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Incorporation of Gossip Based Approach in Ad-Hoc On-Demand Distance Vector (AODV) Routing

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Abstract: A mobile ad hoc network consists of wireless hosts that may move often. Movement of hosts results in a change in routes, requiring some mechanism for determining new routes. Several routing protocols have already been proposed for ad hoc networks. These routing protocols are based on (some variant of) flooding. Despite various optimizations, many routing messages are propagated unnecessarily. We propose a gossiping-based approach, where each node forwards a message with some probability, to reduce the overhead of the routing protocols. Gossiping exhibits bimodal behavior in sufficiently large networks: in some executions, the gossip dies out quickly and hardly any node gets the message; in the remaining executions, a substantial fraction of the nodes gets the message. The fraction of executions in which most nodes get the message depends on the gossiping probability and the topology of the network. For large networks, this simple gossiping protocol uses up to 35% fewer messages than flooding, with improved performance. The network simulator ns-2 is used to accurately model the particular wireless network and to analyze the performance.

Key words: Ad Hoc networks, flooding, gossiping, AODV routing, bimodal behavior

INTRODUCTION

Mobile hosts and wireless networking hardware are becoming widely available and extensive work has been done recently in integrating these elements into traditional networks such as the Internet (Rappaport, 1996). Often times, however, mobile users will want o communicate in situations in which no fixed wired infrastructure such as this is available, either because it may not be economically practical or physically possible to provide the necessary infrastructure or because the expediency of the situation does not permit its installation. An ad hoc network is a multi-hop wireless network with no fixed infrastructure. Rooftop networks and sensor networks are two existing types of networks that might be implemented using the ad hoc networking technology. Ad hoc networks can be usefully deployed in applications such as disaster relief, tether less classrooms and battlefield situations.

In ad hoc networks as shown in Fig. 1, the power supply of individual nodes is limited, wireless bandwidth is limited and the channel condition can vary greatly. Moreover, since nodes can be mobile, routes may constantly change. Thus, to enable efficientcommunication, robust routing protocols must be developed.

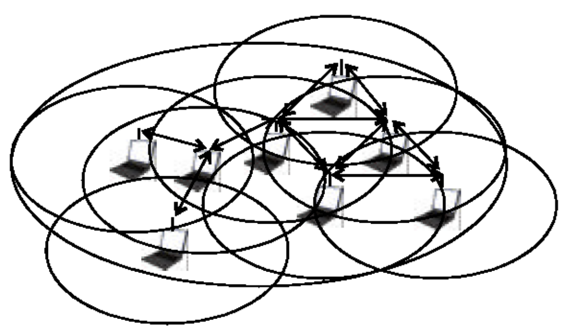

Fig . 1. An Example of Ad hoc network

The routing protocols for ad hoc networks have to adapt quickly to frequent and unpredictable topology changes and must be parsimonious of communications and processing resources (Johnson and Maltz, 1996). Hence designing efficient routing algorithms for such network have been an active research topic in the last few years.

Many ad hoc routing protocols have been proposed. Some, such as LAR, GPSR and DREAM assume that nodes are equipped with GPS hardware and thus know their locations; others, such as DSR, AODV, ZRP and TORA, do not make this assumption. Essentially all

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protocols that do not use GPS (and some that do, such as LAR and DREAM) make use of flooding, usually with some optimizations.

Among of them, the most typical one is called Ad Hoc Distance Vector Algorithm (AODV), which is based on Distance Vector algorithm. AODV is reactive, as opposed to proactive protocols like DSDV. AODV requests a route only when needed and does not require nodes to maintain routes to destinations that are not actively used in communications. AODV uses expanding ring search in Route Discovery and route validation in Route Maintenance.

RELATED WORK

Researchers found that many routing messages are propagated unnecessarily in routing protocols. To control flooding effect, they require nodes to memorize past traffic to avoid forwarding the same message more than once. DREAM (Basagni *et al*., 1998), LAR (Ko and Vaidya, 2000), V-GEDIR (Stojmenovic, 1999), CH-MFR (Stojmenovic, 1999) belong to this class.

