Multi Objective AODV Based On a Realistic Mobility Model

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Abstract

Routing is one of the most important challenges in ad hoc network. Numerous algorithms have been presented and one of the most important of them is AODV. This algorithm like many other algorithm calculate optimum path while pays no attention to environment situations, mobility pattern and mobile nodes status. However several presented algorithm have considered this situation and presented algorithm which named environment aware or mobility based. But in them have not considered realistic movement and environment such as obstacles, pathways and realistic movement pattern of the mobile nodes. This article present new algorithm based on AODV which find optimum path based on multi objectives. These objectives have been mined from a realistic mobility model, internal status of the mobile nodes and its status in routing. In this method the objectives are optional and each node can consider a couple of them in routing. Therefore this method supports GPS less mobile nodes. Evaluation of the new method shows that considering multi objectives influence routing metrics and can improve some of them.

Keywords: *Multi objective AODV ,Realistic Mobility Model, Ad Hoc Network ,Routing Algorithm , Mobility Model ,Multi objective Problem.*

1. Introduction

Wireless ad hoc network has extended more and more because of its application and services. Ad hoc network is a type of wireless network which does not include any static infrastructure. In such network each node plays both host role and router role. It means each node while it is moving in its environment, send and receive its data packet and relay data packets of other nodes to reach their destinations.
Topology of these networks is variable due of movement of their nodes and there is no control center to support network topology, configuration or reconfiguration it.

One of main challenges of ad-hoc networks is routing. Optimum routing algorithm plays a significant role in performance improvement. Problems such as limited bandwidth, limited power and end to end delay cause to need of an optimum and quick routing algorithm.

Many routing algorithm have been presented for this networks that each of them has self special benefits. In standpoint of gathering routing information, routing algorithms are classified to two classes, proactive and reactive [1]. One of the famous routing algorithms is AODV [2] which is one of the useful and effective reactive algorithms.

Graphs can model many things of the world such as transforming networks, traffic control networks, neural networks, communication networks and etc. routing problem can be modeled to graph too and each host can be a vertex and each link between to host can be a edge. Therefore routing problem can be considered as a shortest path problem (PSS) in a graph. In AODV algorithm a path with minimum hop count is selected as optimum path.

In Single Objective Problem (SOP), there is just one objective [3]. AODV algorithm is an example for these problems. Single objective methods are not suitable for some kind of problems. Finding best solution in this kind of problems depend to multi objectives. Therefore a new kind of problem which named Multi Objective Problem emerged that in it multi objective play role [4]. In shortest path problem [5], we can consider multi objective on each edge such as cost, time, distance and etc and solve this problem based on multi objectives or selected path can satisfy multi objectives. So Multi Objective Shortest Path Problem (MOSPP) can find optimum path based on multi objectives.

This paper tries to propose a novel method which can improve AODV routing algorithm in finding best path based on multi objectives. Proposed method can find the path which is optimum in multi objectives. Therefore effective objective in routing must be realized.
There are many research which prove that mobility has a significant effect on routing[6]. Since if a routing algorithm

can be based on mobility of the nodes or can consider mobility parameter in routing, it would present the better performance. For study on such routing algorithm, we need to can simulate it on a network simulator. Mobility of the nodes models with Mobility Model in the simulator. Mobility model dictates initial place and movement of the nodes to them. This model can model environment around the nodes such as obstacles, pathways and etc. A good mobility model must be based on realistic situation of both the nodes and their environment [7]. Therefore if extracted parameter of a realistic mobility model is considered in a routing algorithm, it can present better performance in routing. There is some non mobility objectives such as geographic distance, energy, traffic and etc that play role in an optimum path can be considered too.

In this paper first related works are introduced. Second, Classic AODV algorithm is perused. Third, a realistic mobility model is introduced and forth, by using earned knowledge of mobility model detects effective objectives and propose a multi objective AODV algorithm based on a realistic mobility model and finally proposed method is evaluated and compared with classic AODV.

