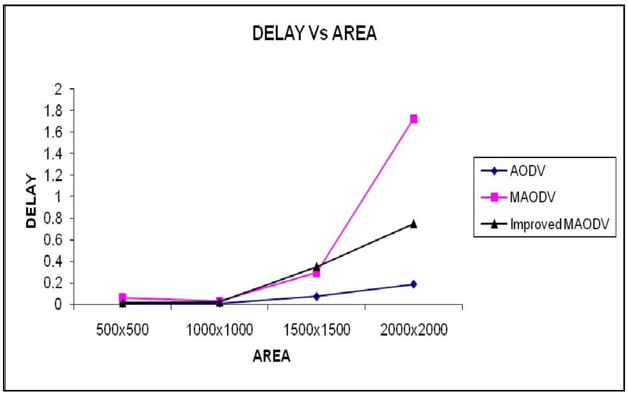

Fig. 1 (a): Delay Vs. Area for mobility rate=5m/s

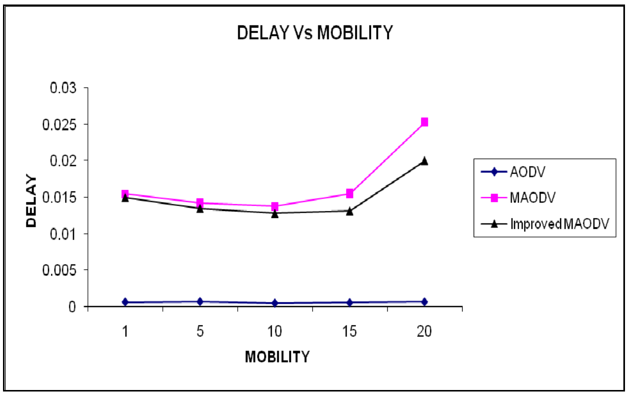

Fig. 1 (b): Delay Vs. Mobility rate for 1000X1000 grid

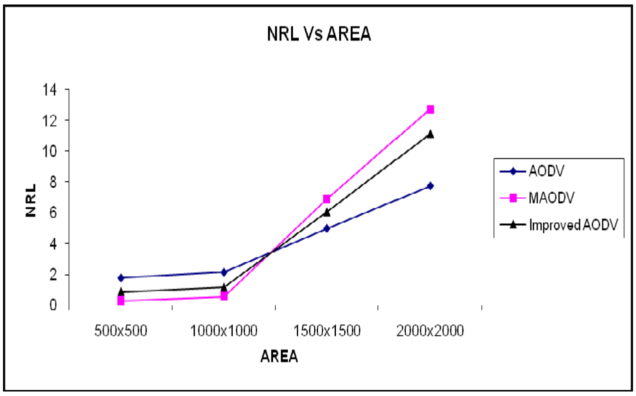

Fig. 2 (a): NRL Vs. Area for mobility rate=5m/s

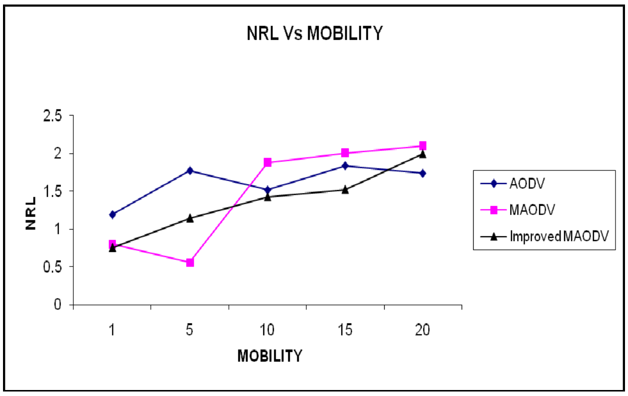

Fig. 2 (b): NRL Vs. Mobility rate for 1000X1000 grid

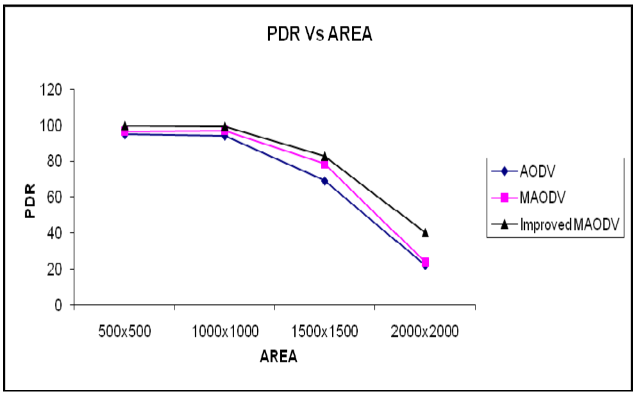

Fig. 3(a): PDR Vs. Area for mobility rate=5m/s

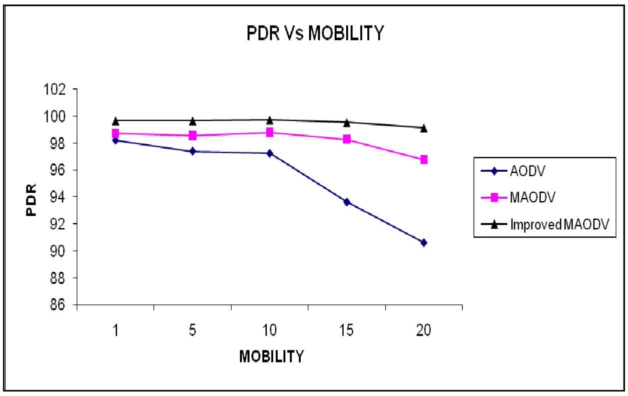

Fig. 3(b): PDR Vs. Mobility rate for 1000X1000 gr**id**

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