Flooding can be partial because it is directed towards nodes in a limited sector of the network (e.g. in DREAM or in LAR) or because it is stopped after a certain number of hops (e.g. in flooding GEDIR family of schemes). Moreover, partial flooding can be used only for path discovery purpose (e.g. LAR) or for packet forwarding (e.g. DREAM). A different approach using flooding and multipath routing is the one taken in Terminode routing (Blazevic *et al*., 2001). Terminode routing addresses scalability, robustness, collaboration and simplicity of the nodes. This routing scheme is a combination of two protocols called Terminode Local Routing (TLR) and Terminode Remote Routing (TRR). Jain, Puri and Sengupta (Jain *et al*., 2001) proposed a strategy called Geographic Routing Algorithm (GRA) that requires nodes to partially store routes toward certain destinations in routing tables.

Instead of flooding those messages, gossiping, essentially, tosses a coin to decide whether or not to forward a message, which can be used to reduce the number of routing messages sent significantly (Zygmunt and Joseph, 2006). Actually gossiping can be applied to any routing algorithms that use flooding to update routing information. However, we will only focus our attention on the on-demand routing algorithms AODV, since it is the one much suited for ad hoc network. In this study, we show that adding gossiping to AODV essentially decides whether to forward or not to forward a message and hence can be used to significantly reduce the number of routing messages sent.

OVERVIEW OF AODV

The Ad-Hoc On-demand Distance Vector (AODV) routing protocol is one of several published routing protocols for mobile ad-hoc networking (Perkins and Royer, 1999). Wireless ad-hoc routing protocols such as AODV are currently an area of much research among the networking community. Thus, tools for simulating these protocols are very important. AODV shares

DSR's on-demand characteristics in that it also discovers routes on an as needed basis via a similar route discovery process. However, AODV adopts a very different mechanism to maintain routing information. It uses traditional routing tables, one entry per destination. This is in contrast to DSR, which can maintain multiple route cache entries for each destination. Without source routing, AODV relies on routing table entries to propagate an RREP back to the source and, subsequently, to route data packets to the destination. AODV uses sequence numbers maintained at each destination to determine freshness of routing information and to prevent routing loops. All routing packets carry these sequence numbers. Figure 2 shows the packet processing in AODV. The important feature of AODV is the maintenance of timer-based states in each node, regarding utilization of individual routing table entries. A routing table entry is expired if not used recently.

Whenever an AODV router receives a request to send a message, it checks its *routing table* to see if a route exists. Each routing table entry consists of the following fields: Destination address, Next hop address, Destination sequence number and Hop count If a route exists, the router simply forwards the message to the next hop (Broch *et al*., 1998). Otherwise, it saves the message in a message queue and then Fig. 3 initiates a route request to determine a route. The following flow chart illustrates this process:

Upon receipt of the routing information, it updates its routing table and sends the queued message(s). AODV nodes use four types of messages to communicate among each other. Route Request (RREQ) and Route Reply (RREP) messages are used for route discovery. Route Error (RERR) messages and HELLO messages are used for route maintenance. The following sections describe route determination and route maintenance in greater detail.

Route discovery: A node broadcasts a request when it determines that it needs a route to a destination and does not have one available. This can happen if the destination is previously unknown to the node, or if the destination is previously valid route to the destination expires. To prevent unnecessary broadcasts of requests the node