2. AODV Routing Protocol

AODV is capable of both unicast and multicast routing. It is an on demand algorithm, meaning that it builds routes between nodes only as desired by source nodes. It maintains these routes as long as they are needed by the sources. Additionally, AODV forms trees which connect multicast group members. The trees are composed of the group members and the nodes needed to connect the members. AODV uses sequence numbers to ensure the freshness of routes. It is loop-free, self-starting, and scales to large numbers of mobile nodes.

AODV builds routes using a route request / route reply query cycle. When a source node desires a route to a destination for which it does not already have a route, it broadcasts a route request (RREQ) packet across the network. Nodes receiving this packet update their information for the source node and set up backwards pointers to the source node in the route tables. In addition to the source node's IP address, current sequence number, and broadcast ID, the RREQ also contains the most recent sequence number for the destination of which the source node is aware. A node receiving the RREQ may send a route reply (RREP) if it is either the destination or if it has a route to the destination with corresponding sequence number greater than or equal to that contained in the RREQ. If this is the case, it unicasts a RREP back to the source. Otherwise, it rebroadcasts the RREQ. Nodes keep track of the RREQ's source IP address and broadcast ID. If they receive a RREQ which they have already processed, they discard the RREQ and do not forward it.

As the RREP propagates back to the source, nodes set up forward pointers to the destination. Once the source node receives the RREP, it may begin to forward data packets to the destination. If the source later receives a RREP containing a greater sequence number or contains the same sequence number with a smaller hop count, it may update its routing information for that destination and begin using the better route.

As long as the route remains active, it will continue to be maintained. A route is considered active as long as there are data packets periodically traveling from the source to the destination along that path. Once the source stops sending data packets, the links will time out and eventually be deleted from the intermediate node routing tables. If a link break occurs while the route is active, the node upstream of the break propagates a route error (RERR) message to the source node to inform it of the now unreachable destination(s). After receiving the RERR, if the source node still desires the route, it can reinitiate route discovery.

RREQ and RREP packet format are illustrated in figures 1 and 2 figure 3 illustrate an entry of route table of a node.

3. Cluster Based Mobility Model

Authors have proposed a realistic mobility model previously which named Cluster Based Mobility Model for Intelligent Nodes [7] which is one of the most realistic mobility models. This section describes it in summary.

In this mobility model to model environment around the mobile nodes, obstacles are determined at the beginning of simulation then pathways are constructed by Voronoi diagram with centroid of obstacles corners [8].

There are different nodes in an Ad-hoc network. Naturally, different nodes have different mobility specifications. For instance, in a campus environment there are automobile nodes, static nodes such as billboards and pedestrian nodes. Even each specific node by itself has different mobility models. For example, pedestrian nodes do not have the same mobility model and teacher nodes may be active in some areas more than the others (e.g. in faculties or libraries) or employee nodes seem to be more active in official places than in other locations. Because of this, it can be said that in an environment, there are different groups of the nodes which can be named clusters. Each cluster have different movement pattern.

But what are the cluster movement specifications? To answer this question, a real campus environment where considered and the movements of different nodes where captured. This reveals the fact that each cluster has the following specifications:
Activity area: it is an area on which the nodes are more active than other areas. It means that the nodes select places in this area or the places near it as their destination more than other locations.

Speed range: speed range of the nodes in each cluster differs from the rate of other clusters. For example automobile clusters have different speed range from pedestrian clusters.

Pause time range: pause time of each cluster is different too. For example, automobiles have shorter pause time than pedestrians.

Capacity: each cluster has a certain capacity. For instance, the number of automobiles is less than that of pedestrians.
Path choice method: the nodes in each cluster have different path choice method. Automobiles, for example, prefer sparser path even if it is longer, but pedestrians prefer shorter path even if it is crowded or some environment aware nodes choose shortcut path but others do not aware about it choose main paths.

The following scenario describes movement behavior of the nodes in their environment.

