International journal of imaging science and engineering

ISSN: 1934--9955 www.ijise.net

Vol-08 Issue-01 March 2013

New and Improved AODV MANET Routing Protocol for AMR-Based Multiple Path Discovery

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Article Info

Received: 17-12-2012 Revised: 21 -01-2013 Accepted: 06-02-2013 Published:15/03/2013

Abstract : In order to improve scalability and decrease transmission time using the AODV MANET routing protocol, this research article aims to build a technique for discovering numerous routes. This work presents an updated AODV Protocol technique that aims to find many pathways to a target node simultaneously. We run simulations on both the standard version of AODV and the modified version, AMR-AODV, to ensure that this method is valid and accurate. The examination of several factors, such as packet delivery ration, routing overhead, number of nodes, terrain range, mobility speed, and mobility model, allows for the comparison and analysis of simulation results. Although AODV is still superior in certain situations, this study concludes that AMR-AODV performs much better than basic AODV in many others.
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Keywords: AODV, AMR-AODV, MANET, MOV, RD, RD Discovery, and Routing Overhead

1. Introduction

2. MANETs are networks of autonomous nodes that move around at random and communicate with one another using wireless networks; they don't need a central hub to function. Researchers have been diligently working on MANET routing protocols since the 1970s, and although protocols like AODV, DSR, and DSDV have been developed, there is still a need for more. It takes time to find a new route in the event of a link failure, inadequate bandwidth, security threats, packet loss, hidden terminal issues, routing overhead, power restrictions, and so on are all problems that continue to plague MANET transmission. In addition to significantly increasing overall transmission time, this route search procedure also uses up network capacity. Based on the findings from the simulations conducted using Network Simulator 2.33, this study endeavors to improve upon AODV by creating a new version that addresses its shortcomings in terms of Alternate Route Discovery. To address these issues, we try to rewrite the AODV algorithm. In order to back up the algorithmic work, AMR-AODV is simulated and compared to the basic AODV in terms of performance [Royer, Elizabeth M. et. al (2000)].

3. MANET Routing Protocols

Ad hoc Routing Protocols are developed with an aim to operate in difficult conditions like disaster situations where MANET is mostly utilized. MANET is designed to operate in very uncomfortable conditions where no base infrastructure and basic support is available. Wireless network i.e. MANET is always exposed to external threats, power restrictions and challenge like maintaining connectivity while all the nodes are randomly moving without any prior information. This leads to link failure and in turn network transmission is affected by dropped packets, additional overhead to send and receive Route Requests along with Route Acknowledgements. Thus Routing in Mobile Ad-hoc Network has been always a subject of extensive research. Routing protocol has two functions, first

is selection of routes for various source-destination pairsand second, Delivery of messages to their correct destination. The succeeding task is theoretically simple using a range of protocols and routing tables [Retrieved from http://www.cs.dartmouth.edu/~campbell/papers/sbl- thesis.pdf, (Browsing date: 16th June 2015)]

As shown in Figure 2.1 and Figure 2.2, Ad-hoc routingprotocols are classified based on different criterion based upon the routing

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mechanism employed by them.

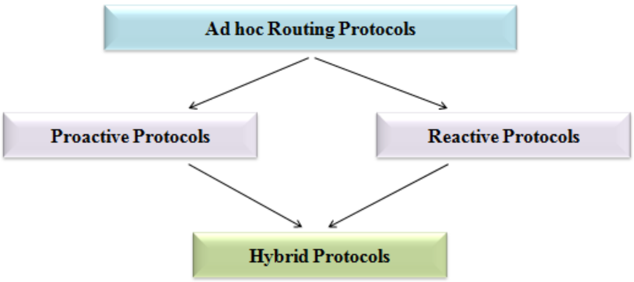

Figure 2.1: Grouping of Ad hoc Routing Protocols

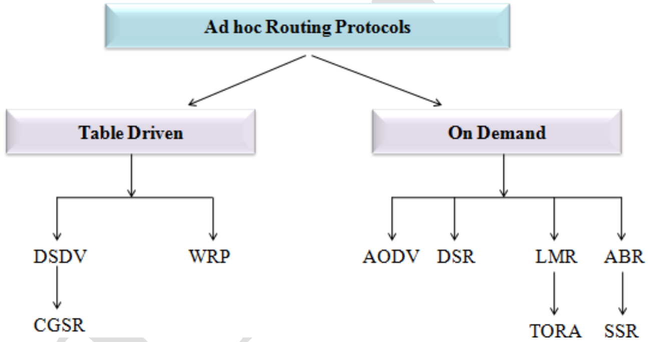

Figure 2.2: Relative Tree of Ad hoc Routing Protocols

Table Driven Routing Protocols (Proactive): Every node in this category continuously maintains fresh routes to every other node in the network. Routing information is periodically transmitted all through the network in order to uphold consistency of the routing table. Transmission occurs without interruption if the route already exists, or else, node needs to obtain routing information corresponding to its destination while traffic packets arewaiting in the queue. Some examples of Proactive routingprotocols are Destination-Sequenced Distance Vector(DSDV), Wireless Routing Protocol (WRP), Global StateRouting (GSR) and Cluster head Gateway Switch Routing(CGSR) [Retrieved fromhttp://www.cs.dartmouth.edu/~campbell/papers/sbl-thesis.pdf, (Browsing date: 16th June 2015)].

Source Initiated on Demand Driven (Reactive): It is a different approach from table driven routing. This type of routing discovers routes only when requested by the source node. Node initiates a route discovery within the network only when it needs route to a destination node. Process is concluded once a route or all possible routes are discovered.Using some sort of Route maintaining algorithm, that path ismaintained only in expectation of destination node becomes unreachable or the route is no longer required. Examples of Reactive protocols includes AODV, DSR, LMR, ABR etc

4. Ad hoc On-Demand Distance Vector(AODV)

The Ad hoc On Demand Distance Vector (AODV) routing protocol is built on the DSDV algorithm, it is a developmentbecause it typically reduces the number of transmissions by producing routes on an On Demand basis, as complementary to maintaining a complete list of routes as inthe DSDV algorithm. AODV is a Pure On Demand Route Acquisition System, as nodes that are not on a chosen path do not hold routing information or participate in routing table exchanges [Royer, Elizabeth M. et. al (2000)].

When a Source node needs to send a message to some other node and does not instantly have a suitable path to that destination node, it begins Path Discovery process to discover the other node. It broadcast a Route Request (RREQ) packet to its neighbours, these neighbours forward this request to their neighbour and this process continues until either the destination or on mediator node with a
–Fresh Enough‖ route to the destination node is found..

Figure 3.1 exemplifies the transmission of the broadcastRREQ across the network. AODV make use of destination sequence numbers to make sure the entire routes are loop free and hold the updated route information.

International journal of imaging science and engineering

ISSN: 1934--9955 www.ijise.net

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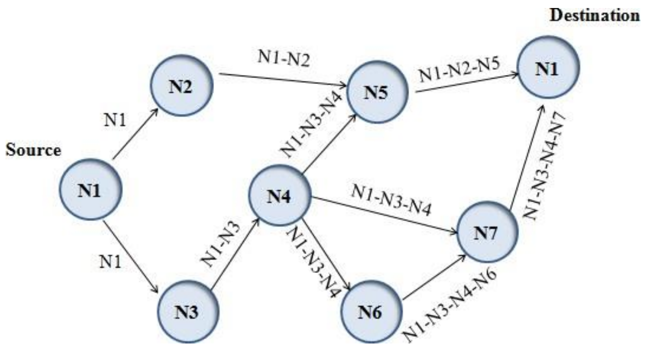

Figure 3.1: Generation of the Route Record in RouteDiscovery

Sequence Number and Broadcast ID is maintained by eachnode. The Broadcast ID is incremented by 1 for every RREQ the node sends and jointly with the node's IP address, exclusively identifies a RREQ the recent sequence number it has for the destination. Intermediary nodes can respond to the RREQ only if they have a route to the destination whose matching destination sequence number is larger than or equivalent to that contained in the RREQ. Intermediate nodes record address of the neighbour from which they received the first copy of broadcast packet, this creates a reverse path, and this is done during the process of forwarding the RREQ.

