Group Partitioning and Merging Mobility Model for Mobile Ad hoc Networks

Mr. Sacko Diouba, Prof. Wang Furong, Prof. Huang Benxiong

Abstract—**In wireless ad hoc network applications, such as outdoor teaching, battlefield, scenes of a fire, flood, and earthquake a number of mobile hosts (MHs) may sometimes move together and sometimes separately. Members within the group have similar mobility patterns and can directly communicate with each other. In this paper, we propose a Group Partitioning and Merging Mobility (GPMM) model for Mobile Ad hoc NETtworks (MANETs). It provides a better reflection of group movement behavior with possible group partitioning and merging. The model presents the trip chain of individuals belonging to a single home. During daily activities, they move from home to some locations and return back after completing daily tasks. Alternatively they partition and merge at some reference points placed on the trip chain. Therefore, at reference points the group members dynamically re-configure themselves triggering group partitioning and merging. We do performance evaluation by simulation. The simulation is written by the network simulator (NS-2) and the graphs are generated using MATLAB.**

Index Terms—**MANET, Group partitioning, Group merging, Simulation.**

I. Introduction

The mobility models proposed so far in the literature assume some kind of permanent group affiliation. Also they require that each node belongs to a single group. In reality in many real life applications, a much more complex mobility behavior is observed. Some nodes move in groups; while others move individually and independently. Moreover, the group affiliation is not permanent. The mobile nodes (MNs) can dynamically re-configure themselves triggering group partitioning and merging. A good realistic mobility model must capture all these mobility dynamics in order to yield realistic performance evaluation results [2]. In this paper, we propose a group mobility model called Group Partitioning and Merging Mobility (GPMM) model for MANETs. The model presents a group of individuals belonging to a single home. Depending on time of the day, individuals either move from home to some locations or return back after completing daily tasks. At some reference points placed on the trip chain, individuals within the group either partition and move individually or merge and move in group. The paper is organized as follows. Section 2 presents the mobile ad hoc networks. We provide in section 3 the activities sequence of individuals. Sections 4 and 5 present the aggregated activities sequence and the aggregated activity matrices; respectively. Section 6 describes the routing protocols and metrics used for performance evaluation. In section 7, we evaluate AODV and DSDV protocols under GPMM model and analyze the performance from different perspectives based on the simulation result and theoretical point of view. In section 8, we emphasize the benefits of the proposed mobility model. Conclusions appear in section 9.

Manuscript received January o7, 2008. This work was supported by the national natural science foundation of China under grant No.60572047 and by the program for New Century Excellent Talents in University, NCET-06-0642

S.Diouba is currently PhD candidate at the Huazhong University of Science & Technology (H.U.S.T), Dept. of E.I.E, 430074-Wuhan, Hubei, P.R China phone: 008627-13871244974, email: sacko_dioba@hotmail.com.
W. Furong is Associate Prof. at the H.U.S.T, Dept. of E.I.E, 430074-Wuhan, Hubei, P.R China, email: wangfurong@mail.edu.cn.
H. Benxiong Prof. at the H.U.S.T, Dept. of E.I.E, 430074-Wuhan, Hubei, P.R China , email: bxhuang@mail.edu.cn

II. Mobile Ad Hoc Networks

Ad hoc network is the infrastructureless mobile network which has no fixed gateways (routers). All nodes are capable of movement and can be connected dynamically in an arbitrary manner. Nodes of these networks function as routers which discover and maintain routes to other nodes in the network. Example applications of ad hoc networks are emergency search-and rescue operations, meetings or conventions in which folks wish to quickly share information, and data acquisition operations in inhospitable terrain [1]. A Mobile Ad hoc NETwork (MANET) is an autonomous system of self-organized mobile nodes without relying on any infrastructure. Node mobility is one of the inherent characteristics of MANET. It is also one of the parameters that most critically affect the performance of network protocols (e.g., routing). Conventional mobility models proposed for MANET can be classified into two categories: Entity models and Group models. Entity models are used to represent the movement of an individual mobile node. One such model is the Random WayPoint mobility (RWP) model; perhaps the most popular mobility model used in the literature [9]. Because entity models cannot reflect the interaction between MNs, group mobility models are proposed. A typical group mobility model is the Reference Point Group Mobility (RPGM) model [10]. The shortcoming of conventional models is that they fail in modelling scenarios where groups may be partitioned and merged; these are most likely to be found in ad hoc networks.