In the proposed model, the nodes become the members of clusters according to their capacity in a random way. They are distributed at Voronoi graph vertices based on their activity area at the beginning of simulation. Then, each node selects a vertex as destination based on its activity area and calculates an optimum path to destination based on path choice method and selects a speed rate between Vmin and Vmax, which has been specified for its cluster at the beginning of the simulation. Then it moves to the destination through the selected path in the predefined pathways. In destination it pauses between pmin and pmax that has been specified for its cluster at the beginning of the simulation. This procedure is repeated to the end of simulation.

4. Proposed Method

As it is mentioned previously, in AODV algorithm path with minimum hop count is chosen. But this method can not be suitable every time and every where. Maybe a path with minimum hop count would have nodes with maximum distance between each others, therefore with minimum movement of the nodes, they exit from transmission range of each other and the path is broken. Since a path with more hop count which consider distance between its nodes is better than a path with minimum hop count which does not consider distance. This matter can be said for energy, traffic and etc. So an optimum path is the path that is selected based on multi objectives.

Proposed method considers not only hop count but also other objectives. These objectives are driven from mobility model, mobile node specification and routing. By considering these objective multi objective AODV can find paths which are optimum based on multi objectives. In proposed method, selecting of objectives that participate in finding path is optional. Since if a node lacks some facilities such as GPS, objectives in which need GPS can be not considered. Therefore proposed method support GPS less mobile nodes.

First objectives which play role in finding path are introduced, then how to use from it will be explained.
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4.1 Geographical Distance

Geographical distance can play a significant role in durability a stability of a path. If distance of two consecutive nodes was so far that with minimum movement they exit from transmission range of each others, the path has not proper durability and stability and maybe break in a short time.

If all nodes have GPS, they will able to have their geographical position every time. Therefore a field that named Position is contrived in RREP packet. Each node when relay RREP packet, fill this field by their geographical position. So each node knows its previous node position and on the other hand knows its position. Since with below formula Eq.(1) can calculate distance between it and previous node.

$$dist = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \quad (1)$$

$$DD = \frac{dist - dist_{min}}{dist_{max} - dist_{min}}$$

In this formula (x_1,y_1) is coordination of previous node and (x_2,y_2) is coordination of next node. $dist_{min}$ is minimum distance that is equal to 0 and $dist_{max}$ is maximum distance that is equal to “ 2 * transmission range of the nodes ”. DD is distance objective which is normal between 0 and 1.

4.2 Cluster Objective

As in cluster based mobility model mentioned each node is belong to a special cluster and have movement specifications of its cluster. Some of these cluster specifications can have a significant effect on durability and stability. For instance if the nodes have lower speed range or higher pause time range, the path can stay stable more.
Since for each cluster can specify a special rank. Thus each cluster which has specifications cause to produce more stable path takes higher rank. These specifications include maximum speed and maximum pause time. This rank can be calculated according Eq.(2).

$$(2)\quad C = ((v_{\max} + v_{\min})/2) + (2/(p_{\max} + p_{\min}))$$

$$DC = \frac{1}{C}$$

In above formula v_{min} and v_{max} are minimum and maximum speed and p_{min} and p_{max} are minimum and maximum speed. In this formula whatever lower value of C is better, so to normalize and taking it to maximum objective, 1/C is considered.

4.3 Activity Area Objective

Each node has specific activity area where it is found there more than anywhere. Therefore if two consecutive nodes in a path belong to the same activity area or their activity areas are close to each other, probability of stability and durability of the path will be raised.

So each node send its cluster number by RREP packet, receiver of this packet according this number verify activity area of previous node and on the other hand know its activity area and since calculate distance between activity area of previous node and activity area of next node. Eq. (3) calculates this distance:

$$dist = \sqrt{(xa_1 - xa_2)^2 + (ya_1 - ya_2)^2} \qquad (3)$$

$$DA = \frac{dist - dist_{\min}}{dist_{\max} - dist_{\min}}$$

In above formula (xa_1,xa_1) is coordination of center of previous node activity area and (xa_2,xa_2) is coordination of center of next node activity area. $dist_{min}$ is minimum distance that is equal to 0 and $dist_{max}$ is maximum distance that is equal to network simulation terrain diameter. DA is normalized objective with value between 0 and 1.

