Information Technology Journal 4 (3): 278-283, 2005
ISSN 1812-5638


# A Performance Comparison of Ad Hoc Routing Protocols Based on Ant Mobility Model

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**Abstract:** In this study, a tool is implemented for generating a special trace model, called ant mobility model. It mimics the ants' movements of an ant colony. The movement is similar to the workers in a store. We focus on the integration between the ant mobility model and the network environment. When users setup the parameters for generating an ant mobility model, such as ant size, food size, the time interval of pheromone, etc., the generated model of trace data can be used directly in the network environment. In order to illustrate the feasibility of ant mobility model, it is compared with the random waypoint mobility model based on the same routing protocols, DSDV, DSR and AODV, by using NS-2 simulator. Three major performance metrics, throughput, network latency and control overhead message, are estimated. As we expected, these three metrics of the ant mobility model are different than that of the random waypoint mobility model. We suggest that a trace model, like ant mobility model, should be integrated quickly with the network environment in the same way.

**Key words:** Ad hoc routing, ant mobility model, AODV, DSDV, DSR

## INTRODUCTION

Multi-hop mobile ad hoc wireless networks (MANET) are formed with some mobile nodes (MNs) or devices. They can dynamically create a wireless network among themselves without using any infrastructure such as base station or access point. Each MN can move arbitrarily and communicate with each other by using multi-hop wireless links. Each MN also acts as a router and forwards data packets to other neighbor MNs. A mobile ad hoc networking (MANET) working group has been formed within the Internet Engineering Task Force (IETF). This kind of network is very useful under certain environments, for example, battlefield, disaster, earthquake recovery, search and rescue, exploration of area, etc. Ad hoc networks involve rapid changes in topology because of the MNs can move freely around. The routing algorithm for constructing route paths between MNs becomes an important research topic. Various ad hoc routing protocols[1-3] were proposed to increase the performance in ad hoc network.

Ad hoc routing protocols can be classified into two main types: table-driven or on-demand. In table-driven routing protocols[4-6], MN will update its routing table when the network topology changes. Consequently, the updated routing table will be sent to the neighbor MNs. When neighbor MNs receive an updated routing table, they will do the same update. Once a source MN wants to send messages to a destination MN, it will send message to the next hop immediately according to the entry in the routing table without trying to find a new route path. Table-driven routing protocols can maintain consistent routing table quickly as the network topology change. But they generally require more CPU time and network bandwidth.

The second type of ad hoc routing protocol is on-demand[7,8]. The MNs do not exchange routing table during network topology change. When a source MN wants to send messages to a destination MN, it will broadcast route request (RREQ) packet to find the destination. Once the destination MN receives RREQ packet, it will send route reply (RREP) packet back to the source MN. Then, the source MN can send data packets when it receives the RREP packet from the destination. When the link breaks during data transmission phase, the intermediate node will sends route error (RERR) packet back to the source MN. When the source MN receives RERR packet, it will reconstruct a new route in the same way. The on-demand routing protocol is more suitable under limited resources such as network bandwidth, memory capacity and battery power.

In order to simulate a routing protocol, it is important to use a mobility model that accurately represents the MNs' mobility behavior. Currently, there are two types of

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mobility models, trace and synthetic models[3]. Trace models are those mobility patterns that are observed in real life systems. Synthetic models are based on random or probabilistic process to mimic the movements of MNs. Trace models are more accurate than synthetic ones[2] and the simulation results by using trace models are more accurate, too. However, new network environments are not easily modeled if traces have not yet been created. That is why most of the simulations are based on synthetic models[9].

On the other hand, by observing the movements of ants in an ant colony, ants are trying to find a food source. Once a source is found, neighbor ants will follow the trail pheromone to carry food back to the nest. The movement of ants is similar to the workers in a store. If we try to define a synthetic mobility model to generate the ants' movement for network simulation, it is almost impossible to define mathematical formulas to generate ants' movement.