III. ACTIVITIES SEQUENCE: DESIGN OF MOBILITY MODEL

Figure 1 illustrates the activities sequence of individuals. In this figure, 4 reference points called switch stations are placed along the trip chain. Alternatively the group members partition and merge at these switch stations. Such group dynamics happen under the control of configured partition and merge probabilities. Each group member is defined with a member stability threshold value. At the switch stations, each individual in the group will check whether its stability value is beyond its group stability threshold value. If it is true, this individual will choose a different path. A group partition happens. When individuals arrive at the same station and select the same path for the next movement, naturally, they will merge into one group. At the station 1 the group from home partition and individuals move toward some locations (L_1, L_2… L_{n-1}, L_n). At the pause time from 12:00 to 13:00, individuals merge into one group at the common favorite restaurant to take lunch (specific switch station). After lunch, they move in group to the station 2 where the group partition; individuals move toward the predefined destinations (L_1', L_2'… L_{n-1}', L_n'). At the end of daily activities, individuals merge into one group at the station 3 and return back home as centroid. Depending on the day of the week, the sets of locations (L_1, L_2… L_{n-1}, L_n) and (L_1', L_2'… L_{n-1}', L_n') represent either workstations or entertainment places.

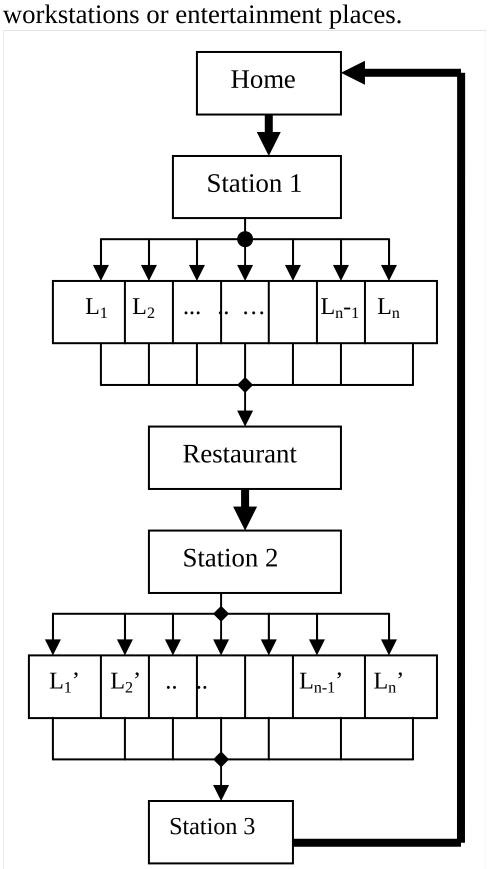
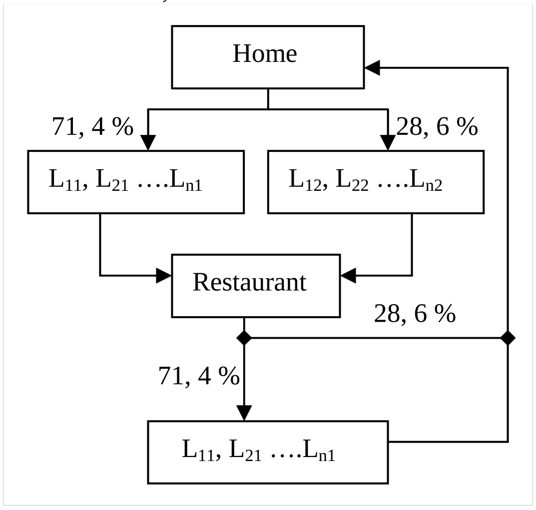


Figure1: Activities Sequence
Group motion

Individual motion

IV. AGGREGATED ACTIVITIES SEQUENCE

Person's behavior can vary in different days in the week. In such a case aggregation of activities is used. Figure 2 illustrates aggregated activities sequence of individuals. Probability of switching to particular activity between states, which is 100%, is omitted.