If more copies of the same RREQ are received later, these packets are destroyed. Once the RREQ reaches the destination or an intermediate node with a fresh enoughroutes, the destination / intermediate node responds by unicasting a route reply (RREP) packet back to the neighbour from which it first received the RREQ, which is shown in Figure 3.2.

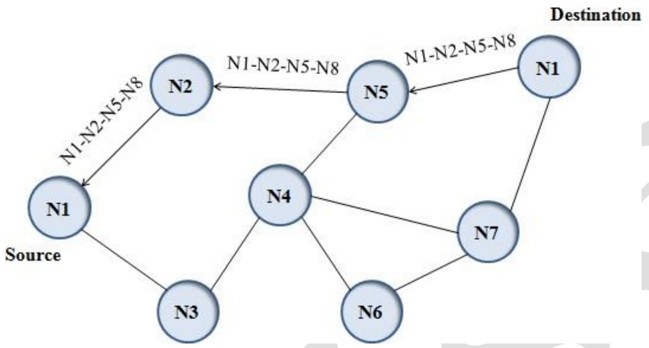

Figure 3.2: Transmission of the Route Reply

As the RREP is routed back along the reverse path, nodeson path set up forward routes entries in their route tables which point to the node from which the RREP arrived.These forward route entries show the active forward route. Linked with each route entry is a router timer which causes the deletion of the entry if it is not utilized within the given lifetime. Because the RREP is forwarded along the pathestablished by the RREQ, AODV only supports the use of symmetric links.

Routes are maintained as follows [Krco, Srdjan et. al (2004)]:

- If the Source node changes its position, it is able to restart the route discovery protocol to find a new route to the destination.
- If a node along the route changes its position, its upstreamneighbour senses the move and transmits a link failure notification message (a RREP with infinite metric) to each of its active upstream neighbours to let them awareof the deletion of that portion of the route.
- This node in turn transmits the link failure message to their upstream neighbours, and soon until the source node is reached.
- The Source node possibly will then opt to re-start route discovery for that destination if a route is still required.

A supplementary feature of the protocol is the utilization of hello messages, intervallic local broadcasts by a node to inform each mobile node of other nodes in its neighbourhood. Hello messages can be used to conserve the local connectivity of a node. However the use of hello messages is not obligatory. Nodes pay attention for retransmission of data packets to assure the next hop is still within reach. If such a retransmission is not heard, the node may use any one of a number of techniques, along with the reception of hello messages, to discover whether the next hop is within transmission range. The hello messages may list the other nodes from which a mobile has heard, by this means yielding a greater knowledge of the network connectivity.

5. Previous Work on AODV Modification

Royer, Elizabeth M et. al (1999) provides descriptions of several routing schemes proposed for Ad hoc mobile networks. This paper also provides a categorization of these schemes according to the routing approach i.e. table driven and on demand. It presents a comparison of these two categories of routing protocols highlighting their features differences and uniqueness. Finally possible applications and challenges facing Ad hoc mobile wireless networks were recognized. While it is not clear that any particular algorithm or class of algorithm is the best for all scenarios each protocol has definite advantages and disadvantages andhas certain situations for which it is well suited. The field of Ad hoc mobile networks is rapidly growing and changing and while there are still many challenges that need to be met, it is likely that such networks will see wide spread use within the next few years [Royer, Elizabeth M et. al (1999)].

Das, S. R. et. al (2000) presents a distance vector algorithm that is suitable for use with ad-hoc networks. Conclude that within the limits imposed by worst case route establishment latency as determined by the network diameter. AODV is anoutstanding alternative for ad-hoc network establishment. It will be useful in applications for emergency services, conferencing battlefield communication and community based net working.

Royer, Elizabeth M. et. al (2000) developed and implemented the AODV routing protocol. In the course of writing the implementation, some key changes needed to be made to both the protocol and the Linux kernel to enable AODV to operate correctly. As AODV continues to be refined it is possible that further changes will be required, particularly when QoS operation is implemented. Additionally tunnel management may also indicate the need for further modifications.

Lee, Sung-Ju et. al (2000) presented a scheme that utilizes a mesh structure and alternate paths. Scheme presented can be incorporated into any ad hoc on-demand unicast routingprotocol to improve reliable packet delivery in the face of node movements and route breaks. The mesh configuration provides multiple alternate routes and is constructed withoutyielding any extra overhead. Alternate routes are utilized only when data packets cannot be delivered through theprimary route [Kalwar, Neha et. al (2013)].

Marina, Mahesh K. et. al (2001) presented AOMDV - a multipath extension to AODV showing about 25% reductions in routing load.

Marina, Mahesh K. et. al (2001) concluded that DSR and AODV both use on-demand route discovery, but with dissimilar routing technicalities. DSR uses source routing and route caches and does not rely on any intermittent or timer-based actions. DSR exploits caching aggressively and maintains numerous routes per destination. AODV, on the other hand, uses routing tables, one route per destination,and destination sequence numbers, a means to prevent loopsand to determine newness of routes. With detailed simulation model it was observed that for application oriented metrics such as delay and throughput, DSR outperforms AODV in less ―stressful‖ situations, i.e., smaller number of nodes and lower load and/or mobility. AODV, however, outperforms DSR in more stressful situations, with widening performance gaps with increasing stress. DSR, however, consistently generates less routing load than AODV. The research expects that mechanisms to expire routes and/or determine freshness of routes in the route cache will benefit DSR's performance significantly. Concurrently with our work, the performance effects of a variety of route caching strategies have been recently explored in Husieen, Naseer Ali et. al (2011)]. On the otherhand, AODV's routing loads can be reduced considerably by source routing the request and reply packets in the route discovery process. Since AODV keeps track of actively used routes, multiple actively used destinations also can be searched using a single route discovery flood to controlrouting load. In general, it was observed that both protocols could benefit (i) from using congestion-related metrics (suchas queue lengths) to evaluate routes instead of emphasizing the hop-wise shortest routes, and (ii) by removing ―aged‖ packets from the network. The aged packets are typically not important for the upper layer protocol, because they will probably be retransmitted. These stale packets do contribute unnecessarily to the load in the routing layer. We also observed that the interplay between the routing and MAC layers could affect performance significantly. For example, even though DSR generated much fewer routing packets overall, it generated more unicast routing packets which were expensive in the 802.11 MAC layer we used. Thus DSR's apparent savings on routing load did not translate to an expected reduction on the real load on the network. This examination also emphasizes the serious need for studying connections between protocol layers when designing wireless network protocols [Das, S. R. et. al (2000)].

