Original Article

ANT Based Trustworthy Routing in Mobile Ad Hoc Networks Spotlighting Quality of Service

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ABSTRACT

Mobile ad hoc network (MANET) is a impartial network capable of sovereign operation where nodes communicate with each other without the need of any obtainable infrastructure. Nodes are mobile since topology is very dynamic and are often vulnerable to failure thus making mobile ad hoc networks open to threats and attacks. Nodes sometimes fail to transmit and start dropping packets during the transmission. Such nodes are responsible for untrustworthy routing. Nature-inspired algorithms (swarm intelligence) such as ant colony optimization (ACO) algorithms have shown to be a good technique for developing routing algorithms for MANETs. In this paper An ANT based trusted AODV is presented. Trust is introduced and nodes are considered for routing only if they have trust level higher than the threshold).Ant optimization is implemented to increase the optimization of MANET routing. The proposed protocol increases PDR and decreases delay thereby enhancing the QoS metrics and trustworthiness in AODV based MANET routing. The work is implemented and simulated on NS-2. The simulation result shows the proposed AODV provides more trustworthy and optimized routing compared with general AODV.

Keywords: MANET, ANT, AODV, ACO.

INTRODUCTION

A Mobile ad hoc network is a tremendously complicated dynamic network. Mobile Ad-Hoc network[1] is a system of wireless mobile nodes that self-organizes itself in dynamic and temporary network topologies. Nodes can connect and depart the network at anytime and should be in position to relay traffic. The primary goal of MANET is to find an end to end path or route, minimizing overhead, loop free and route maintenance. These are often called infrastructure-less networking since the mobile nodes in the network dynamically establish routing paths between themselves. Examples are conference, battlefield, rescue scenarios, sensor networks placed in an area

to monitor the environment, mesh networks for wireless Internet access etc. Routing solutions must address the nature of the network, and aim at minimizing control traffic, to preserve both bandwidth and energy at nodes. A few challenges faced in mobile ad hoc networks are mobility, variable link quality, energy constrained nodes, heterogeneity and flat addressing.

Most traditional mobile ad hoc network routing protocols were designed focusing on the efficiency and performance of the network[2]. These protocols should meet some basic requirements like self starting, self organizing, loop free paths, dynamic topology maintenance, minimal traffic overhead etc to deal with the challenges involved in routing. Existing MANET routing protocols can be classified into mainly two types- proactive routing protocols and reactive routing protocols. Table driven (proactive) routing protocols such as dynamic Optimized Link State Routing (OLSR), Destination-Sequenced Distance-Vector routing (DSDV), Topology Broadcast based on Reverse Path Forwarding (TBRPF) and On-demand (reactive) routing protocols such as Ad hoc on demand Distance Vector (AODV), Signal Stability-based Adaptive routing (SSA), Dynamic Source Routing (DSR). AODV is a reactive protocol where route discovery initiated when required only using route request (RREQ) and route reply (RREP) packets and stores only active routes in routing table. Explicit route error notification is done by using route error (RERR). Ad-hoc on demand Distance Vector (AODV) routing protocol[3] is an on demand routing protocol that focuses on discovering the shortest path between two nodes with no consideration of the reliability of a node. By broadcasting HELLO packets in a regular interval, local connectivity information is maintained by each node. However, the traditional AODV protocol seems less than satisfactory in terms of delivery reliability there by affecting quality of service.

Due to the dynamic nature of Mobile Ad-Hoc Networks, there are many issues which need to be tackled and one of the areas for improvement is Quality of Service (QoS) routing. When it comes to QoS routing, the routing protocols have to ensure that the QoS requirements are met[4]. A few challenges faced in providing Qos are persistently changing environment, unrestricted mobility which causes recurrent path breaks and also make the link-specific and state-specific information in the nodes to be inaccurate.