Legend:
L_{11}, L_{21} …, L_{n1}: Workstations for persons 1, 2... (n); respectively
L_{12}, L_{22}…, L_{n2}: Entertainment places for persons 1, 2… (n); respectively.

Figure 2: Aggregated activities sequence

A. *Proof of the figure 2: Stochastic Properties*

Persons transit from home to workstations five times per week (from Monday to Friday).Therefore, the frequency of switching is 5 and the probability of switching is: (5/7) x100 = 71, 4 %. They transit from home to entertainment two times per week (Saturday and Sunday).Therefore, the frequency of switching is 2 and the probability of switching is: (2/7) x100 = 28, 6 %. The sum of probabilities is: 71, 4 % + 28, 6 % = 100 %. Indeed, individuals from home transit either to workstations or to entertainment.

Persons return back from restaurant to workstations five times per week (from Monday to Friday). Therefore, the frequency of switching is 5 and the probability of switching is: (5/7) x100 = 71, 4 %. They transit from restaurant to home two times per week (Saturday and Sunday). Therefore, the frequency of switching is 2 and the probability of switching is: (2/7) x100 = 28, 6 %. The sum of probabilities is: 71, 4 % + 28, 6 % = 100 %. Indeed, individuals from restaurant transit either to workstations or to home.

The values 71, 4 % and 28, 6 % give us the probabilities (frequencies) of transition weekly between different locations.

V. AGGREGATED ACTIVITY MATRICES

For aggregated activity matrices, the next activity is chosen from a set of alternatives with a certain probability.

A. Activity Transition Matrix

Activity transition matrix stores transitions between activities for each person depending on time of the day. At different time of the day unlike changes between activities are possible. For example, after work, at 12:00 a person is likely to go to lunch, but at 17:00 he is more likely to go home [6]. Probability transition matrix indicates the probability for an individual to transit from the current location to the next depending on time of the day. According to the figure 1, we consider that the probability is equal to 1 if a person can transit directly from the current location to the next and 0 if no direct transition between current and next locations. The probabilities 1/2, 1/3, and 2/3 indicate the probabilities (frequencies) of transition between locations along the trip chain. The probability matrix used during weekdays by each individual is given by table 1 below:

Table 1: Activity transition matrix

Current Loc.	**Next Location**			
	H	S	W	R
H	0	1	0	0
S	1/3	0	2/3	0
W	0	1/2	0	1/2
R	0	1	0	0

Legend:
H, S, W, R = Home, Switch stations (station 1, station 2, and station 3), Workstations (L_{11}, L_{21}…L_{n1}), Restaurant; respectively.

B. Proof of the table 1: Stochastic Properties

Let us pose p (W→ H) be the probability to transit from Work to Home. According to the figure 1, we get the following probabilistic values:
p(H→H) = p(H → W) = p(H→ R) = p(S→ S)= p(S→R) =
= p(W →H) = p(W → W) = p(R → H) = p (R → W) =
= p (R→ R) = 0; no direct transition between a pair of locations
p (S→ H) = 1/3; transition from Station 3 to Home
P(S → W) = 1/3 + 1/3 (=2/3); transition from station 1 to Work and from Station 2 to Work
p (H → S) = p (R→ S) = 1; direct transition between a pair of locations (from Home to Station 1; from Restaurant to Station 2)
p (W→ S) = p (W→ R) = 1/2; direct transition between a pair of locations (from Work to Station 3; from Work to Restaurant)
Note that the sum of (p) per row is unity.

C. Activity Duration Matrix

Activity duration matrix stores the information about duration of person's activities at certain time period. At various time periods, the same activity can last for different amount of time. For example, a lunch in a restaurant at 12:00 can take 30 minutes, but after 19:00 it might take 3 hours [6]. According to the figure 1, we get the below probability matrix used during weekdays by each individual (table 2). The probability is equal to 1 if the duration corresponds at the amount of time spent daily by each individual at the corresponding location. Otherwise the probability is equal to 0.