Gwalani, Sumit et. al (2003) proposes a new protocol thatmodifies AODV to improve its performance. The protocol, AODV-PA, incorporates path accumulation during the routediscovery process in AODV to attain extra routinginformation. It is evident from the results that AODV-PAimproves the performance of AODV under conditions ofhigh load and moderate to high mobility. AODV-PA alsoscales better than AODV in large networks. Under mostconditions, AODV-PA has a higher packet delivery ratioand lower delay than DSR, though the routing load of DSRis slightly less than that of AODV-PA. The difference in therouting load of AODV-PA and DSR decreases with anincrease in the load. AODV-PA can be used either as analternative to AODV or as an optimization under moderateto high load scenarios. AODV-PA could also be suitableeither if overall routing load or if application orientedmetrics such as delay and packet delivery ratio are importantfor the ad hoc network application [Retrieved fromhttp://dl.packetstormsecurity.net/papers/general/RO-AODV.pdf, (Browsing date: 24th April 2015)]

Lee, Sung-Ju et. al (2003) evaluated the scalability of on- demand ad hoc routing protocols by selecting arepresentative from this set of protocols and simulating it in networks of up to 10,000 nodes. To improve the performance of on-demand protocols in large networks, fivemodification combinations have been separately incorporated into an on-demand protocol, and their respective performance has been studied. It has been shown that the use of local repair is beneficial in increasing the number of data packets that reach their destinations. Expanding ring search and query localization techniquesseem to further reduce the amount of control overhead generated by the protocol, by limiting the number of nodes affected by route discoveries. While the performance improvements of the modifications have only been demonstrated with the AODV protocol, we believe that other on-demand ad hoc routing protocols will show similar improvements when incorporated with the modifications westudied. The verification of this belief, however, remains future work. Scalability in ad hoc mobile networks is inherently difficult due to the mobility of the nodes and the transience of network links. Work on large-scale ad hoc networks is likely to uncover techniques that would be valuable for stabilizing routing protocols in the Internet at large, leading to faster route convergence and reduced route flaps. Creating ad hoc routing protocols which experience minimal performance degradation when used in increasinglylarge networks is a challenge, and there remains a significant amount of work to reach this goal [Lee, Sung-Ju et. al (2002)].

Chakeres, Ian D. et. al (2004) analysed design possibilities for AODV implementations. This paper first identified the unsupported events needed for AODV to perform routing, then examined the advantages and disadvantages of three strategies for determining this information. This analysissupported the decision to use small kernel modules with a user-space daemon [Gupta, Prinima et. al (2010)]. Finally, we comparison was performed on forwarding strategies and link break detection designs.

Krco, Srdjan et. al (2004) a problem related to the behaviourof WLAN 802.11 b network cards when working in the ad - hoc mode is described. This behaviour was noticed during experimental evaluation of an ad hoc network that was usingthe AODV (ad hoc On-demand Distance Vector) routing protocol. The observed problem affects the neighbour detection algorithm of the AODV routing protocol and has adeteriorating impact on performance of ad hoc networks thatuse this protocol. An improvement of the neighbour detection algorithm based on the differentiation of good and bad neighbours using signal to noise ratio (SNR) value is proposed, described and experimentally verified Krco, Srdjan et. al (2004).

6. Problem Identification

After Literature survey it was identified that, when a route breaks due to node mobility or node failure, flat routing protocol like AODV typically discard the whole original route and initiate another round of route discovery to establish a new route from the source to the destination. However, when a route breaks, usually only a few hops are broken, but other hops are still intact. Discarding the whole

route wastes the knowledge of the original route and causes considerable overhead in global route discoveries.

An optimization to AODV is Multiple Route Discovery in advance, even before transmission begins. Local repair is only suitable for situations where link failures occur near thedestination. As per AODV draft, when a link break in an active route occurs, the node upstream of that break may choose to repair the link locally by choosing alternative root discovery. The reason for this limitation is that intermediate nodes only know the destination and the next hop for a routeand the target of the local repair has to be the destination. Ifa link failure occurs far from the destination, it would be better for the source to be ready with information of alternative routes.

Therefore, the main purpose of this work was to discover allthe possible routes to a destination and wherever the link failure happens along the route, already availableinformation of alternate route is used to reduce the number of global route discoveries. Consequently, the routing protocol reduces routing overhead and improves scalability and performance.

In this research, improved routing algorithm for AODV protocol is to implement in MANETs by modifying theAODV Source Code and performance comparison isperformed with Traditional AODV using Simulation results observed from Network Simulator 2.

7. Contribution of this Research Work

The following improvements to multipath routing for mobile ad hoc networks were inspired by the notion of multipath routing:

1. Implementation of AMR-AODV for wireless ad-hoc networks.
2. Performance Comparison of AMR-AODV vs. Traditional AODV protocol behaviour theoretically and through simulation.

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3. Identification of the applicability of the AMR-AODV in aparticular scenario.
4. Study of AMR-AODV in various mobility models and simulation.
5. Advanced algorithm for AODV protocol for improving reliability and saving of Route Discovery in case of link failure.
6. Reduced overhead of additional route discovery attempts.
7. Reduced routing overhead by the use of secondary paths.
8. Reduced route error transmission during route break recovery.

In this work modification is performed on base AODV Source Code and Multiple Route Discovery Mechanism to develop reduced Route Discovery Overhead in the situation of route failure. Outcome of this work is detailed analysis ofthe existing AODV Routing Protocol and enhanced performance for efficient functionality to solve the link failure problem and reduce intermediate route discovery overhead.

7. Mobility Models

To assess the performance of a protocol for an ad-hoc network, it is essential to examine the protocol under realistic circumstances, particularly including the movementof the mobile nodes. Since not many MANETs have been deployed, most of this research is based on simulation.

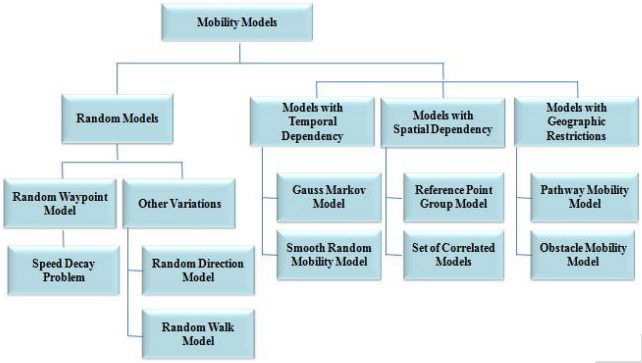

Figure 7.1: Different categories of Mobility Models

The mobility model is designed to explain the movement prototype of mobile users, and how their location, speed andacceleration vary over time. Since mobility patterns may play an important role in determining the protocol performance, it is desirable for mobility models to imitate the movement pattern of targeted real life applications in a logical way. Else, the observations made and the conclusions drawn from the simulation studies may be ambiguous. Thus, when evaluating MANET protocols, it is essential to select the proper underlying mobility model. Forexample, the nodes in Random Waypoint model behavequite in a different way as compared to nodes moving in groups. It is not suitable to evaluate the applications where nodes tend to move mutually using Random Waypoint model. Therefore, there is an actual requirement fordeveloping a thorough understanding of mobility modelsand their effect on protocol performance.

One instinctive technique to generate realistic mobility patterns would be to build trace-based mobility models, in which precise information about the mobility traces of users could be provided. However, since MANETs have not been implemented and deployed on a wide scale, obtaining real mobility traces becomes a major challenge. Therefore, avariety of researchers projected diverse kinds of mobility models, trying to capture various characteristics of mobility and symbolize mobility in a somewhat 'realistic' manner. Figure 7.1 shows proposed type of Mobility Models which may be considered for introducing realistic scenarios in network simulation. Much of the present research has focused on the so-called synthetic mobility models that are not trace-driven.

In the preceding studies on mobility patterns in wireless cellular networks, researchers mostly focus on the movement of users relative to a particular area (i.e., a cell) at a macroscopic level, such as cell change rate, handover traffic and blocking prospect. However, to model and examine the mobility models in MANET, we are more concerned in the movement of individual nodes at the microscopic-level, including node location and speed relative to other nodes, because these factors straightforwardly determine when the links are formed and broken since communication is peer-to-peer.

8. Network Simulator 2

The Network Simulator-2 (ns2) is a discrete event driven simulator developed at UC Berkeley is part of the VINT project. The goal of ns2 is to support networking research and education. It is suitable for scheming new protocols, comparing different protocols and traffic evaluations. Ns2 isdeveloped as a collaborative environment. It is distributed freely and open source. A

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large amount of institutes and people in development and research use, preserve and build up ns2. Versions are available for FreeBSD, Linux, Solaris, Windows and Mac OS.