4.4 Node Energy Objective

Mobile nodes are notebook computers or portable wireless device, since they equipped to battery and maybe their energy com to end. Therefore if in a path energy of one or more nodes com to end, the path will be broken. So a path which includes nodes with sufficient energy is more stable and durable.

Suppose energy of a node is a value between 0 and 100 that 100 is maximum energy and 0 means node has no energy to communication. Energy is decreased in 3 ways. 1. As time passed a constant value of energy is decreased. 2. For sending each packet a constant value of energy is decreased. 3. For receiving each packet a constant value of energy is decreased. Energy is a maximum objective, it means higher value of it is better. But for justify this objective to others, it is taken to minimum objective. So below formula calculate this objective.

$$(4)\quad p' = p - 100$$

$$DP = \frac{p' - 1}{100 - 1}$$

In Eq.(4) DP is energy objective that is normalized and is taken to range 0 to 1.

4.5 Traffic objective

Next objective is traffic through a path. A longer path with less traffic is better than a shorter path with high traffic. A high traffic link can cause to partitioning of total of a path. Because this link change to a bottleneck of a path and keep packets in long queue and even drop them. Therefore traffic can has a significant role in stability and durability of a path.

To control traffic, each node in its neighbor table apply a new field that increases it per each packet is sent or relayed through this neighbor link. Thus this field determine number of packets that are sent trough this neighbor link during simulation.

To use this objective, each node which wants to send or relay a RREP packet adds this traffic objective to it that is calculated by Eq.(5).

$$DT = \frac{1}{T} \qquad (5)$$

T in above formula is value of mentioned field in neighbor table and DT is objective of traffic in finding path which convert T to a minimum objective and normal it to range 0 and 1.

4.6 Environment Obstacle Objective

Environment obstacles can effect on stability or durability of a path. This is because nodes of an ad-hoc network are mobile usually and this movement can cause placing an obstacle among two consecutive nodes that can inhibit signal of them and partition the path. Therefore not only distance of two consecutive nodes of a path can effect on stability of it but also environment obstacle around them.

But how the effect of these obstacles can be calculated. To reach this goal, two consecutive nodes which have two spheres with radius equal to transmission range of each node is considered. If these two spheres have an overlap region, mentioned two nodes are connected. Whatever area of this region is more, two nodes have stronger link.

When two circle have an intersection area, it can cause to creation of a sector in each circle. This pizza-like slice has been illustrated in Figure 1 as BAC sector in circle with center A and BDC sector in circle with center D. These sectors can be considered connection area for two nodes despite it has some extra region but we do not decide to calculate it exactly. There is a rectangle as an obstacle in figure 1. There are two other sectors, eDf and gAh which have been created by mentioned obstacle. These two sectors can not be considered as connection area for two nodes, so for calculating effective region for connection of two nodes these regions are subtracted from sectors BAC and BDC.

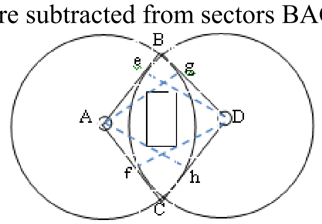

Fig 1. Effect of an obstacle in connectivity of two nodes

$S_1 = (\text{Angle}(BAC)/360).\pi.r^2$ Area of sector BAC
$S_2 = (\text{Angle}(BDC)/360).\pi.r^2$ Area of sector BDC
$S_3 = (\text{Angle}(gAh)/360).\pi.r^2$ Area of sector gAh (6)
$S_4 = (\text{Angle}(eDf)/360).\pi.r^2$ Area of sector eDf
$S = (S_1+S_2) - (S_3+S_4)$ Area of effective section