The proposed protocol is to perform its task based on the trust based scheme where trust values calculated for each node and to decide whether the node can take part or to be isolated from routing. If nodes trust value is less than the threshold then the node is declared to be untrustworthy node and an alternate path is chosen. This trust based routing scheme facilitates in identifying and isolating untrustworthy nodes thus providing trustworthy routing in MANET and also improves the performance Qos parameters.

Swarm intelligence (SI)[5] is a type of artificial intelligence based on the collective behavior of decentralized, self-organized systems. One such SI based optimization is ANT colony optimization. ACO[6] is a branch of a newly developed form of Artificial Intelligence called Swarm Intelligence. The amount of pheromone deposited varies in quantities. An ant chooses a trail depending on the amount of pheromone deposited on the ground. The larger the concentration of pheromone in a particular trail, the greater is the probability of the trail being selected by an ant. These ants use the notion of stigmergy to communicate indirectly among the ants. They dynamically find a path on the fly. The ACO technique is quite amenable to ad hoc networks due to their

similar characteristics. An artificial ant acts like a mobile agent or a node in an ad hoc network. An ant creates a path dynamically on the fly as the routing protocols in MANETs.

Thus proposed work calculates trust values for every node that takes part in routing and compares it with threshold value. The node with sufficient trust value is considered for routing. Finally the optimization is done using ACO to yield more optimized performance. This scheme facilitates in providing optimized and trusted routing in MANET and also improves the performance Qos parameters like PDR and delay.

Literature survey

Mobile ad hoc network is capable of autonomous operation, operates without base station infrastructure, nodes cooperate to provide connectivity and operate without centralized administration. MANETs have put on more significance in recent applications areas like security, routing, resource management, quality of service etc. The significance of routing protocols in MANETs has anticipated for a lot of competent and inventive routing protocols. Continuous evaluation of node's performance and collection of neighbour node's opinion value about the node are used to calculate the trust relationship of this node with other nodes[7]. In this paper, existing AODV routing protocol has been modified in order to adapt the trust based communication feature and the proposed trust based routing protocol equally concentrates both in node trust and route trust.

RAODV (Reliant Ad hoc On demand Distance Vector Routing)[8] is a security-enhanced AODV routing protocol that uses a modified scheme called direct and recommendations trust model and then incorporating it inside AODV. This scheme assures that packets are not handed over to malicious nodes. Based on this trust value a node is selected to perform packet transfer. This protocol results in higher percentage of successful data delivery compared to AODV. A routing algorithm is proposed that adds a field in request packet which stores trust value indicating node trust on neighbour[9]. Based on level of trust factor, the routing information will be transmitted depending upon highest trust value among all that results not only in saving the node's power but also in terms of bandwidth. A trusted path irrespective of shortest or longest path is used communication in the network.

A routing protocol[10], that adds a field in request packet and also stores trust value indicating node trust on neighbour based on level of trust factor. This scheme avoids unnecessary transmit of control information thus efficiently utilizing channels and also saves nodes power. Route trust value is calculated based on the complete reply path, which can be utilized by source node for next forthcoming communication in the network that results in improvement in security level and also malicious node attacks are prevented. A trust based packet forwarding scheme[11] for detecting and isolating the malicious nodes using the routing layer information that uses trust values to favour packet forwarding by maintaining a trust counter for each node. A node will be punished or rewarded by decreasing or increasing the trust counter. If the trust counter value falls below a trust threshold, the corresponding intermediate node is marked as malicious.

A framework[12] for estimating the trust between nodes in an ad hoc network based on quality of service parameters is proposed based on Probabilities of transit time variation, deleted, multiplied and inserted packets, processing delays. It has been shown that only two end nodes need to

be involved and thereby achieve reduced overhead. A Node-based Trust Management (NTM) scheme in MANET[13] is introduced based on the assumption that individual nodes are themselves responsible for their own trust level. Mathematical framework of trust in NTM is developed along with some new algorithms for trust formation in MANETs based on experience characteristics offered by nodes. The above listed works are spotlighting on reliability that is provided to the mobile ad hoc network by using trust schemes.