Table 2: Activity duration matrix

Loc.	**Duration (H)**			
	10-12	3:00-3:30	5-8	0:30-1:00
H	1	0	0	0
S	0	1	0	0
W	0	0	1	0
R	0	0	0	1

Legend:
H, S, W, R = Home, Switch stations (station 1, station 2, and station 3), Workstations (L_{11}, L_{21}…L_{n1}), Restaurant; respectively.

VI. DESCRIPTION OF ROUTING PROTOCOLS AND PERFORMANCE METRICS

Our studies are based on two routing protocols: A proactive routing protocol called Destination-Sequenced Distance-Vector routing protocol (DSDV) and a reactive routing protocol called Ad hoc On-demand Distance Vector routing protocol (AODV). The following performance metrics [8] are evaluated: Packet delivery ratio, Throughput, Drop packets, and Routing packet overhead.

A. Destination- Sequenced Distance-Vector routing (DSDV)

Destination-Sequenced Distance-Vector routing protocol is a proactive table driven algorithm based on classic Bellman-Ford routing. In proactive protocols, all nodes learn the network topology before a forward request comes in. In DSDV protocol each node maintains routing information for all known destinations. The routing information is updated periodically. Each node maintains a table, which contains information for all available destinations, the next node to reach the destination, number of hops to reach the destination and sequence number. The nodes periodically send this table to all neighbors to maintain the topology, which adds to the network overhead. Each entry in the routing table is marked with a sequence number assigned by the destination node. The sequence numbers enable the mobile nodes to distinguish stale routes from new ones, thereby avoiding the formation of routing loops [5].

B. Ad hoc On-demand Distance Vector routing (AODV)

In AODV, when a source node wants to send a packet but does not have a valid path to the destination, it initiates and broadcasts a route request (RREQ) message to its neighbors which then forward the request to their neighbors and so on, until either the destination or an intermediate node with a "fresh enough" route to the destination is located. Each node that forwards the RREQ creates a reverse route for itself back to source node. The destination or intermediate nodes with a "fresh enough" route to the destination responds by unicasting a route reply (RREP) packet back to the neighbor from which it first received the RREQ. The RREP is routed back along the reverse path hop-by-hop. If a route is no longer valid, the source reinitiates the route discovery protocol to find a new route to the destination [4].

C. Packet Delivery Ratio

Packet delivery ratio (%) = [received pkts / sent pkts] x 100

Received packets and sent packets number could be easily gotten from the first element of each line of the trace file. Data packets delivery ratio was calculated as percentage of data packets being delivered to total number of data packets being sent. It describes percentage of the packets which reach the destination.

D. Throughput

Total packets received at the destination node divided by the total simulation time. By definition, the throughput needs to be calculated at the bottleneck node, not sender. For the throughput calculation, in general, divide the successfully received packets by the simulation time will give us the answer, when the network is in a stable status. In the trace file, there are different levels of received packets, such as the RTR or AGT level. The packets received by the node in its AGT level will the "real received packets". You can filter those packets out from the trace file using awk or perl script.

E. Drop Packets

When congestion happens, low priority packets are dropped at a faster rate than that for high priority packets. For interactive and streaming traffic, high packet loss rates result in the failure of the receiver to decode the packet. In this tool, they are measured during specified intervals. The received packet is considered lost if its delay is beyond a predefined threshold.

F. Routing Overhead

If all the routing packets no matter broadcasting or unicasting per -hop should be count once. There are some options:

1. The total number of routing packets, counted once per hop
2. The total number of routing bytes, counted once per hop
3. The # of routing packets, count with sequence number, this means end-to-end, not calculated by per-hop basis.

Routing overhead = (routing packets sent / received)

Routing Packet Overhead is calculated as percentage of route request packets to total number of packets being sent (route discovery, data send, data relay).