Formulas 6 calculated effective region area of two circle. Whatever S is more, link between two nodes is stronger. OA convert it to a minimum objective and DO normalize it to range 0 and 1. (Eq.(7))

$$(7) \qquad OA = \pi r^2 - S$$

$$DO = \frac{A}{\pi r^2}$$

5. Proposed Method

As it is mentioned previously, optimum path is the path which is optimum based on multi objectives. Objectives that are mentioned in previous section were not all the same. Some of them were minimum objectives and some maximum objectives. But all of them are converted to minimum objective and are normalized to range 0 and 1. Now with such objectives, each node can by a Pareto method select its path based on 6 mentioned objectives. To reach this end, AODV is improved by using a weighted sum method. It means all objectives are added to each others and be a single objective.

There are just two mentioned objectives which need to have mobile nodes equipped GPS receiver to calculate their position, geographical distance and obstacle effect. Proposed method able not to consider some objectives and it is optional for nodes when they want to find a path. Thus proposed method support both GPS equipped nodes and GPS less.

In proposed method some fields are added to routing table, RREP packet and RREQ packet. Figures 2, 3 and 4 illustrate them.

Source Address	Destination Address	Number of source sequence	Number of destination sequence	Request number	Route selection priority	Hop counts

Fig.2. Route request message frame

Source Address	Destination Address	Number of Destination sequence	Life time	Hop count	Geographic coordination	Route selection priority	Sum Of objectives (OBJS)

Fig.3. Route response message frame in new algorithm

Destination Address	Number of destination sequence	Next hop to destination	Lifetime	Routing register	Hop count to destination	Route selection priority	Sum of objectives (OBJS)

Fig.4. Files of Route Table at each node in new algorithm

There is a field In RREQ packet which named objectives primitives that determines primitive of RREQ sender for its required path. In this 6 bit field, each bit has been associated to an objective. If each bit of this field has 0 value, associated objective of it will not be used for finding path and RREQ generator does not consider that objective.

There is just one field for all objectives in RREP packet and routing table. It is because of using a Weighted Sum [9] method. In fact all objectives are added to each others according to below formula and result placed in OBJS field.

$$F = F_{old} + \Sigma (w_i \times f_i) \forall f_i \in \{DD, DC, DA, DTDP, DO\} \quad (8)$$

F_{old}, in Eq.(8) is calculated as follow:
If node which wants to send RREP is generator of it and is destination of path, value of F_{old} will be considered 0.
If node which wants to send RREP is generator of it and is a node which has a path to destination, value of F_{old} will come from OBJS field of routing table.

If node which wants to send RREP is not generator of it and is an intermediate node, value of F_{old} will come from OBJS field of received RREP packet.

W_i , in above formula is routing primitives which RREQ generator considers to determines which objectives play role in finding a path.

Each node when receive RREP packet insert a reverse path in its routing table. But at the time of inserting, if there was a same entry with the same destination and has the same objective primitives, higher value of OBJS field of RREP packet and routing table entry determines which of them must be stays in routing table. If there is no entry with the same destination or even the same objective primitives new path from RREP packet insert directly in routing table. Indisputable just fresh routes (not expired) of routing table are considered. After updating routing table RREP packet forward to next hop to reach source of path.

6. Simulation

Main goal of simulation is evaluation of proposed method and comparing it with previous methods. Since, proposed method has been compared with classic AODV. There are 3 diagrams to evaluation performance of new method as follow:
Proposed method: this diagram considers all mentioned objectives.

Proposed method for GPS less network: this diagram has not considered GPS related objectives (distance and obstacle effect) in simulations.

AODV algorithm: this diagram has been created by classic AODV algorithm and is a criterion of performance of proposed method.

Simulation has been done 3 time with different variable parameter.

Simulation in variable speed: in which simulation was with 50 nodes and in simulation with size 1000x1000. Speed of the nodes was variable between 0 to 10 m/s.

Simulation in variable number of nodes: in which number of the nodes was variable in 20 to 70 and simulation terrain size was 1000x1000 and speed of each node was a random number between 0 to 2.