In this study, we try to generate the ant mobility model in a trace way. A tool is implemented for generating a trace, i.e., ant mobility model. The design of the tool is based on the behavior modeling of an ant colony[10]. We focus on the integration between the ant mobility model and the routing network environment. When users setup the parameters for generating an ant mobility model, such as ant size, food size, the time interval of pheromone, etc., the generated model can be used directly for simulation in the network environment.

In order to illustrate the feasibility of ant mobility model, it is compared with the random waypoint mobility model based on the same routing algorithm, DSDV (Destination-Sequenced Distance-Vector)[6], DSR (Dynamic Source Routing)[7] and AODV (Ad hoc On Demand Vector)[8], by using network simulator (NS-2)[11]. Three major performance metrics, throughput, network latency and control overhead message, are estimated. As we expected, these three metrics of the ant mobility model are different than that of the random waypoint mobility model. We suggest that a trace model, like ant mobility model, should be integrated quickly with the network environment in the same way.

**Destination-Sequenced Distance-Vector Routing Protocol (DSDV):** The DSDV routing protocol is a table-driven algorithm according to its characteristics. As implied by the name (table-driven), each mobile node in the MANET maintains a route table that lists all available destinations and exchanges periodically the routing information by the way of broadcast or multicast even though the node does not need to transmit datagrams. The entry in the route table contains a sequence number, the address of destination node and the number of hops to reach the destination node. The sequence number is tagged by the destination node and it can avoid the formation of routing loops and keep the freshness of route information. If the node detects a failed link to next hop through the link layer, it sets the field of hop count to ∞ and broadcasts the information. Any nodes that receive an information with ∞ hop count and have an equal or later sequence number with a finite hop count value would disseminate the unreachable information about that destination node.

**Dynamic Source Routing Protocol (DSR):** DSR is based on the on-demand source routing concept used in our protocol. One of the primary differences between DSR and AODV is the control packets (RREQ, RREP, RERR) that carry the complete path from the source to the destination.

In the route discovery procedure, the source broadcasts the RREQ packet. Each RREQ packets carries the ID of the passed node in the packet header. Once a RREQ packet reaches the destination, the destination replies RREP packet with the complete path to the source host. Data packets in the DSR routing scheme are routed to the destination by the intermediate nodes using the complete path contained in the packet header.

In the route maintenance phase, if the transmission link is broken and the next node is currently not its neighbor, then the node broadcasts an RERR packet back to the source as AODV, indicating that the route topology has changes. The source node must execute a route request procedure to find a new path.

Figure 1 shows the route discovery procedure of the DSR routing protocol. Each intermediate node will append its node ID in the packet header. Firstly, node $S$ appends its node ID in the RREQ packet and broadcasts. The intermediate nodes $B$ and $C$ receiving the RREQ will appends their node IDs. After receiving the RREQ, the destination can know the complete path (S->B->C->E) and sends a RREP packet back to the source node.

**Ad hoc On-demand Distance Vector routing protocol (AODV):** AODV is an on-demand dynamic routing protocol that uses routing tables with one entry per destination. When the source MN has no routing

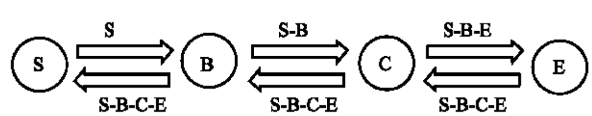


Fig. 1: The routing packet in DSR

information about the destination, it will initiate route request procedure to find a route to the destination.

First the source MN broadcasts a route request (RREQ) message to its neighbors. If its neighbors have a route to the destination MN, they send back a route reply (RREP) packet to the source MN. Otherwise they will update their routing table and build reverse link to the node that sends RREQ message and re-broadcast the RREQ message. After the route request procedure repeats, the RREQ message will arrive to the destination.

When the destination MN receives the RREQ, it will generate a RREP message and send to the source MN along the reverse links that built before. Each intermediate node receives the RREP will build forward link to the destination and send back to the source MN.