Proposed work

In MANET, providing reliable routing is difficult because of its dynamic nature that keeps nodes moving and not stable. In spite of this nature nodes communicate with each other and exchange data among the nodes that are in its range on the network. But still there are nodes in the MANET which take part in routing but drop packets while transmitting packets which affects the performance of the protocol. Thus trusted AODV is introduced which checks each node before involving it in the routing process. The design of the proposed work is presented in figure 1.

Trust model

In the MANET an observation is made on all nodes that transmit packets. The total packets they transmit, packets they receive and the packets they drop are taken in to account. Once a particular transmission is to be made the protocol decides the route and the nodes which are going to participate in routing are checked against their trust values which are calculated based on the total packets handled by each node. Based on this trust value a node is located if it is about to drop packets. Thus these packet dropping nodes are spotted and removed from the routing path and the protocol again checks for an alternate node for proceeding the routing. Thus an alternate path is identified based on the trust values of the node that is to be included recently in the routing path to carry on the routing effectively. Thus trusted AODV removes packet dropping nodes in the routing path which causes the performance of the network to decline and resulting in lower QoS values. These packet dropping nodes may result in reducing trust values of nodes by indirectly affecting them in the network. (See figure 1.)

The trust level value calculation is based on the parameters shown in the table 1. The count field describes about two criteria success and failure which describes whether the transmission was a successful transmission or a failure. (See table 1.)

RREQ and RREP are the route request and route reply respectively which are exchanged between nodes in the network. Data refers to the payload transmitted by the nodes. The parameter qrs is defined as the query request success rate which is calculated based on number of neighbouring nodes who have successfully received (rreq) from the source node which has broadcasted it, qrf defined as the query request failure rate which is calculated based on number of neighbouring nodes which have not received the query request, qps is defined as the query reply success rate which is calculated as successful replies (rrep) received by the source node which has sent the rreq and qpf is defined as the query reply failure rate which is calculated based on the number of neighbouring nodes which have not sent the replies for the query request received. qds is defined as the data success rate calculated based on successfully transmitted data and qdf is defined as data failure rate calculated based on data which have failed to reach destination. However, it is known that for every network there will be minimum data loss due to various constraints.

$$Qr = \frac{q_{rs} - q_{rf}}{q_{rs} + q_{rf}} \quad (1)$$

$$Qp = \frac{q_{ps} - q_{pf}}{q_{ps} + q_{pf}} \quad (2)$$

$$Qd = \frac{q_{ds} - q_{df}}{q_{ds} + q_{df}} \quad (3)$$

Where Qr, Qp and Qd are intermediate values that are used to calculate the nodes Request rate, Reply rate and Data transmission rate. The values of Qr, Qp, and Qd are normalized to fall in range of -1 to +1. If the values fall beyond the normalized range then it clearly shows that the failure rate of the node is high and denotes that the corresponding node may not be suitable for routing.

$$TL = T(RREQ) * Qr + T(RREP) * Qp + T(DATA) * Q_d$$

Where, TL is the trust level value and T (RREQ), T (RREP) and T (DATA) are time factorial at which route request, route reply and data are sent by the node respectively. Apart from the above mentioned normalised range, using the above formula the trust level value (TL) is calculated for each node during routing and is checked against the threshold value (average of trust values of neighboring nodes). If lesser than threshold then there is a possibility for this node to drop packets for the current transmission and will not be suitable for routing and an alternate path is selected for routing. However, this node may be the best node for some other transmission between some other source and destination in the same network at different time interval. Therefore based on the above calculation the following two cases are derived based on the threshold value. Case 1: The nodes trust value is checked with the threshold value and if the value is greater than the threshold value then the node is defined a trustworthy node and are allowed to participate in routing thereby assuring a trustworthy routing in MANET. Case 2: If the nodes trust value is less than or equal to threshold value then the node in defines as untrustworthy node which cannot be allowed to participate in routing which causes packet dropping. In both cases the trust calculation is performed regularly to check the nodes performance and help it to be marked trustworthy or not. The trust calculation is done for all nodes in the routing path to monitor nodes reliability. If the failure rate increases it automatically affects the Qr, Qp and Qd values thus making them fall beyond the normalized values thus resulting in trust value less than the threshold.