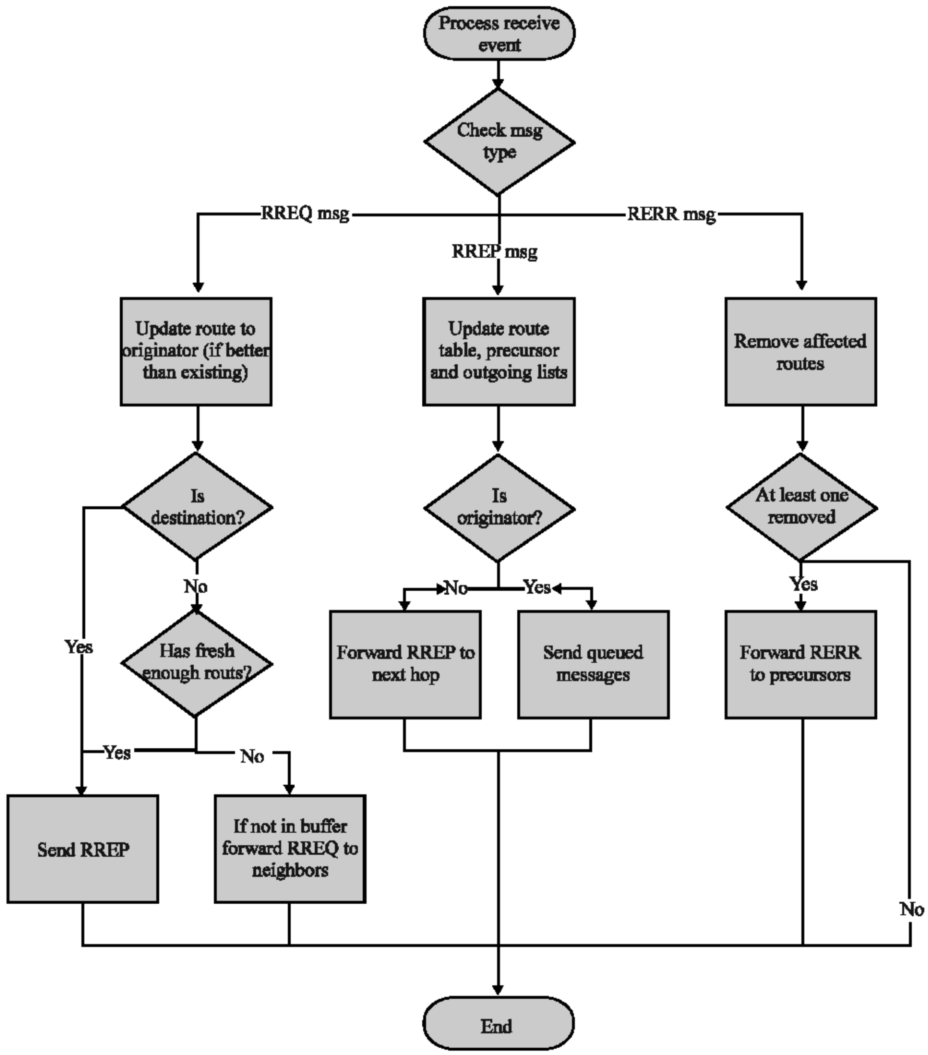

Fig. 2: Rout request

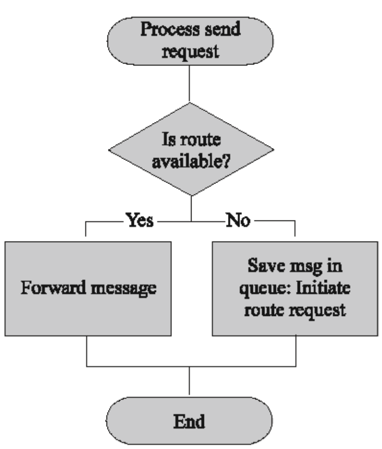

Fig. 3: Packet processing in AODV

uses an expanding ring search technique as an optimization (Chandra *et al*., 2001). In the expanding ring search, increasingly larger neighborhoods are searched to find the destination. The search is controlled by the Time-To-Live (TTL) field in the IP header of the request packets. If the route to a previously known destination is needed, the prior hop-wise distance is used to optimize the search Fig. 4 shows the trace of the route.

Route maintenance: Every routing table entry maintains a route expiry time, which indicates the time until which the route is valid. Each time the route is used to forward a data packet, its expiry time is updated to be the current time plus ACTIVE_ROUTE_TIMEOUT. A routing table entry is invalidated if it is not used within such expiry time. AODV uses an active neighbor node list for each

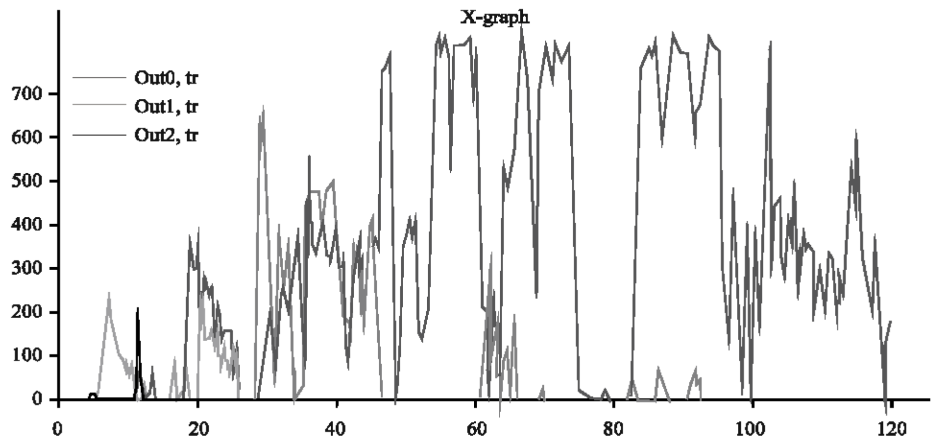

Fig. 4: X-graph for tracing the route

routing entry to keep track of the neighbors that are using the entry to route data packets. These nodes are notified with route error packets when the link to the next hop node is broken. Each such neighbor node, in turn, forwards the error packet to its own list of active neighbors, thus invalidating all the routes using the broken link (Das *et al*., 2000).