VII. SIMULATION

A. Network Simulator

Simulations to study network behavior under different mobility models can be performed, by using the NS-2 (Network Simulator Version 2) discrete event simulator developed by the University of California at Berkeley and the VINT project. The simulator provides a mobility generator tool that can be used for many scenarios. NS began as a variant of the real network simulator in 1989 and has evolved substantially over the past few years. Furthermore, NS has a tool for the visualization of the generated trace files, entitled NAM (Network AniMator) (figure 3) [7].

Figure 3: A sample screen-shot of NAM animating an ad hoc network topology

B. Simulation Description

We will evaluate the performance of DSDV and AODV routing protocols under the Group Partitioning and Merging Mobility (GPMM) model. Our evaluations are based on the simulation using Network Simulator environment (NS-2); we extracted the useful data from trace file [7]. The graphs are generated using Matlab [3]. Simulation environment consists of 20 wireless nodes forming an ad hoc network, moving over a 1000X1000 flat space. DSDV and AODV routing protocols for 60 seconds of simulation time; the Time To Live (TTL) is 50 seconds. The traffic consists of tcp type with 7 connections; packet size is 1060 bytes.

C. Simulation Results

Figures 4, 5, and 6 show the packet delivery ratio versus simulation time. In these figures, packet delivery ratio under DSDV increases linearly. In figures 4 and 5, packet delivery ratio under AODV remains stable in higher level. In figure 6 and under AODV, it remains stable in higher level when sending packets from node 6 to node 0 and increases linearly when sending packets from node 5 to node 0. In figures 4, 5, and 6, AODV performs rather stable in general and in higher level than DSDV. That one relies on the information stored in the routing table that may become invalid very soon with the node mobility. As a result, such invalid route information will cause the generation of route errors and initiate new route requests resulting in the relatively higher overhead than AODV. Figure 7 shows the throughput versus simulation time. The throughput under AODV remains stable and in higher level while it increases linearly under DSDV. Figure 8 shows the drop packets versus simulation time. In this figure, graphs under AODV and DSDV evolve similarly. The amount of drop packets first remains stable and in higher level, it decreases greatly and then increases linearly. When the distance between nodes increases the probability of drop packets increases, too. Figure 9 shows the routing packet overhead versus simulation time. The routing overhead under AODV remains stable in lower level while under DSDV it decreases to low level. As AODV routing protocol does not rely on the routing table, route to recipient can be found without initiation of additional route rediscoveries. As a result, AODV manages to achieve a relatively lower overhead than DSDV. Figures 4, 5, 6, 7, 8, and 9 are obtained during individual motion of group members. Traffic between MNs exists only when MNs move separately and individually.