Simulation in variable size of simulation terrain size: in which simulation was with 50 nodes and simulation terrain size was variable between 800x800 and 1800x1800 and speed of each node was a random number between 0 to 2.
Each point of diagrams has been calculated by 30 time simulation with different random Seed.

6-1. Simulation Parameters

All simulations have been done with Glomosim [10] network simulator which is one of most popular wireless network simulator.

Mobility model is Cluster Based Mobility Model for Intelligent Nodes which was explained in previous sections. The simulation terrain as shown in figure5 is 1000m*1000m with 7 obstacles and 3 clusters that each cluster have an activity area shown with different colors.
The maximum node transmission range is 250m. However, in the presence of obstructions, the actual transmission range of each individual node is likely to be limited. At the MAC layer, the IEEE 802.11 DCF protocol is used, and the bandwidth is 2Mbps.
After initial distribution of the nodes, the nodes move for 60 seconds so that they are distributed throughout the simulation area. Ten data sessions are then started. The data packet size is 512 bytes and the sending rate is 4 packets/second. The maximum number of packets that can be sent per data session is set to 6,000.Movement continues throughout the simulations for a period of 1800 seconds. Each data point is an average of 30 simulation runs with the nodes distributed in different initial positions.

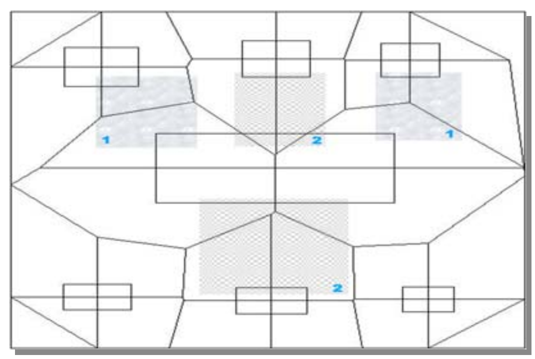

Fig5. simulation terrain

6-2. Simulation Metrics

Routing metric has been measured to performance evaluation of proposed algorithm and comparing it with AODV. These metrics are as follow:
Data Packet Reception: The number of data packets received at their intended destinations.

Control Packet Overhead: The number of network-layer control packet transmissions.

End-to-End Delay: The end-to-end transmission time for data packets. This value includes delays due to route discovery.

Above metric are measured in 3 different mentioned situations.

6-3. Simulation Results

a. Average End-End Delay

End to end delay is consumed time to point to point transmission of a data packet. This time includes delay that is because of routing. In this section, average end to end delay is evaluated in 3 separate situations, variable range speed, variable number of nodes and variable size of simulation terrain. These were shown in figure 6 , 7 and 8 Using distance and activity area provides path with shorter and more stable link and cause to send data quicker and more dependable. Using traffic objective prevents standing packets in long queue to they are sent rapidly. Consideration energy and cluster cause to produce more stable paths too. Obstacle effect objective decrease probability of exiting nodes from transmission range of each others with a bit movement.

Best results is belong to proposed method with consideration all objectives in all diagrams. Since it can result all objectives play role in finding stable and short paths. While when two objectives of 6 objectives are not considered, result is worse than previous diagram. It means two objectives distance and obstacle effect play a significant role in finding stable paths. But GPS less diagram has the better result than classic AODV too. It means remained objectives in GPS less diagram retain theirs effect on finding path and produce more stable path than AODV algorithm.

Increasing speed cause to increases average end to end delay in all diagrams. This is because of increasing movement of nodes which cause to nodes exit from transmission range of each others and paths failure rate increased.

But increasing average end to end delay while increasing number of node is unexpected. This is because of increasing of node density and therefore data sessions and it can raise average of end to end delay. This matter is reversed for diagram with variable simulation terrain size.

b)Average Data Packet Reception

Average data packet reception in variable speed, number of nodes and simulation terrain size are illustrated in figures 9, 10 and 11 Considering mentioned objectives play significant role in improving data packet reception and using all of them has best result. This is because of mentioned effect of objectives in previous metric evaluation section.