INTRODUCTION TO GOSSIPING

Recent works are going on in incorporating the concept of gossiping into AODV and hence to improve the performance of Ad hoc networks. The concept of gossiping is as following:

The bimodal behavior of gossiping: Our basic gossiping protocol is simple. A source sends the route request with probability 1. When a node first receives a route request, with probability p it broadcasts the request to its neighbors and with probability 1 p it discards the request; if the node receives the same route request again, it is discarded (Birman *et al*., 1999). Thus, a node broadcasts a given route request at most once. This simple protocol is called GOSSIP1(p).

GOSSIP1 has a slight problem with initial conditions. If the source has relatively few neighbors, there is a chance that none of them will gossip and the gossip will die. To make sure this does not happen, we gossip with probability 1 for the first k hops before continuing to gossip with probability p. We call this modified protocol GOSSIP1(p, k).1

The performance of GOSSIP1(p, k) clearly depends on the choice of p and k. Clearly, GOSSIP1(1,1) is equivalent to flooding. What happens in general? That depends in part on the topology of the network (particularly its average degree), the gossip probability p and the initial conditions (as determined by k). If we think of gossiping as spreading a disease in an epidemic, this simply says that the likelihood of an epidemic spreading depends in part on how many people each person can infect (the degree), the likelihood of the infection spreading (the gossip probability) and how many people are initially infected.

Incorporating gossiping in AODV: Regular networks may allow us to easily analyze how GOSSIP1 and may respond to different parameters, such as the gossip probability. In random networks, nodes are placed at random on a two-dimensional area. These networks can be easily represented by regular and random graphs, respectively.

An edge is placed between any pair of nodes less than a fixed distance d apart. Random graph seems appropriate for modeling a number of applications involving ad hoc networks.

Nodes have a limited amount of power and so can communicate only with reasonably close nodes. The random placement can be viewed as modeling features such as the random mobility of nodes and the random placement of sensors in a large region. Gossiping really depends on issues like the network topology, mobility and how frequently messages are generated. Larger networks with high mobility many of the optimizations will be much less effective. In this case, flooding will occur more frequently, so gossiping will be particularly advantageous. Gossiping can provide significant advantages even in small networks. To test the impact of gossiping, we considered AODV, one of the best-studied ad hoc routing protocols in the literature. We compare pure AODV that use flooding to a variant of AODV that uses gossiping. We do not have the resources to simulate the protocols in large networks. However, our results do verify the intuition that, with high mobility (when flooding will be needed more often in pure AODV), gossiping can provide a significant advantage.

IMPLEMENTATION

Ns2 is an event driven network simulator developed at UC Berkeley that simulates variety of IP networks (http://www.isi.edu/nsnam/ns). It implements network protocols such as TCP and UPD, traffic source behavior such as FTP, Telnet, web, CBR and VBR.

The simulation of our AODV protocol is achieved in Ns2 written in C++ or Tcl scripts.

CMU's wireless extension to Ns-2 (incorporated in the release ns-2.1b9a) provides the implementation of the DSR, AODV, DSDV, TORA routing protocols. Nam is the basic Visualization of ad hoc simulations. Here Fig. 5 represents the routing for the node generation using origanl AODV. Writing the Tcl code to setup the wireless simulation components: network components types, parameter like the type of antenna, the radio-propagation model, the type of ad hoc routing protocol, traffic models and node movement models used by mobile nodes etc. After each simulation, trace files recording the traffic and node movements are generated. These files need to be parsed in order to measure the performance metrics.

Simulation: The simulation is done in the ns-2 simulator. This is also the simulator the literature uses to evaluate AODV. We use the AODV implementation in ns-2 downloaded from one of the author's web site, using IEEE 802.11 as the MAC layer protocol. The radio model simulates Lucent's Wave LAN with a nominal bit rate of 2Mb/secand a nominal range of 250 meters. The radio propagation model is the two-ray ground model. Our application traffic is CBR (Constant Bit Rate). The source-destination pairs (connections) are chosen randomly.