Ant colony optimization

Ant-colony optimization (ACO) algorithms evolve not in their genetics but in their social behavior. ACO was developed by Dorigo *et al*.[14] based on the fact that ants are able to find the shortest route between their nest and a source of food. This is done using pheromone trails, which ants deposit whenever they travel, as a form of indirect communication. As shown in Figure 2, when ants leave their nest to search for a food source, they randomly rotate around an obstacle, and initially the pheromone deposits will be the same for the right and left directions. When the ants in the shorter direction find a food source, they carry the food and start returning back, following their pheromone trails, and still depositing more pheromone. (See figure 2.)

As indicated in Figure 2, an ant will most likely choose the shortest path when returning back to the nest with food as this path will have the most deposited pheromone. For the same reason, new ants that later starts out from the nest to find food will also choose the shortest path. Over time, this positive feedback (autocatalytic) process prompts all ants to choose the shorter path[15]. Implementing the ACO for a certain problem requires a representation of

S variables for each ant, with each variable i has a set of ni options with their values lij, and their associated pheromone concentrations { T_{ij} }; where i=1, 2,., S, and j=1, 2,., ni. As such, an ant is consisted of S values that describe the path chosen by the ant. In the ACO, the process starts by generating m random ants (solutions). An ant k (k=1, 2,., m) represents a solution string, with a selected value for each variable. Each ant is then evaluated according to an objective function. Accordingly, pheromone concentration associated with each possible route (variable value) is changed in a way to reinforce good solutions, as follows:

$$T_{ij}(t) = P\,T_{ij}(t-1) + D\,T_{ij};\ t = 1,2,\ldots J \qquad (1)$$

Where J is the number of iterations (generation cycles); T_{ij} (t) is the revised concentration of pheromone associated with option lij at iteration t, T_{ij} (t-1) is the concentration of pheromone at the previous iteration (t-1); D T_{ij} = change in pheromone concentration; and P is the pheromone evaporation rate (0–1). The reason for allowing pheromone evaporation is to avoid too strong influence of the old pheromone to avoid premature solution stagnation. In Eq. (1), the change in pheromone concentration DT_{ij} is calculated as:

$$D\,T_{ij} = \sum_{k=1}^{m} \frac{R}{\text{fitness}\,k} \qquad (2)$$

Where R is a constant called the pheromone reward factor; and fitnessk is the value of the objective function (solution performance) calculated for ant k. It is noted that the amount of pheromone gets higher as the solution improves. Therefore, for minimization problems, the Eq. (2) shows the pheromone change as proportional to the inverse of the fitness. In maximization problems, on the other hand, the fitness value itself can be directly used. Once the pheromone is updated after an iteration, the next iteration starts by changing the ants' paths (i.e. associated variable values) in a manner that respects pheromone concentration and also some heuristic preference. As such, an ant k at iteration t will change the value for each variable according to the following probability:

$$P_{ij}(k.t) = [\,T_{ij}(t)]^{\alpha}\ X\ [n_{ij}]^{\beta}\ /\ \sum_{Tij}\,[T_{ij}(t)]^{\alpha}\ X\ [n_{ij}]^{\beta} \qquad (3)$$

Where Pij (k, t) = probability that option lij is chosen by ant k for variable i at iteration t; T_{ij} (t) = pheromone concentration associated with option lij at iteration t; n_{ij} =heuristic factor for preferring among available options and is an indicator of how good it is for ant k to select option lij (this heuristic factor is generated by some problem characteristics and its value is fixed for each option lij); and a and b are exponent parameters that control the relative importance of pheromone concentration versus the heuristic factor[16]. Both α and β can take values greater than zero and can be determined by trial and error. Based on the previous discussion, the main parameters involved in ACO are: number of ants m; number of iterations t; exponents α and β; pheromone evaporation rate r; and pheromone reward factor R.