GPS less diagram has better result than classic AODV but not better than the diagram which considers all objectives. This matter manifests role of two missed objectives, distance and obstacle effect. These two objectives have a significant effect on stability of a path. Distance objective cause to shorten the path and obstacle effect objective cause to select more stable and durable path.

As speed or size of terrain simulation increased average data packet reception is decreased. This is because of decreasing node density which cause to creation less path and therefore less data packet are sent or received. But this matter is reverse when numbers of the nodes are increased.

c)Average Control Packet Overhead

Average control packet overhead is evaluated in 3 different cases, different speed range, different simulation terrain size and different numbers of the nodes. As it is illustrated in figures12, 13 and 14 average overhead in diagram of proposed methods is higher than classic AODV in all diagrams. This can due of prioritized requesting of a path. It means when a node request a path with self defined primitives, it may received by an intermediate node which know a path to destination but its path primitives is not matched to requested path primitives. Therefore path finding process will not be stopped while intermediate node knows a path to destination. This is while in classic AODV path finding process will be stopped in the same situation. Since in proposed method more control packet is consumed than classic AODV.

Overhead in GPS less diagram is some less than diagram which consider all objectives. This is because of restriction of primitives in GPS less diagram which decreases variation of paths.

As speed is increased overhead is increased, because number of broken path is increased and new path need new control packets. But why overhead increased while number of nodes increased. It can because of increasing number of nodes which relay control packets. Overhead decreased when size of simulation terrain increased. This matter is because of decreasing node density which lead to less data packet reception and as a result less control packets.

7. Conclusion

There is just one objective, shortest hop count in finding path in classic AODV. But this objective can not be proper in every case everywhere. Maybe a path has the least hop count but has some other non optimistic objectives. This paper proposed new Multi Objective AODV that is based on a realistic mobility model which could improve performance of ad-hoc network in some metrics. Using of a multi objective algorithm, proposed routing algorithm could consider most important objectives which play role in routing directly or indirectly.

Previous research shown mobility model have a significant effect on routing algorithm, since authors have used a realistic mobility model that they have proposed previously and extracted its parameter and used them as objectives in routing algorithm.

One of the important points in proposed method is supporting both GPS equipped and GPS less nodes. This ability is because of possibility of selecting objectives in finding a path.