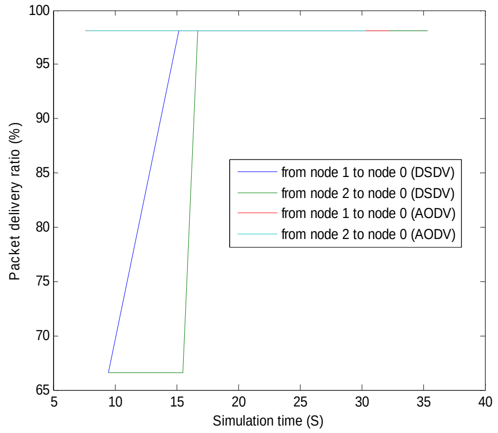


Figure 4: Packet delivery ratio vs. time

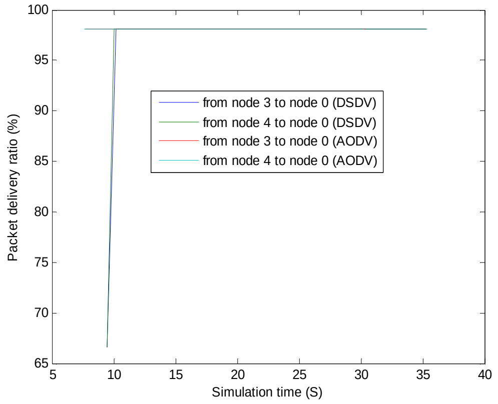


Figure 5: Packet delivery ratio vs. time

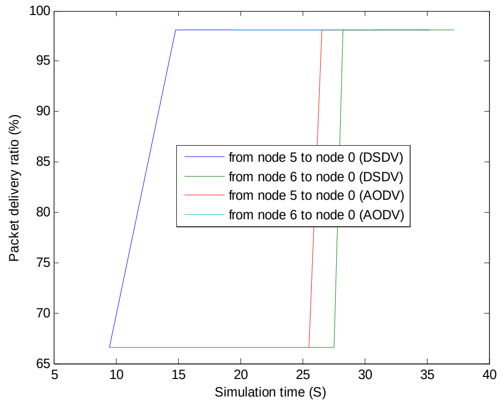


Figure 6: Packet delivery ratio vs. time

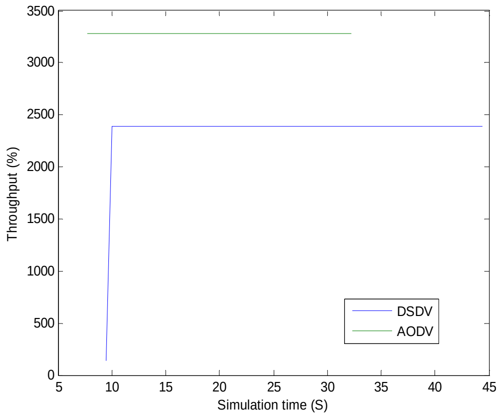


Figure 7: Throughput vs. time

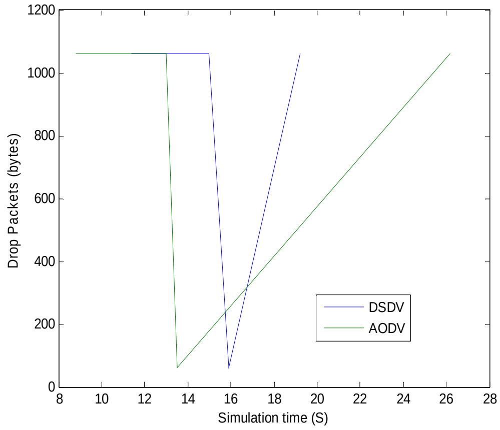


Figure 8: Drop packets vs. time

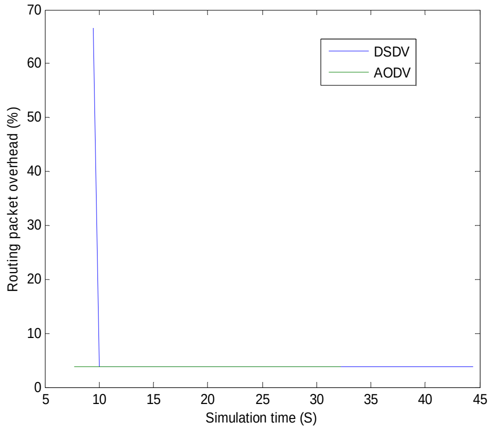


Figure 9: Routing packet overhead vs. time

VIII. BENEFITS OF OUR MODELING APPROACH TO MOBILITY

Before concluding this article, we would like to emphasize the main contributions of our model. We believe our mobility model will allow the unification of existing mobility models. In fact, the proposed mobility model breaks the barrier between individual and group mobility models by unifying them under the same formalism of rules. It is capable to describe "heterogeneous" mobility behavior such as group partitioning and merging; these are most likely to be found in ad hoc networks. We hope that this model will contribute to the definition of more realistic models and push simulation performance evaluations a step forward. Our goal was to propose an approach to mobility modelling that can be easily apprehended by the networking community at large.