EVALUATION RESULTS

The proposed AODV protocol's performance is analyzed using NS-2 simulator. The network is planned and implemented using network simulator with node size varying from 25 to 300. The simulator is applied with traditional AODV and with proposed AODV and results are obtained for assessment. The proposed AODV protocol has shown good progress over the Qos parameters like PDR & Delay. PDR is increased and delay is reduced compared to the traditional AODV. The performance of the proposed protocol is also represented graphically where it clearly shows the betterment of the Qos parameters. The traditional AODV doesn't provide reliable routing since the nodes present in

the network drop packets and take long paths while routing which degrades the performance of routing and results in reduced packet delivery ratio and increased delay.

The Qos parameter values are showing better improvement when the routing takes place with the proposed AODV protocol which works using energy values that identifies untrustworthy nodes in the route and immediately take an alternate path to provide trustworthy and successfully routing. The results shown in the result comparison table clearly shows the PDR and delay increases as number of nodes increases (success rate higher as number of nodes increases. Figure 3. Specifies the increase in PDR by implementing the proposed AODV (PROP AODV) protocol compared to the general AODV (GEN AODV) protocol. Figure. 4. Specifies the decrease in delay while using the proposed AODV compared to traditional AODV. (See figure 3 and 4.)

CONCLUSION AND FUTURE ENHANCEMENTS

In this paper a trust based optimized AODV protocol is proposed that identifies the nodes that drop packets during data transmission. Trust value for each node is calculated to spot the untrustworthy nodes in the path during routing. A node is declared as a trustworthy node if its trust value is greater than the threshold value thus resulting in a trustworthy MANET routing. This trust based selection of nodes is more optimized using Ant colony optimization thus providing trusted and optimized routing path in MANET. This proposed scheme has shown a good development over Qos parameters like PDR and delay and has also provided trustworthy routing. The same scheme can also be implemented on other MANET routing protocols and check the performance with respect to Qos parameters. The future work may provide an encryption scheme for secured packet transmission and also to consider energy levels of the nodes participating in the routing to enhance reliability in MANET routing.

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Table 1. Node trust calculation parameters