Network Simulator 2 is shown in Figure 8.1. It is the result of an on-going effort of research and development that is administrated by researchers at Berkeley. It is a discrete event simulator targeted at networking research. It provides considerable support for simulation of TCP, routing, and multicast protocols. The simulator is written in C++ and OTcl. User writes an OTcl script which defines the network,the traffic in the network and which protocols it will use. NSuses this script of simulations. Output of these simulations isa trace file which is used to process the data using which delay, throughput is calculated. NAM is a visualization tool that animates the packets as they transmit through the network. A general idea of simulation is as shown below.

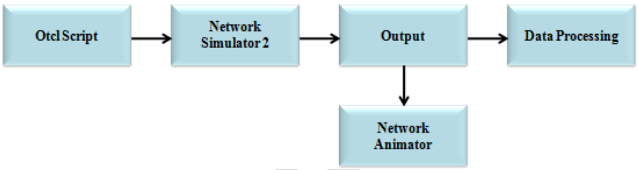

Figure 8.1: Network Simulator

5.1 Structure of Network Simulator 2

Network Simulator 2 is based on object oriented methods in C++ and OTcl (object oriented variant of Tcl).

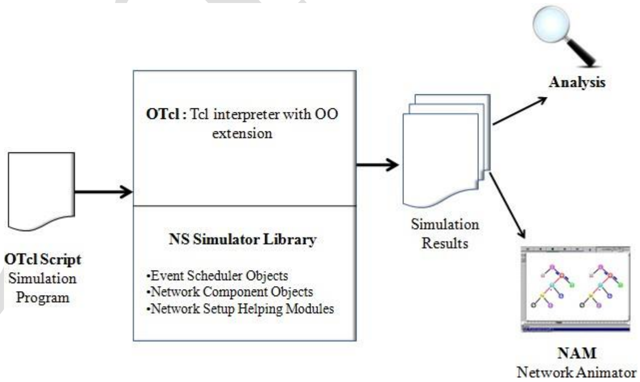

Figure 8.2: Simplified User's View of NS

Interpreting OTcl script in NS2, A user has to set the different components like event scheduler objects, network components libraries and setup module libraries up in the simulation surroundings. Figure 8.2 shows basic user view of NS, where the user writes his simulation as an OTcl script, plumbs the network components together to the complete simulation. If he needs new network components, he is free to implement them and to set them up in his simulation as well. The event scheduler as the other major component besides network components triggers the actionsof the simulation like sends packets, starts and stops tracing.

9. Performance Metrics Used

This research work has been implemented using various simulation tools like Network Simulator 2.33 [Retrieved from http://www.isi.edu/nsnam/ns/, browsing date: 07 March 2015], Network Animator, Tracegraph and Bonnmotion [Retrieved from http://www.bonnmotion.net, browsing date: 27 March 2015]. Simulation on these routingprotocols where performed after taking following performance metrics into consideration.

Routing Overhead: Routing overhead defines total number of routing packets to be sent to complete data packets transmission [Ambhaikar, Asha et. al (2010)].

Average Delay: Average Delay represents time taken for a packet to travel from source to the destination.

Average Throughput: Average Throughput defines total number of bits forwarded to upper layers per second (bps). This is total data that a receiver actually receive from the source divided by total duration taken to receive the last packet.

Packet Delivery Ratio (PDR): Packet Delivery Ratio is calculated by dividing incoming data packets and totally received packets at the end of transmission [Kumar, Sanjeevet. al (2013)].

Routing Packet Sent: This metric describes how many routing packets were sent for route discovery and route maintenance.

Loss Packet Ratio (LPR): It is a ratio of number of packets that never reached the destination and the number of packetsoriginated by the CBR source [Deshmukh, Rajesh et. al(2013)].

10. Methodology

The methodology that has been adopted can be summarized as shown in Figure 10.1

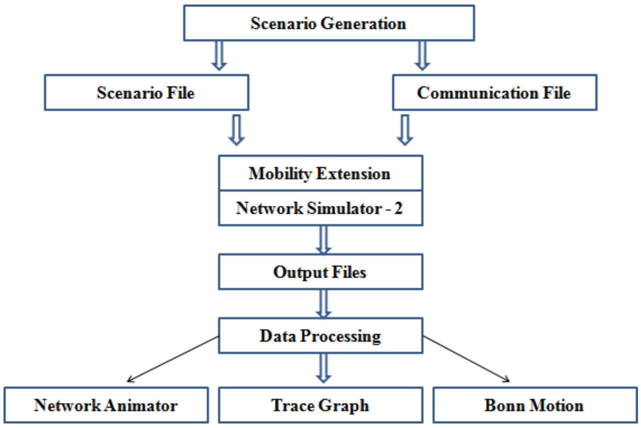

Figure 10.1: Simulation Overview

11. Simulation Setup

11.1 Performance Comparison of AODV and AMR-AODV with Reference to Variable Pause Time

Table 1 shows Simulation setup for Scenario 1. Simulationsare carried out by Network Simulator 2.33. Continuous Bit Rate (CBR) traffic sources are used. The source destination pairs are spread without direction over the network. The mobility model use Random Waypoint mobility model in a 1000 m x 1000 m field with network load of 4 packet/s whereas pause time is varies from 5 s to 20 s while keeping the network size constant at 100 nodes. Here, each packet starts its journey from a random position to a random destination with randomly chosen speed. Once the destination is reached, another random destination is aimed after a pause. Simulations are run for 100 simulated secondswhereas Maximum speed is 10 m/s.

Table 1: Simulation Setup for varying Mobility

Parameter	*Value*
Protocols	AODV, AMR-AODV
Simulation Time	100 s
Number of Nodes	100
Network Load	4 Packets / sec
Pause Time	5, 10, 15, 20 sec
Environment Size	1000 m x 1000 m
Traffic Type	Constant Bit Rate
Maximum Speed	10 m / s
Mobility Model	Random Waypoint
Network Simulator	NS 2.33

11.2 Performance Comparison of AODV and AMR-AODV with Reference to Network Size

Table 2 shows Simulation setup for Scenario 2. Simulationsare carried out by Network Simulator 2.33. In thissimulation, average packet size of 512 bytes, a rate of 4 packets/s with 100, 110, 120, 130, 140 and 150 nodes. Oncethe destination is reached, another random destination is aimed after a pause. The pause time, which affects thecomparative speeds of the mobiles, is kept steady at 10 m/s.Simulations are executed for 100 virtual seconds. This simulation investigates how the two protocols AODV and AMR-AODV behaves related to packet loss and packetdropped when network load is gradually increased.

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Table 2: Simulation Setup for varying Network Size

Parameter	*Value*
Protocols	AODV, AMR-AODV
Simulation time	100 s
No. of Nodes	100, 110, 120, 130, 140, 150
Pause time	10 s
Environment Size	1000 x 1000
Traffic Type	Constant Bit Rate
Maximum Speed	10 m/s
Packet Rate	4 packets / s
Mobility Model	Random Waypoint

11.3 Analysing the behaviour of AODV and AMR- AODV with Reference to variable Speed and Terrain Range

Table 3 shows simulation setup for Scenario 3. Continuous bit rate (CBR) traffic sources are used. The source- destination pairs are spread aimlessly over the network. Themobility model uses the Random Waypoint model in a rectangular field with three different field configurations as:900 m x 700 m, 1100 m x 600 m, 1400 m x 900 m field with 4 packet/s network load whereas network size is constant at 100 nodes. Here, each packet starts its journey from a random location to a random destination with arandomly chosen speed. Once the destination is reached, another random destination is aimed after a pause. The pause time, which affects the relative speeds of the mobile hosts, is kept constant at 5 s. Simulations are run for 100 simulated seconds. Maximum speed is varied at 5, 10, 20, 30, 40 m/s.