During the transmission phase, if the intermediate MNs move out of the communication range and cause the routing path to be broken. Its neighbor MNs will generate route error (RERR) packet to the source MN indicate that the destination is unreachable. Once the source node receives the RERR packet, it will do the route request procedure to find another new route again.

Figure 2 shows that the routing table of AODV during the route discovery procedure. D is the destination node, N is the next hop node, H is the number of hops and S is the sequence number. During the route request phase, node S broadcasts a RREQ packet. The intermediate node B and node C record their reverse links, with the next hops being node S and node B, in order. Then they rebroadcast the RREQ packet. During the route reply phase, the destination node E replies RREP packet to the source node. Node C and node B also record their forward links with the next hops being node E and node C, in order.

**The generation of ant mobility model:** In real world, ants can release a substance called pheromone to communicate with other ants. When ants want to find foods (foraging mode), they move randomly anywhere. Once they are attracted by the scent of food sources, they will follow the scent and reach to a food source. While ants are carrying food back to the nest, they deposit trail pheromone on the ground. Other ants can smell the scent of trail pheromone and follow the path to the food source. With time had elapsed; the food will be picked to exhaust. The pheromone becomes weaker and last disappears completely.

Detailed description of the ant's behavior model is described by Heck and Ghosh[10]. We re-implemented the tool with some modifications for generating ant mobility model. The tool's screen shot is shown as Fig. 3. The nest is yellow and in the center of screen, the food source is green and the pheromone is pink. The red dots represent

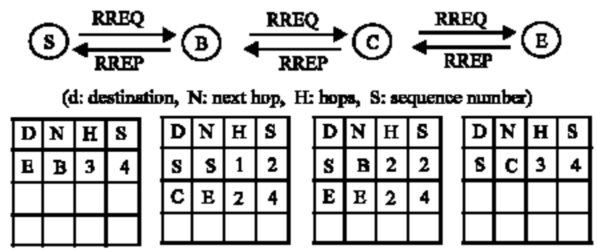


Fig. 2: The routing table of AODV

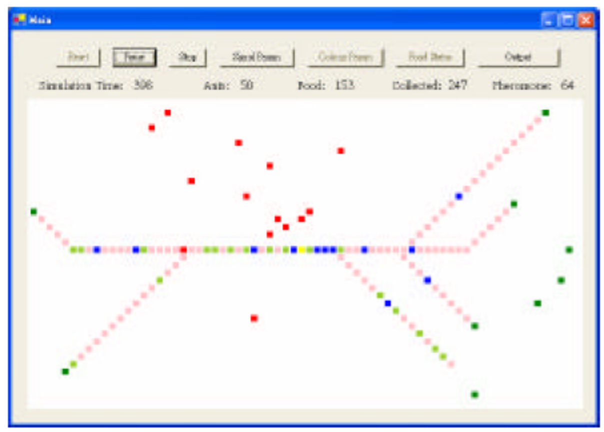

Fig. 3: The screen shot of an actual simulation run

ants in a foraging mode, the grass green dots correspond to ants following the pheromone to food sources and blue dots correspond to ants returning to nest with food particles.

Before running the tool for generating ant mobility model, several parameters must be determined, including map size, ant size, food size, etc. Among these parameters, two parameters, trace start time and stop time, are designed specifically for ant mobility model. Initially, all of the ants' locations are assigned at the nest. So, the start period of the simulation is not suitable for network simulation. We use these two parameters to define the time period to generating the ant mobility model.

While the simulation is running, the tool generates a TCL (Tool Command Language) program simultaneously. A part of the generated TCL program is shown in Table 1.

The generated ant mobility model (TCL program) of Table 1 can be separated into three parts marked by the dashed line. The first part defines the initial positions of ants and foods. The second part defines the labels to be shown in the NS-2 simulator. The third part defines the position of ants for each time slot. The screen shot of generated ant mobility model executed on the NS-2 simulator is shown in Fig. 4.