The application packets are all 512 bytes. We assumed a sending rate of 2 packets/second and 30 connections. For mobility, we use the *random waypoint* model in a rectangular field. The simulation scenarios are as follows:150 nodes are randomly placed in a grid of 3300×600 m ; there are 30 connections, each generating 2 packet sec^{-1}; simulation time is 525 seconds; each node moves with a randomly chosen speed (uniformly chosen from 0-20 m sec^{-1}), then pauses for τ seconds after reaching a randomly set destination. We vary the pause time to simulate different mobility scenarios.

Each data point represents an average of five runs using the identical traffic model, but with different randomly generated mobility scenarios. To preserve fairness, identical mobility and traffic scenarios are used for AODV and AODV + G. The above Fig. 6 shows the route nodes traced by AODV+G.

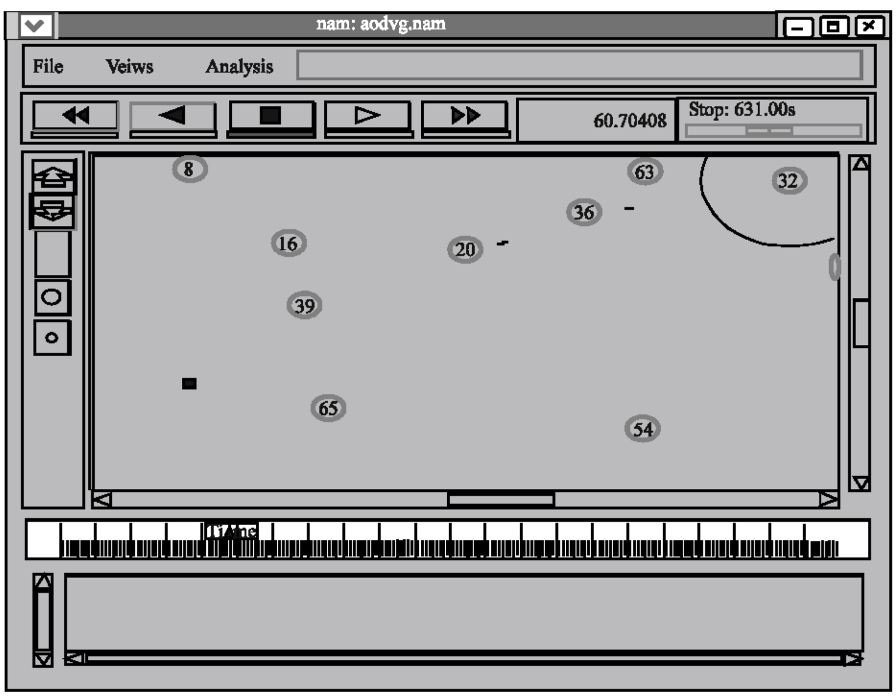

Fig. 5. Nam file generated for Original AODV

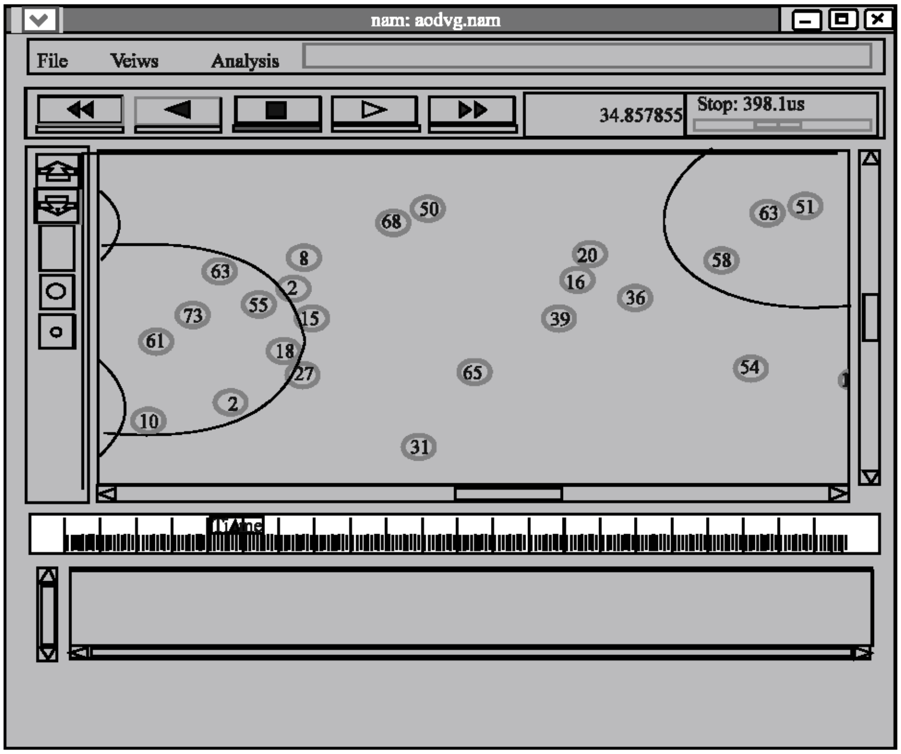

Fig. 6. Nam file generated for AODVG

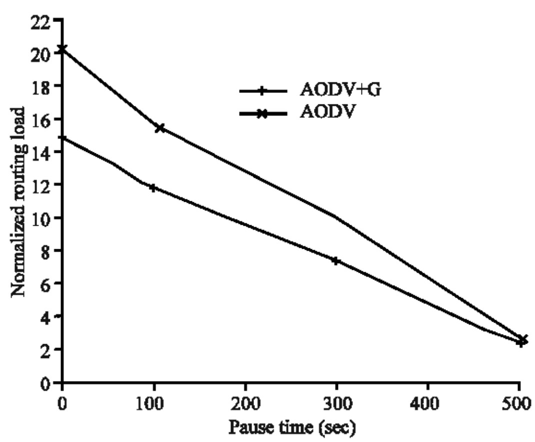

Fig. 7. Packet delivery ratio (AODV and AODVG)

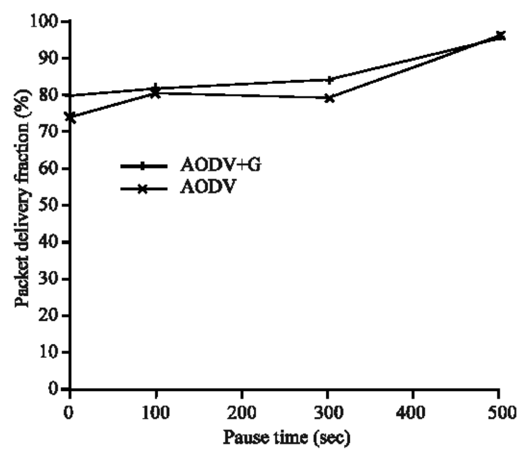

Fig. 8. Routing overhead (AODV and AODVG)

Evaluation metrics: We study the performance of the routing with the following three metrics:

- Packet delivery fraction represents the ratio of the number of data packets successfully delivered to the number of data packets generated by the CBR sources. The performance of AODVG is better compared with AODV as shown in Fig. 7.