Simulation was carried out using Network Simulator 2.33. In this simulation, network load at the rate of 4 packets / s with uniform 100 nodes and constant pause time 5s has been referred in Table 3.4. This simulation investigates howthe protocol behaves with different considered terrain areas and mobility.

Table 3: Simulation Setup for varying Speed and TerrainArea

Parameters	*Value*
Protocols	AODV, AMR-AODV
Simulation time	100 s
No. of Nodes	100
Pause time	10 s
Environment Size	900m x 700m, 1100m x 600m, 1400m x 900m
Traffic Type	Constant Bit Rate
Maximum Speed	5, 10, 20, 30, 40 m/s
Packets Rate	4 packets / s
Mobility Model	Random Waypoint

11.4 Effect of varying Network Load and Mobility Speed on AMR-AODV

Table 4 shows simulation setup for Scenario 5. Traffic and mobility model based on Continuous bit rate (CBR) traffic sources are used. The source-destination pairs are spread aimlessly over the network. Only 512- byte data packets areused. Number of sources, destinations and the packet sending speed in each duo are mixed to change the presented load in the network. Random waypoint model is used in a rectangular field of 500 m x 500 m with 10, 20,30, 40, 50, 60, 70, 80, 90 and 100 nodes. Here, each packet starts its journey from a random location to a random destination with Maximum speed at 10 and 20 m/s. Once the target is reached, another random destination is aimed after a break. The pause time, which affects the relative speeds of the mobile nodes, is kept constant at 10. Simulations are executed for 100 simulated seconds.Matching mobility and traffic scenarios are used across protocols to gather reasonable results.**Table 4:** Simulation setup for varying Network Load

Parameters	*Value*
Protocols	AODV, AMR-AODV
Simulation time	100 s
No. of Nodes	10, 20, 30, 40, 50, 60, 70, 80, 90, 100
Pause time	10
Environment Size	500 m x 500 m
Traffic Type	Constant Bit Rate
Maximum Speed	10, 20 m/s
Packet Size	512 bytes
Packets Rate	4 packets / s

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Mobility Model	Random Waypoint

11.5 Effect of varying Network Size and Pause Time on AODV and AMR-AODV

Table 5 shows simulation setup for Scenario 6. Random waypoint model is used in a rectangular field of 1000 m x 1000 m with 20, 30, 40, 50 nodes. Here, each packet starts its journey from a arbitrary location to random destinations with an aimlessly selected speed (consistently distributed between 0 m/s to 10 m/s). Once the target is reached, another random destination is aimed after a pause. The pause time, which affects the relative speeds of the mobiles,is varied as 0, 5, 10, 15, 20 s. Simulations are run for 100 simulated seconds. Matching mobility and traffic scenarios are used across protocols to gather reasonable results. This simulation investigates how these two protocols behave when network load and pause time increases.

Table 5: Simulation Setup for varying number of nodes andvelocity

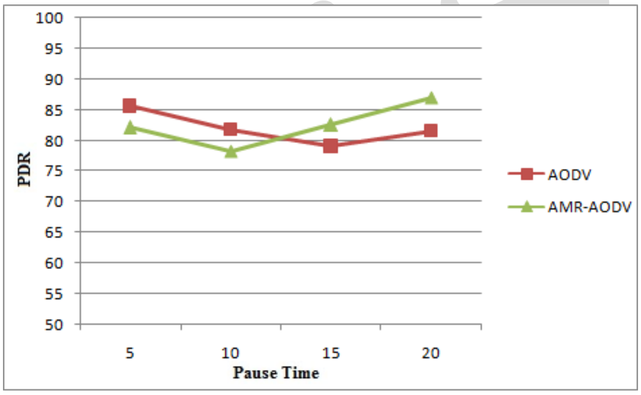
Parameter	*Value*
Protocol	AODV, AMR-AODV
Simulation time	100 s
No. of Nodes	20, 30, 40, 50
Pause time	0, 5, 10, 15, 20
Environment Size	1000 x 1000
Traffic Type	Constant Bit Rate
Maximum Speed	10 m/s
Packet Size	512 bytes
Packets Rate	4 packets / s
Mobility Model	Random Waypoint

12. Results and Discussions

Empirical results demonstrate that the performance of a routing protocol varies extensively across diverse mobility models and hence the results from one model cannot be applied to other model. Hence the mobility of an applicationhas been considered while selecting a routing protocol. The experimental results show the following important observations were noted.

12.1 Observation for Performance Comparison of AODV and AMR-AODV with Reference to Variable Pause Time

The performance of two routing protocols is shown in Figure 12.1, Figure 12.2 and Figure 12.3. These results may vary commonly across diverse network parameters andhence these results cannot be applied to any other scenario.



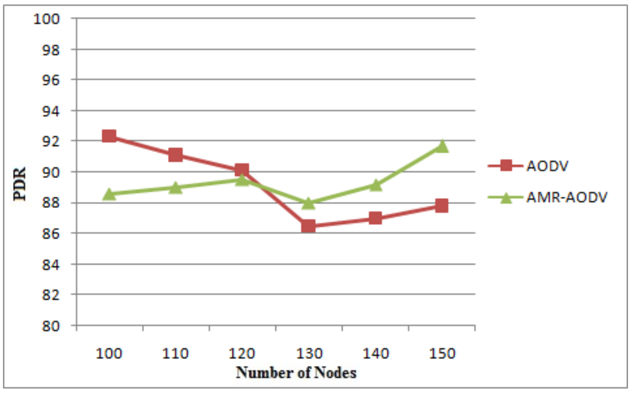


Figure 12.1: Packet Delivery Ratio Vs Pause Time

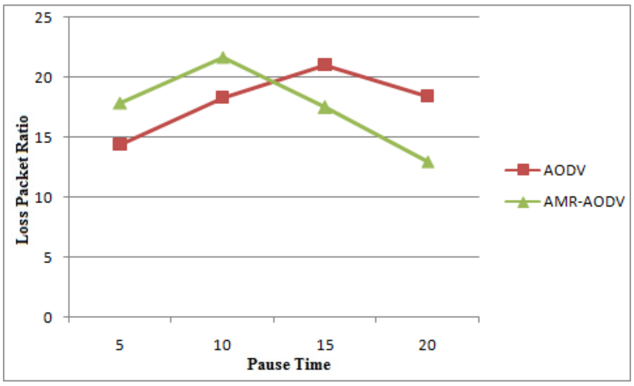


Figure 12.2: Loss Packet Ratio Vs Pause Time

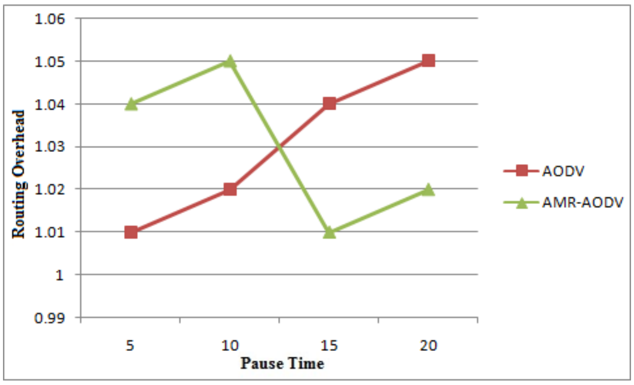


Figure 12.3: Overhead Vs Pause Time

Pause time had to be considered in an application while selecting a routing protocol. Simulation results have given an indication that AMR-AODV performs better on increased pause time with given scenario while, AODVperforms better on lesser pause time with the same scenario.