Table 1: A part of the generated ant mobility model (TCL program)

```
$node_(0) set X_ 340
$node_(0) set Y_ 190
$node_(0) set Z_ 0.0
$node_(1) set X_ 340
$node_(1) set Y_ 190
$node_(1) set Z_ 0.0
...
$ns at 0.0 "$node_(0) label Ant(0)"
$ns at 0.0 "$node_(1) label Ant(1)"
...
 $ns at 0 "$node_(0) setdest 340 190 50"
 $ns at 0 "$node_(1) setdest 340 190 50"
...
 $ns at 128 "$node_(0) setdest 320 320 50"
 $ns at 128 "$node_(1) setdest 210 190 50"
...
 $ns at 168 "$node_(0) setdest 270 190 50"
 $ns at 168 "$node_(1) setdest 230 190 50"
...
```

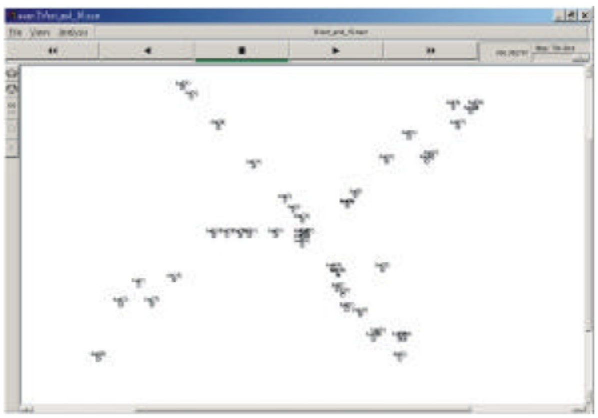

Fig. 4: The screen shot of ant mobility model running on NS-2 simulator

## Simulation

**Simulation environment:** The performance of the ad hoc routing based on the ant mobility model is studied here. The parameters for generating ant mobility model are shown as Table 2. In Table 3 shows the parameters for NS2.

The ant mobility model is simulated on NS-2 version 2.1b9. The distributed coordination function (DCF) of IEEE 802.11[12] for wireless LANs is used as the MAC layer. WaveLAN is a shared-media radio with a nominal bit-rate of 2Mb/sec and a radio range of 250 m. In our simulation, the performances of three routing protocols (DSDV, DSR, AODV) based on ant mobility mode and random waypoint mobility model are estimated, respectively. We suppose a 50 nodes network in a place with dimensions 1000m × 1000m. Traffic sources are CBR (continuous bit-rate) 512 byte data packets and 2 packets/sec. The pause time is 0~5 sec. There are 5, 10 source-destination sessions are chosen randomly over the network. Simulations are run for 300 simulated seconds.

Table 2: Ant mobility model parameters

| Parameter | Value | Parameter | Value |
|---|---|---|---|
| Map size | 1000×1000 points | Food sources | 30 |
| Nest size | 1 | Particles per food source | 50 |
| Nest position | (500, 500) | Food scent | 50 points |
| Ant size 50 | Pheromone scent | 64 points | |
| Ant speed | 2~20 points/sec | Pheromone time | 50 time slots |
| Trace start time | 200 time slots | Trace stop time | 500 time slots |

Table 3: The parameters of NS2 simulation

| Parameter | Value |
|---|---|
| Map size | 1000×1000 m |
| Center size | 1 |
| Center position | (500, 500) |
| Mobile Nodes | 50 |
| MN speed | 2~20 m/sec |
| Pause time | 0~5 sec |
| start time | 200 sec |
| stop time | 500 sec |

The present simulation results show that mobility affects the performance of three routing protocols (DSDV, DSR, AODV) in the same scenarios. The metrics used were suggested by the Internet Engineering Task Force (IETF) Mobile Ad hoc Network (MANET) working group for routing protocol evaluation. We evaluate three key performance metrics: 1. Packet throughput ratio; 2. Average end-to-end delay; 3. Normalized routing load.