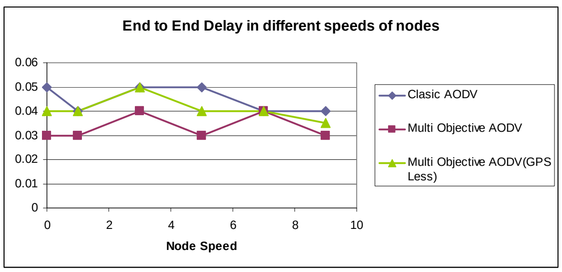

Fig. 6 End to end delay in variant speeds

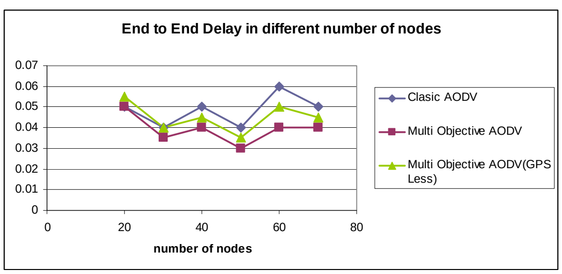

Fig. 7 End to end delay in variant number of nodes

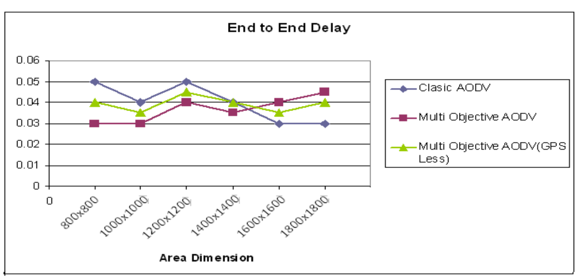

Fig 8. End to end delay in variant size of terrain

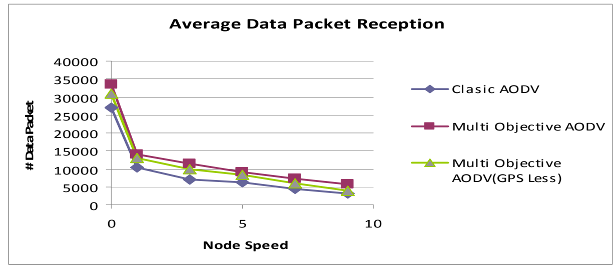

Fig. 9 Average Data Packet Reception in variant speeds

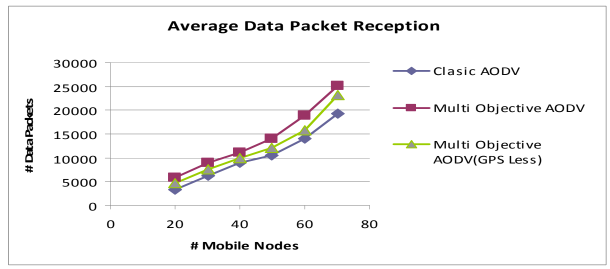

Fig. 10 Average Data Packet Reception in variant number of nodes

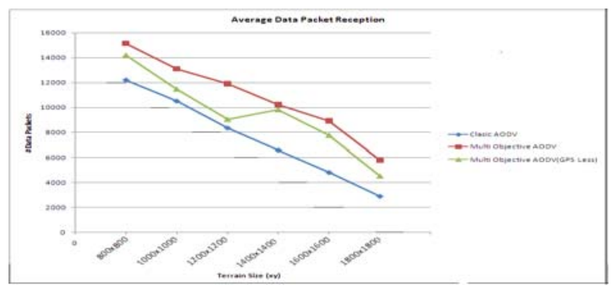

Fig. 11 Average Data Packet Reception in variant size of terrain

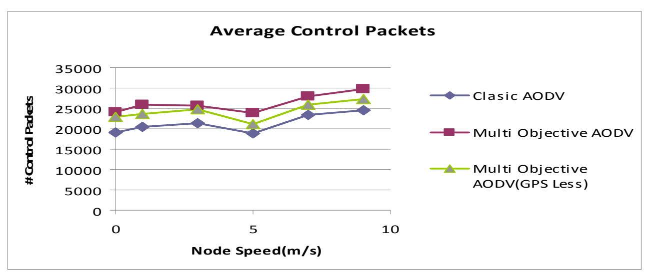

Fig. 12 Average Control Packet Overhead in variant speeds

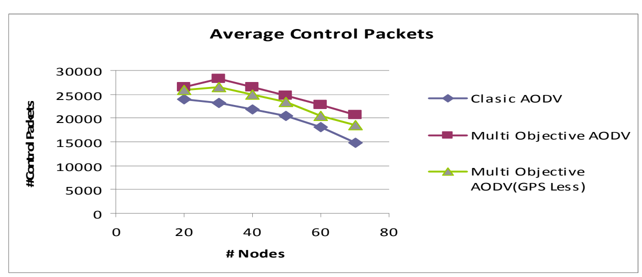

Fig. 13 Average Control Packet Overhead in variant number of nodes

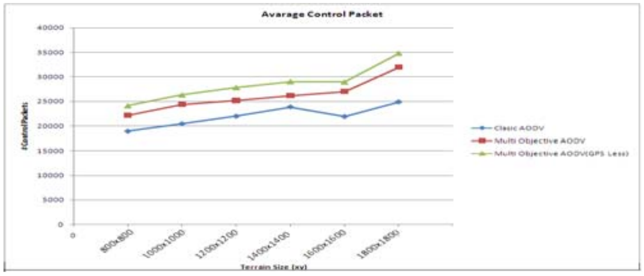

Fig. 14 Average Control Packet Overhead in variant size of terrain

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