12.2 Performance Comparison of AODV and AMR-AODV with Reference to Network Size

The performance of a routing protocol is shown in Figure 12.4, Figure 12.5 and Figure 12.6. These results may vary commonly across diverse network parameters and hence these results cannot be applied to any other scenario.**Figure 12.4:** Number of Nodes Vs Packet Delivery Ratio

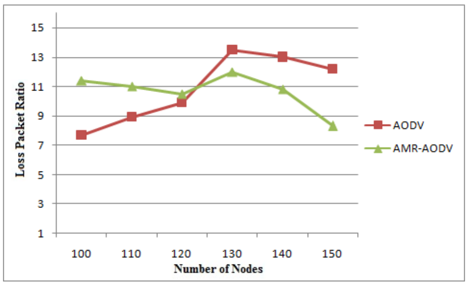


Figure 12.5: Number of Nodes Vs Loss Packet Ratio

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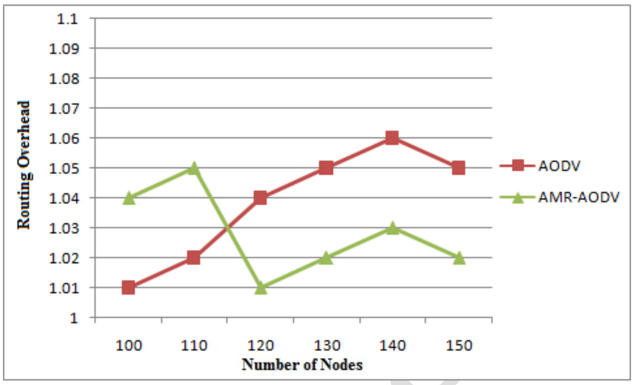


Figure 12.6: Number of Nodes Vs Routing Overhead

Network size of an application is considered while selectinga routing protocol. Simulation results have given an indication that in given scenario AMR-AODV performsbetter on increased number of nodes with given set-up and AODV performs better on lesser number of nodes.

12.3 Analysing the behaviour of AODV and AMR- AODV with Reference to variable Speed and Terrain Range

Comparative performance of AODV, AMR-AODV withrespect to varying Terrain Range is shown in Figure 12.7, Figure 12.8, Figure 12.9, Figure 12.10, Figure 12.11 and
Figure 12.12.

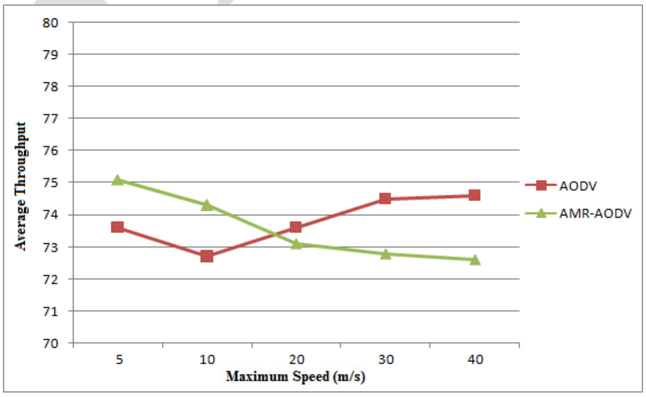


Figure 12.7: Average throughput in terrain range 900m x700m

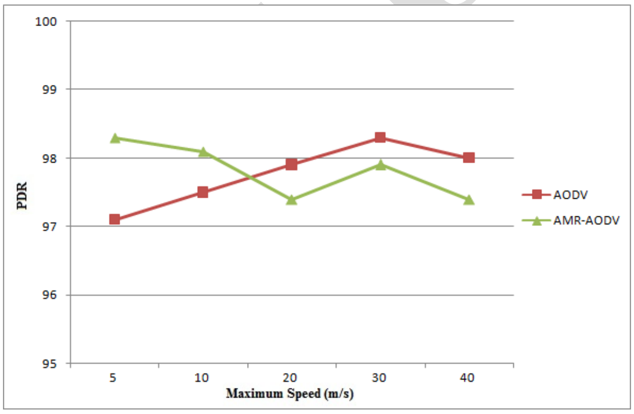


Figure 12.8: Packet Delivery Ratio in terrain range 900m x700m

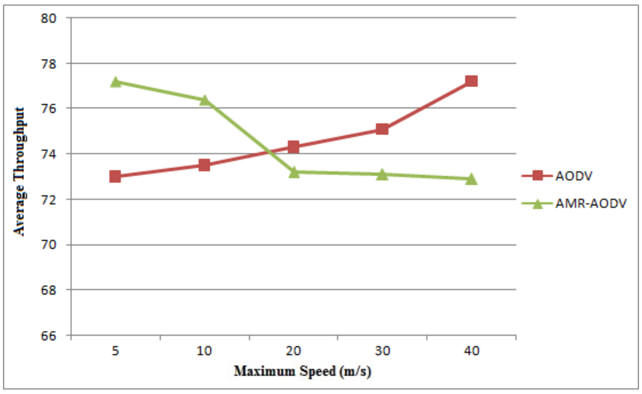


Figure 12.9: Average throughput in terrain range 1100m x600m

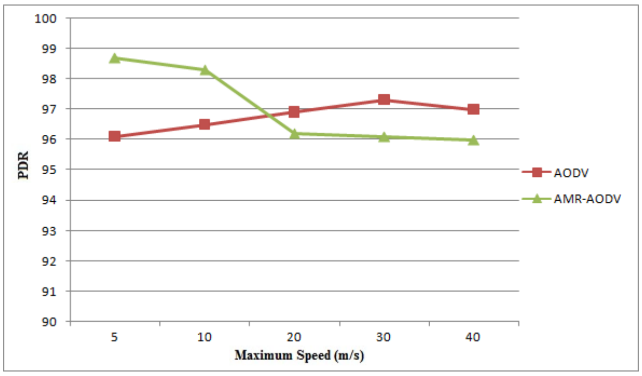


Figure 12.10: Packet Delivery Ratio in terrain range 1100mx 600m

Figure 12.11: Average throughput in terrain range 1400m x900m

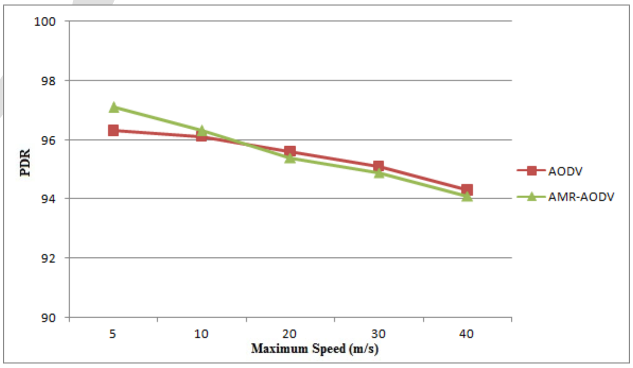


Figure 12.12: Packet Delivery Ratio in terrain range 1400mx 900m

Performance of AODV and AMR-AODV under three different terrain ranges compared at varying speed. Theeffect of speed and terrain area on the average throughput and number of dropped packets has been examined. When the speed increases; both routing protocols experience areduction in throughput. Higher speeds cause numerous linkchanges and connection failures. AMR-AODV performs better at lower speeds and AODV performs better than AMR-AODV at higher speed.

Both AMR-AODV and AODV shows differentdistinctiveness. In general, examination such as average throughput and number of dropped packets, AMR-AODV performs better for lower speeds but AODV performs bestat higher mobility speeds. Source route caching helps AMR-AODV to drastically improve its performance at lower speeds. AMR-AODV protocols exhibit higher number of dropped packets with increased speed and AODV transmits periodically broadcast message that generates routing packets and thus decreases throughput. It is also observed that with the increase in the terrain range and increased speed the average throughput as well as number of dropped packets is also increasing.