IX. CONCLUSION

Over the years, a number of group mobility models have been proposed for ad hoc networks. Most of them such as Reference Point Group Mobility model, model the movement of pre-defined groups, where nodes in the same group always stay together throughout the simulation process. Such models fail in modelling scenarios where groups may be partitioned and merged. These kinds of application scenarios can be found in search and rescue operations, battlefield, conference, seminar sessions, and conventional events. In this paper, we propose Group Partitioning and Merging Mobility (GPMM) model, which provides a better reflection of group movement behavior with possible group partitioning and merging. In section 3, we presented the design of our mobility model. At the switch stations, individuals dynamically re-configure themselves triggering group partitioning and merging. Indeed, sometimes they merge and move in group and sometimes they partition and move separately. In section 7, we evaluated the performance of DSDV and AODV routing protocols under GPMM model. From simulation results, we see that, AODV in general performs better than DSDV. We implemented mobility model in NS-2 environment and converted the useful trace file to graphs using Matlab. Obtained results agree with expected results based on the theoretical analysis. We expect the proposed mobility model will play an important role in simulating emergency recovery and scenarios where various mobility behaviors typically coexist.

References

[1] Amitava Mukherjee, Somprakash Bandyopadhyay, and Debashis Saha, *Location Management and Routing in Mobile Wireless Network* (International Standard Book Number: 1-58053-355-8, Library of Congress Catalog Card Number: 2003041889, ISBN 1-58053-355-8, Cover design by Yekaterina Ratner, Artech House mobile communications series, © 2003 ARTECH HOUSE, INC., 685 Canton Street, Norwood, MA 02062, Artech House Boston · London, 2003), Available: www.artechhouse.com .

[2] Biao Zhou, Kaixin Xu, and Mario Gerla, Group and Swarm Mobility Models for Ad Hoc Network Scenarios using Virtual Tracks. Computer Science Department, University of California, Los Angeles, CA 90095, *MILCOM 2004 –2004 IEEE Military Communications Conference, 0_7803_8847_X/04/$20.00 © 2004 IEEE.* Email :{zhb, xkx, gerla}@cs.ucla.edu.

[3] Brian D.Hahn and Daniel T. Valentine, *Essential MATLAB* ^{R} *for Engineers and Scientists, Third edition* (ISBN 13: 9-78-0-75-068417-0, ISBN 10: 0-75068417-8, Butterworth-Heinemann is an imprint of Elsevier, Linacre House, Jordan Hill, Oxford, OX2 8DP, 30 Corporate Drive, Burlington, MA 01803, 2007).

[4] C. E. Perkins and E. M. Royer, Ad-hoc On-Demand Distance Vector Routing, *Proceedings of the 2nd IEEE Workshop on Mobile Computing Systems and Applications*, New Orleans， February 1999， pp.90-100.

[5] Charles E Perkins and Pravin Bhagwat, Highly Dynamic Destination Sequenced Distance Vector Routing (DSDV) for Mobile Computers, *SIGCOMM 94*, 1994, pp.234-244.

[6] Illya Stepanov, *Integrating Realistic Mobility Models in Mobile Ad Hoc Network Simulation* (Diplomarbeit Nr.1989, Institut fur parallele und verteilte systeme (IPVS), Abteilung Verteilte Systeme, Breitwiesen str. 20-22, 70565 Stuttgart. Universitat Stuttgart Fakultat Informatik. CR-Klassifikation: C.2.1,C.4,H.3.4,I.6.0, 2002).

[7] Kevin Fall and K.Varadhan, *The ns Manual* (University of Southern California, Information Sciences Institute (ISI), 2002), Available: www.isi.edu/nsnam/ns/ns-documentation.html.

[8] Mingjie Lai. ICS243E/Wireless Networking, *Final Report- Mobile Ad-hoc Networks Routing Protocols Simulation and Comparison*, EECS Department, Univ. of California, Irvine, March 5, 2005, 19429781, Available: mlai@uci.edu.

[9] T. Camp, J. Boleng, and V. Davies, A Survey of Mobility Models for Ad Hoc Network, *Research in Wireless Communication and Mobile Computing (WCMC): Special issue on Mobile Ad Hoc Networking: Research, Trends and Applications*, 2002, vol.2, no. 5, pp. 483-502.

[10] X. Hong, M. Gerla, G. Pei, and C. Chiang. A group mobility model for ad hoc wireless networks. *In Proceedings of the ACM International Workshop on Modeling and Simulation of Wireless and Mobile Systems (MSWiM)*, August 1999