Count Type	RREQ	RREP	Data
Success	Qrs	Qps	Qds
Failure	Qrf	Qpf	Qdf

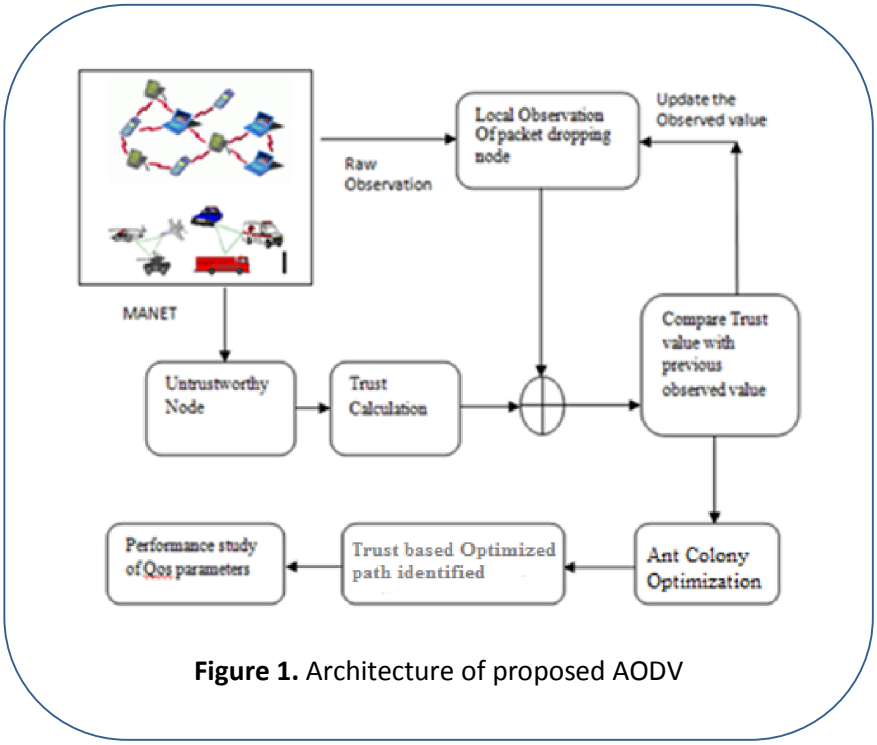

Figure 1. Architecture of proposed AODV

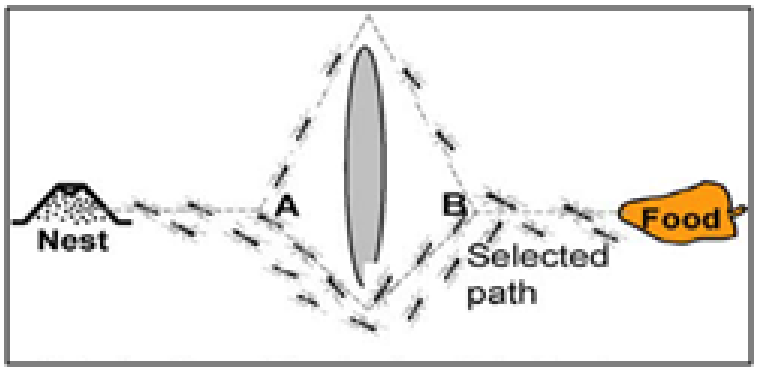

Figure 2. Ants choosing path

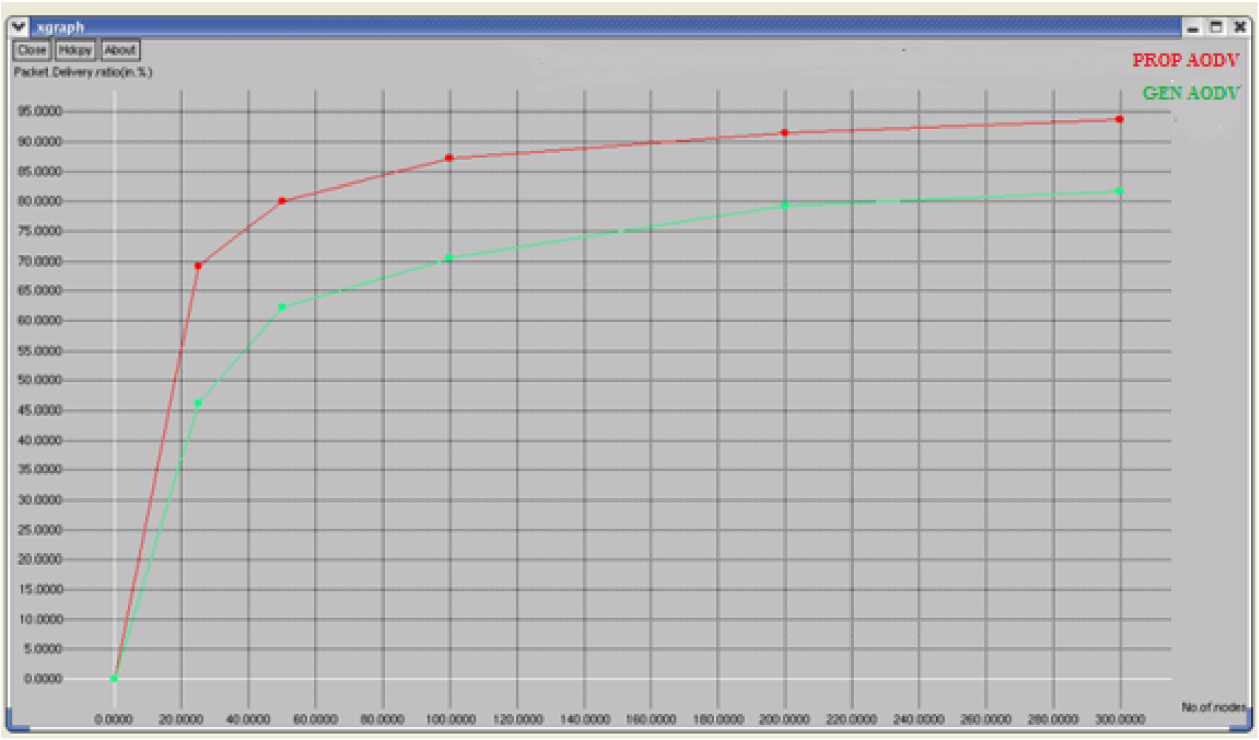