## Simulation results

**Packet throughput ratio:** It is the ratio of data packets delivered to the destination to those sent by the source. The estimation results are shown in Fig. 5 (5 sources) and Fig. 6 (10 sources). AODV has the highest throughput and DSDV has significance grown up in ant mobility models. The MN that moves with a high speed decreases the throughput of DSR. In ant mobility model, every MN has a task to move. The connections between these MNs will stable than in random waypoint model. The average throughput in the ant mobility model is higher than that of random mobility model.

**Average end-to-end delay:** Average end-to-end delay of data packets includes buffering during route discovery, queuing delay at the interface, retransmission delay at the MAC, propagation, and processing time. The estimation results are shown in Fig. 7 (5 sources) and Fig. 8 (10 sources). DSDV has the lowest delay whether in ant mobility model or random mobility model. DSR has the longer delay than that of other protocols. The average end-to-end delay of the ant mobility model is less than that of random waypoint mobility model. This is because that the random movement of MNs easily causes the transmission path to break.

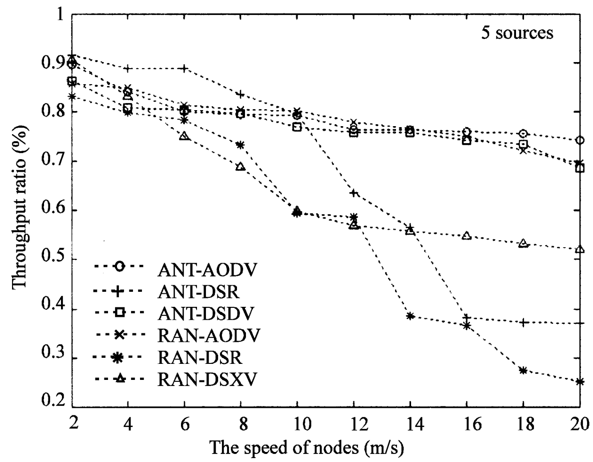


Fig. 5: Throughput ratio (5 sources) vs. speed

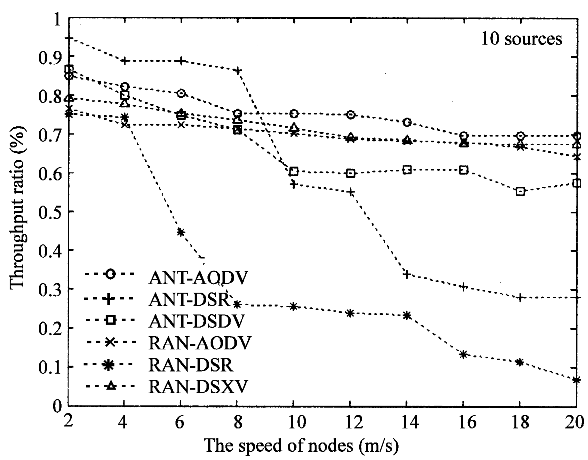


Fig. 6: Throughput ratio (10 sources) vs. speed

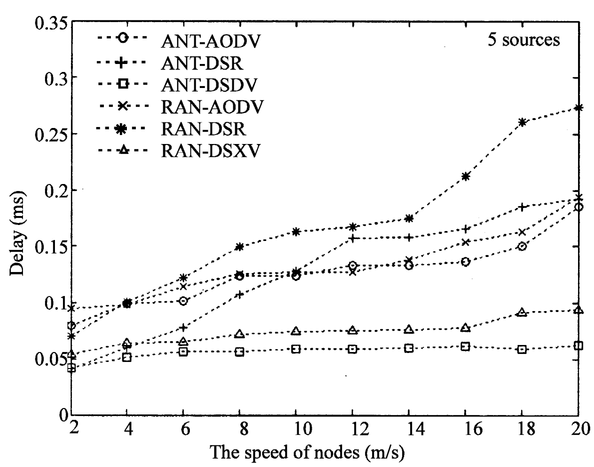


Fig. 7: Average end-to-end delay (5 sources) vs. speed

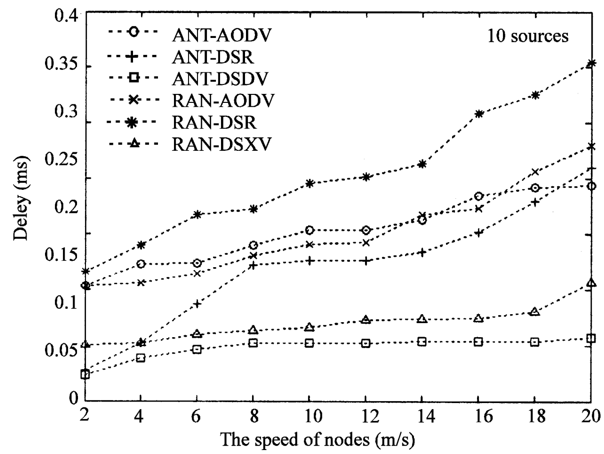


Fig. 8: Average end-to-end delay (10 sources) vs. speed

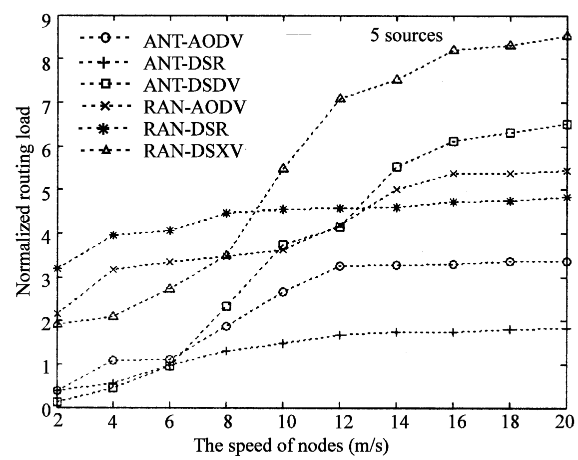


Fig. 9: Normalized routing load (5 sources) vs. speed