12.4 Effect of varying Network Load and MobilitySpeed on AMR-AODV

The performance of AODV and AMR-AODV with varying number of Nodes and Mobility Speed is shown in Figure 12.13 and Figure 12.14.

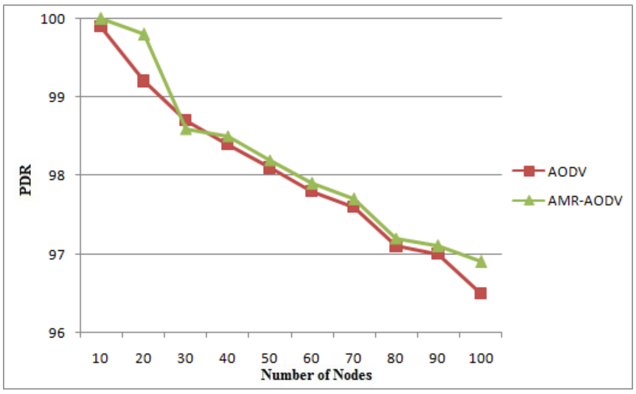


Figure 12.13: Packet Delivery Ratio for speed 10 m/s

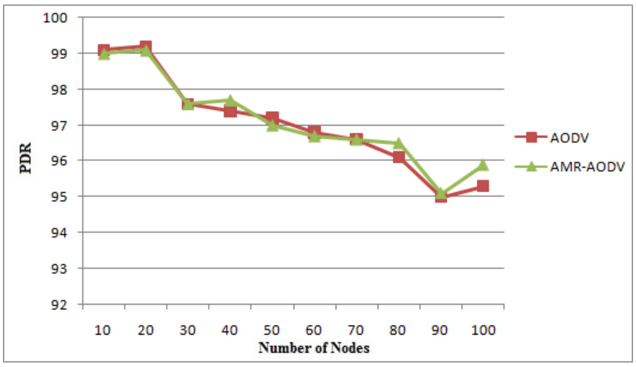
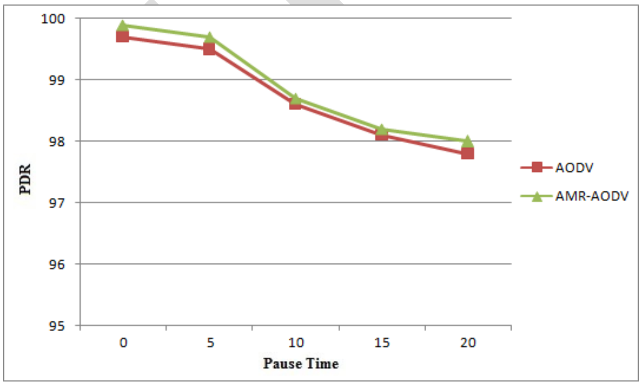


Figure 12.14: Packet Delivery Ratio for speed 20 m/s

In view of the fact that AODV has at most one route per destination in its routing table, link failures activate new route discoveries. Thus, the occurrence of route discoveries in AODV is directly proportional to the number of route breaks. The reaction of AMR-AODV to link failures incomparison is mild and causes less route discovery, becauseof the great quantity of cached routes at each node. The route discovery is delayed in AMR-AODV until all cached routes fall short. AMR-AODV repeatedly performs better than AODV in lower mobility scenarios, because the probability to find the route in one of the caches is much higher. Most of the times AMR-AODV has a lower routing load than AODV. AMR-AODV is more likely to find a route in the cache by high calibre of aggressive caching, and causes less frequent route discovery than AODV. Reactive On-demand routing strategy is used by AODV andAMR-AODV. Overhead involved in updating all the nodes with the new routing information in AODV is much more than AMR-AODV, in the case of link failures caused by high mobility.

With different routing techniques, AMR-AODV and AODV both use on-demand route discovery. AODV uses routing tables, one route per destination, and destination sequence numbers, this is a mechanism to prevent loops andto determine routes are fresh. The observation from thesimulation is that for application-oriented metrics such as packet delivery fraction and delay, AODV performs better than AMR-AODV in more tough situations. AMR-AODV constantly generates less routing load than AODV. Aggressive caching seems to help AMR-AODV at low mobility speed and also keeps its routing load down. For lower loads, AODV is more effective while for higher loadsAMR-AODV is more effective to improve scalability.Effect of varying Network Size and Pause



Time onAODV and AMR-AODV

The performance of AODV and AMR-AODV with varying number of Nodes and Pause Time is shown in Figure 12.15, Figure12.16, Figure 12.17 and Figure 12.18.

Figure 12.15: Packet Delivery Ratio for 20 Nodes andvarying Pause Time

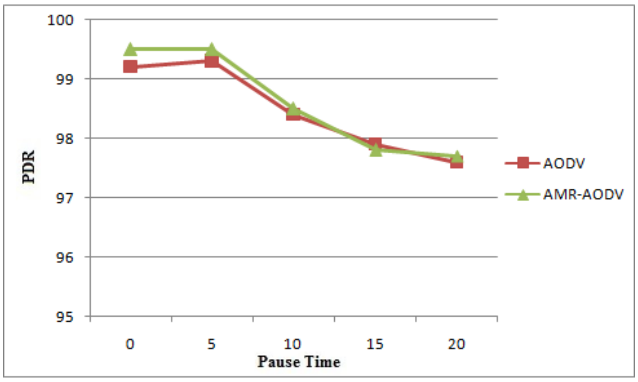


Figure 12.16: Packet Delivery Ratio for 30 Nodes andvarying Pause Time

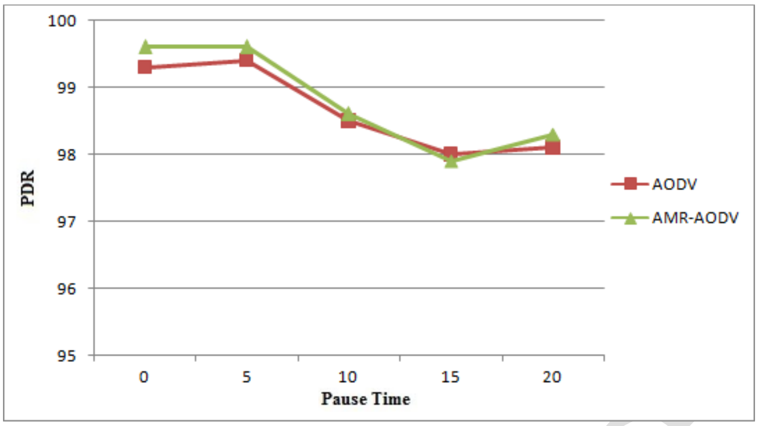


Figure 12.17: Packet Delivery Ratio for 40 Nodes andvarying Pause Time

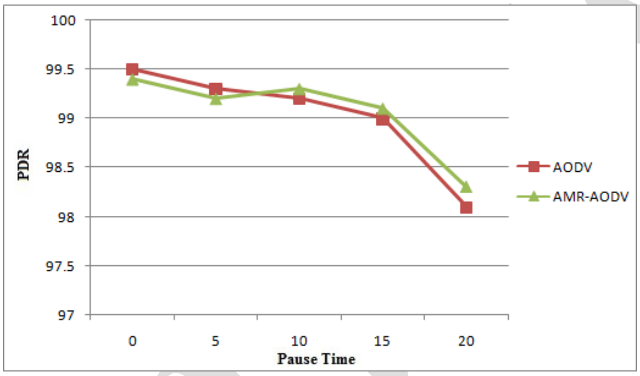


Figure 12.18: Packet Delivery Ratio for 50 Nodes andvarying Pause Time

In the case of AODV, for 20 node scenarios at 0s pause time PDR is the highest and it decreases with increasing pause time that is, for 5, 10, 15, 20s pause-time PDR is in between 97% to 99%. For 30 nodes PDR is the highest at pause time 5s and again starts decreasing for higher pause time. Similarly, for 40 nodes PDR is the highest at pause- time 5s and for 50 nodes PDR is around 98% and is the lowest at pause-time of 20s.