Figure 3. Comparison of general AODV PDR and proposed AODV PDR

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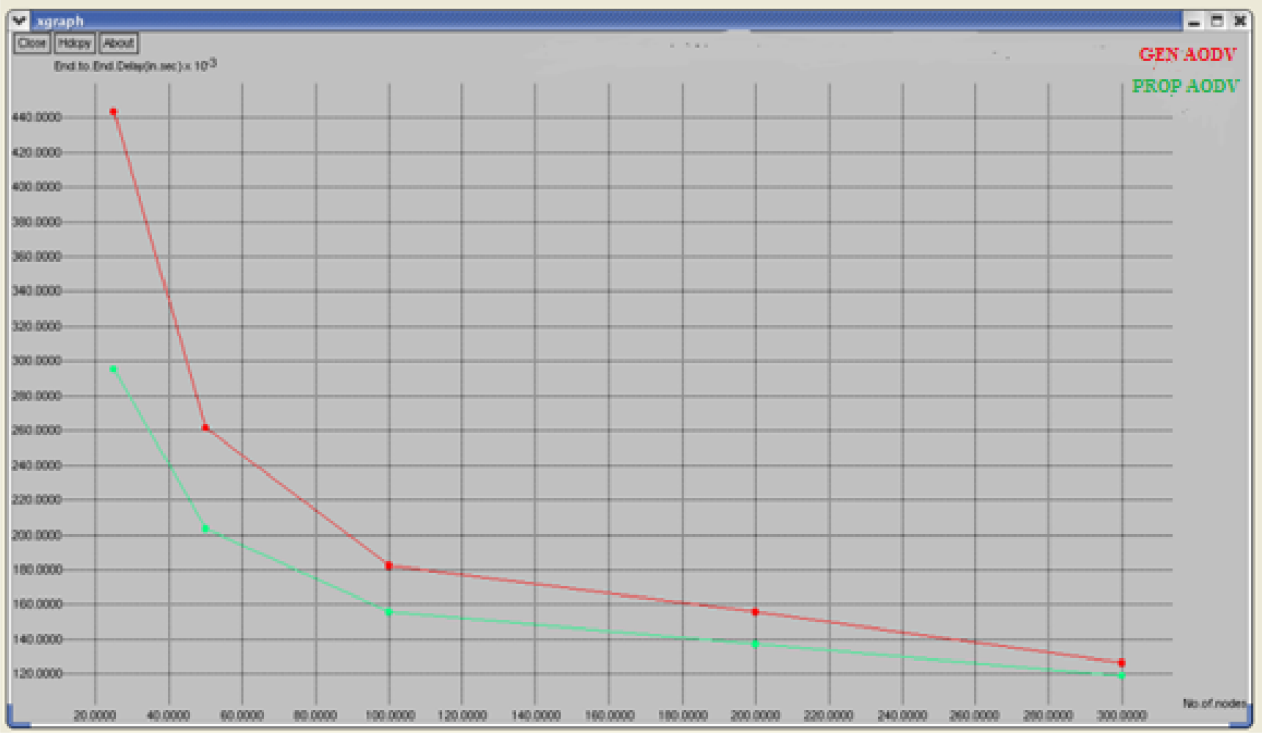

Figure 4. Comparison of general AODV Delay and proposed AODV Delay