**Normalized routing load:** The normalized routing load overhead is presented as the number of routing packets transmitted per data packet delivered at the destination. In Fig. 9 (5 sources) and Fig. 10 (10 sources), the estimation results show all normalized routing load in ant mobility and random mobility. DSDV almost always has a higher normalized routing load than DSR and AODV. In ant mobility model, average three protocols has a lower than that of in random waypoint model.

In summary, the above results illustrate that a mobility model has a large effect on the performance evaluation of an ad hoc network protocol. It is important to choose an appropriate mobility model for a given performance evaluation.

**Conclusion and Future Works:** In real world, there are different mobility models in different places. Trace models

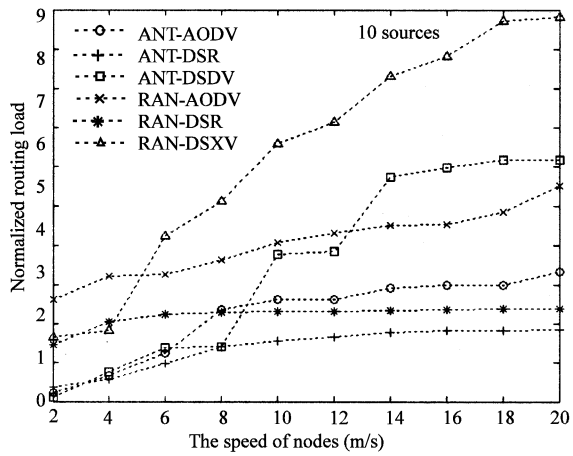


Fig. 10: Normalized routing load (10 sources) vs. Speed

are more accurate than synthetic models. However, it is usually difficult and time-consuming to build a new trace model in a network simulator for simulation. To overcome the above problem, a tool is proposed in this paper. The tool can generate an ant mobility model based on the behavior model of ant colony. The generated model can be integrated (i.e., executed) directly in the network simulator. It provides an efficient way for the simulations of network protocols on a new mobility model. In the near future, we plan to design tools to generate various trace models for network simulation in the same way.

## ACKNOWLEDGMENT

This research was partially supported by the National Science Council, Taiwan, Republic of China, under contract No.: NSC 92-2218-E-324-005

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