Overall, AMR-AODV performs superior in all the above scenarios as compared to ADOV, because it gets advantage from increased Pause Time and increased number of Nodes.This increased number of nodes improves the caching capability and thus enhances the prospect of increased number of alternate routes. Increased pause time offers AMR-AODV more time to search for alternate route from its fellow node in case of link failure.

As per the result obtained, it is clear that AMR-AODV shows better performance for PDR than AODV. AODV for lower node density performs well but its performance is degraded with higher node density.

12.5 Implementation of Modified AODV Algorithm

This research brings an improvement over the basic AODV routing protocol which have better performance than the conventional AODV. Route Discovery of traditional AODV is modified to use effectively the routing information provided by the new neighbour nodes so that they are used to store alternate routes to the destination.

Imagine a scenario where Node A wishes to send some information to Node Z. Initially Node A will broadcast NewRoute Request (RREQ) throughout the network. All thenodes in the network will receive that RREQ; each of them will look for the requested route information in their neighbour nodes by exchanging Route Table information.

All possible routes from Node A to Node Z are as follows:A > C > I > E > Z
A > C > I > E > J > Z
A > C > I > E > D > F > H > G > J > ZA > C > B > F > H > G > J > Z
A > C > B > F > D > E > Z
A > C > B > F > D > E > J > Z
A > D > E > Z (Shortest Path)A > D > E > J > Z
A > D > F > H > G > J > Z
A > D > F > B > C > I > E > Z
A > D > F > B > C > I > E > J > Z
A > D > F > B > C > I > E > D > F > H > G > J > Z
A > D > F > B > C > I > E > D > F > H > G > J > E > Z

Those nodes who find the route to Node Z will send RREP to their neighbour nodes. Again all the nodes will share thatroute information with their neighbour nodes. Such a way, all the nodes in the network will be conscious of all the possible routes to Node Z. This routing information will be cached in all the nodes and apparently this information will be available with immediate neighbours of Node A also.Once Node A exchange the whole routing table with one of its neighbours, in Node A all the possible entries toward Node Z are created in the routing table as built up paths. Built up paths obtain the sequence number, number of hops and expiry time from the Node Z.

With this modification, Node A can discover and change to a better path even if the currently chosen path is suddenly broken or becomes unavailable. The alternatively built up paths will also decrease the number of Route Discovery cycles and reduce the delay time for finding a path and keeps the transmission process uninterrupted. This design therefore improves the performance of AODV.

We call this new protocol Alternate Multiple Routes - Ad hoc On-demand Distance Vector (AMR-AODV).

To begin, Node A will select best available route fromNode A to Node Z and begin the transmission. In case of link failure, Node A does not need to start New RouteDiscovery, it will simply look for alternate route from the Routing Table which was already created in Initial Route Discovery and resume the transmission without any delay.

12.6 Route Maintenance in the Proposed AMR-AODV

There remains a possibility that while Node A is transmitting data to Node Z using one of the routes, alternate routes information already gathered may become unavailable or broken due to several reasons. In case of route failure, When Node A needs alternate route then selected alternate route may show unavailability and cause the interruption in transmission.

To avoid this situation we need to have a mechanism where alternated routes information can be kept updated. For that nodes may send periodic updates among all the nodes which are not presently involved in transmission. They mayperiodically exchange their Routing Table and hold updatedlist of all the possible routes to all the nodes. This may create additional overhead

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on the network and increase the storage capacity requirement of each node, but it will considerably increase the transmission reliability and save enormous time invested in route discovery. Ultimately itwill drop down final transmission time taken and muchmore data can be transmitted in minimum amount of time without any interruption.

- To keep Alternate Route information updated those nodeswhich are not a part of transmission may send periodic updates (HELLO Messages) among themselves.
- They may periodically exchange their Routing Table and hold updated list of all the possible routes to Node Z
- It will considerably increase the transmission reliability and save enormous time invested in route discovery.
- Ultimately it will drop down final transmission time taken and much more data can be transmitted inminimum amount of time.

Figure 12.19 shows Flow Chart for Proposed Algorithm of AMR-AODV.

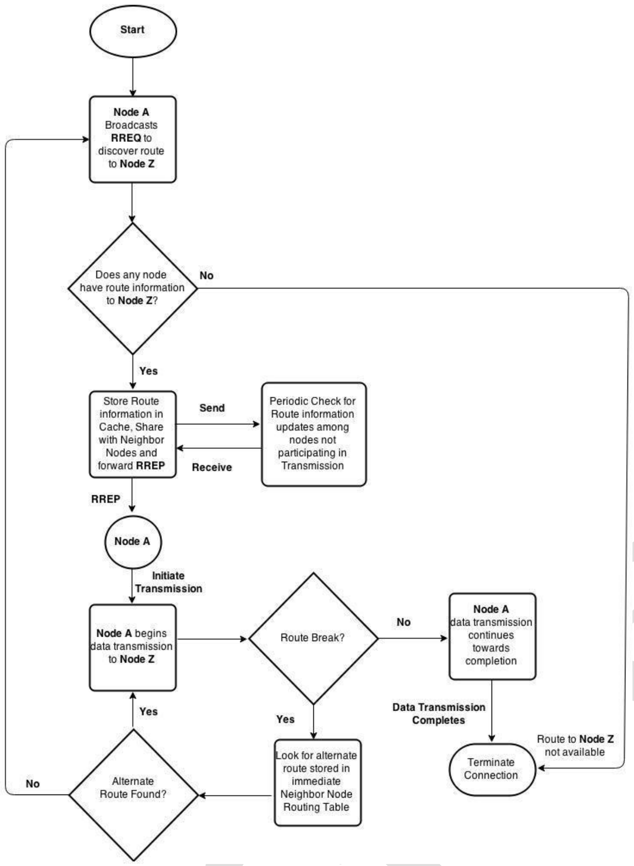

Figure 12.19: Flow Chart for Proposed Algorithm ofAMR-AODV

13. Conclusion and Future Work

An improvement of existing AODV and comparing its performance with AMR-AODV on various parameters, AMR-AODV functions much better than AODV in various situations. Simulation results support to take a decision that the AMR-AODV is better than conventional AODV with reference to increased PDR, throughput and decreased average end to end delay. AMR-AODV protocol comes forward by using alternate route information and it resolves link break immediately.

This simulation draws the conclusion that the AMR-AODV protocol is a better choice for reliable communication at Lower Mobility Speed, Larger Network Size, Larger TerrainRange and in Complex Mobility Models.

14. Scope of Future Scope

- The future scope is to develop the on the wholeperformance of AMR-AODV protocol in various situations which could not be evaluated in present study.
- Attempts will be made to allow AMR-AODV perform better when Network Load and Size exceed the current limits.
- Supplementary study of AMR-AODV will set right known flaws and find out new deficiencies.
- The further study will include comparison of differentversions of AODV protocol with AMR-AODV.Additional simulation needs to be performed for the performance assessment with variations in number of nodes, pause time, network load, mobility

speed, mobility models etc.

- Several MANET routing protocols have been introduced and all perform fine in some performance metrics while notable shortcomings are there in some performance metric.
- Still it is necessary to evaluate the protocols having diverse performance parameters with a range of scenarios and dissimilar situations.

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