- Average end-to-end delay of data packets includes all possible delays caused by buffering during routing discovery, queuing at the interface queue, retransmission at the MAC layer, propagation and transfer time. Figure 8 depicts routing overhead comparison between AODV and AODVG. It is found that the routing overhead is less in AODVG compared with AODV.

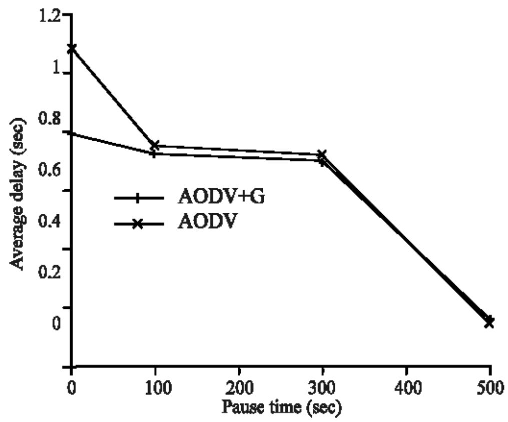

Fig. 9. Path optimality (AODV and AODVG)

- Normalized routing load represents the number of routing packets transmitted per data packet delivered at the destination. Each hop-wise packet transmission is counted as one transmission." Here Fig. 9 shows the path optimality relations between AODV and AODVG. It is observed from the figure that the performance of AODVG is better than AODV.

CONCLUSION

The AODV has many advantages over other protocols and hence we have chosen AODV to incorporate the Gossip based approach. Current works are done to add Gossip1(p,k) to AODV. Our protocol is simple and easy to incorporate into existing protocols. When we add gossiping to AODV, simulations show significant performance improvements in all the performance metrics, even in networks as small as 150 nodes. Future works will be done to determine the effective probability value and hence to further reduce the traffic overhead.

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