A New Group Mobility Model for Mobile Adhoc Network based on Unified Relationship Matrix

S.GUNASEKARAN*
N.NAGARAJAN**
*Anna University
Coimbatore
India
gunaphd@yahoo.com
**CIET
Coimbatore
India
swekalnag@gmail.com

Abstract: -. Most of the mobile Adhoc network protocols are validated by simulation environment. The validation is meaningful when they use realistic movement mobility models, which directly impacts the performance of the protocols. Once the nodes have been initially distributed, the mobility model dictates the movement of the nodes within the network. If this movement is unrealistic, the simulation results obtained may not correctly reflect the true performance of the protocols. The majority of existing mobility models for adhoc networks do not provide realistic movement. Mobility model based on social network theory predicts the node movements more realistic. Our paper reinforces the model by using Unified Relationship Matrix, which improves the movements of groups. Unified Relationship Matrix helps to represent the relationships of inter and intra type of nodes. Movements of nodes and groups are evaluated by keeping a small distance between each node and maintaining each group velocity, direction and movements. Group velocity is calculated by inter relationship matrix and cumulative nodes velocity. Group movements are calculated and directed by Unified Relationship Matrix.
Key-Words: - Adhoc networks, Mobility, Social Networks, Unified Relationship Matrix, Mobile Nodes, Mobile Groups

1 Introduction

In order to thoroughly simulate the new routing protocols for Mobile ad-hoc network (MANET), it is imperative to choose and use a mobility model that accurately depicts the Mobile Nodes that will eventually utilize the given protocol. These mobility models should give more realistic movements to nodes in the simulation which directly impact the performance result of the simulation. A perfect realistic mobility model should determine whether the proposed protocol will be useful or not. Currently there are two types of mobility models are available in the simulation of MANET: one is traces and another one is synthetic models. Traces produce the mobility patterns based on the real life systems. Traces are formed from long observation period and large number of participants, so that they can provide accurate information for the simulation environments. However; new network environments are not easily modeled, if traces have not yet been created. Synthetic mobility models mimic the realistic representation of the behaviors of Mobile Nodes without the use of traces. In this paper we present a new synthetic mobility models.

There are many number of synthetic mobility model available for MANET. Typically, a simple abstract mobility model such as random waypoint or random walk is used. Random way point model fails to provide a steady state in that the average nodal speed consistently decreases over time, and therefore should not be directly used for simulation [1]. The overheads and performance of mobile systems usually depend strongly on node mobility. These random mobility models do not attempt to reflect real human mobility behavior.

Most of the Mobile networks and wireless devices are handled by human beings. The hope, however, is that a simple model captures enough of the key characteristics of human mobility to make protocol evaluations meaningful. Humans, of course, rarely move randomly. Here we illustrate a typical public park as an example. Park users will be unevenly distributed over this landscape. Some of them will be stationary and others will move at different characteristic speeds: for example walkers, joggers and bikers. The route that mobile users take will not be random. Some will move to attraction points such as snack bars, restrooms, play areas, etc.…These sort of human behaviours are mostly handled by social network mobility models [2].

Social network theory is a widely used concept in the network world. In Mobile Adhoc Network it represents the Mobile Nodes (MNs) by social relationship matrix. This matrix gives the information about the attractiveness of nodes with in the group [2, 3]. In this paper, we modify the mobility model that is founded on social network theory by changing the relationship matrix to Unified Relationship Matrix (URM). Input to this mobility model is social network, which links the individuals carrying the mobile devices. Based on the results we generate realistic synthetic network structures.

One of the strengths of our model is that the input network can be arbitrary. Thus, the model is highly flexible and may be used to explore the effects of any social network on ad hoc network applications. However, we are specifically interested in so called scale-free networks that seem to model the structure of social networks most accurately. Our model can be applied to the Adhoc network, which contains any number of nodes.

The purpose of our research is to find effective and efficient means of representing the relationships from multiple heterogeneous Mobile Groups (MG). We are also focusing the movement and direction of the Mobile Groups. In this paper, we use the Unified Relationship Matrix to represent relationships from multiple and heterogeneous MG's. We further claim that iterative computation, over the URM, will improve the quality and performance of mobile adhoc networks, which has variety of heterogeneous mobile nodes.

The paper is organized as follows. In section 2, we describe the brief concept of social network theory used in mobile adhoc networks. In section 3, we portray the Unified Relationship Matrix concepts. Section 4 gives the details about the implementation and conclusion and future works are discussed in the last section.

2 Social Network representation for MANET

In recent years, the research on complex networks has produced some remarkable results that indicate the existence of an omnipresent law governing the structure of diverse networks. Social networks, i.e. networks of humans and their relationships, were among the first to be studied in this respect. Models were found, that enable us to grow and examine such networks.

Recent research in Social Networks Theory brings the more realistic mobility model for mobile adhoc networks. Social networks analysis is the mapping and measuring of relationship among peoples, groups, organizations, animals, computers and other knowledge processing entities. Social network theory applies to a wide range of human organizations, from small groups of people to entire nations. The term network refers to a set of objects, or nodes, and a mapping or description of the relationship between the objects. Representation of this relationship in a Social Network model is as follows [11],

1) Descriptive methods, also through graphical representation
2) Analysis procedure, often based on a decomposition of adjacency matrix
3) Statistical model based on probability model.

Graphical methods for representing the network use nodes or points to denote the actors and edges to show their relationship. Arrow in the edges represents the attraction direction. This graphical method is simple approach to analysis the social networks. The following diagram shows the example.

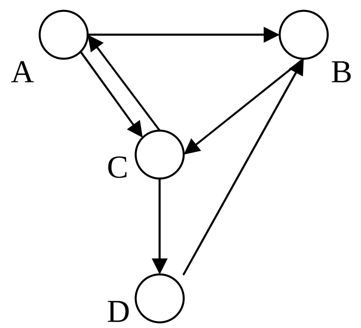

Fig. 1 Using Graphs to represent Social Network

A matrices method for representing the social network is a simple one composed of rows and columns. It is a $N \times N$ matrix, where N is number of nodes or actors in the networks. This kind of matrix is the starting point for almost all network analysis, and is called adjacency matrix because it represents the adjacent nodes. The above figure 1 can be represented using adjacency matrix as follows;

Table1. Using Matrices to represent Social Network

	A	B	C	D
A	-	1	1	0
B	0	-	1	0
C	1	0	-	1
D	0	1	0	-

The statistical literature on modeling Social Networks assumes that there are n entities called actors and information about binary relations between them. Binary relations are represented as an $n \times n$ matrix Y, where $Y_{i,j}$ is 1, if actor i is somehow related to j and 0 otherwise. For example, $Y_{i,j} = 1$ if i considers j to be friend. The entities are usually represented as nodes and the relations as arrows between the nodes. If matrix Y is symmetric, then the relations are represented as undirected arrows. More generally $Y_{i,j}$ can be valued and not just binary, representing the strength (or value) of the relationship between actors i and j .

In this paper, we follow the weighted graph model [3, 4] to represent the social network. By defining, the weights associated with each edge of the network to model the strength of the direct interactions between individuals. In this case, interactions are said to be direct if they take place between people who are co-located. It is our explicit assumption that these weights, which are expressed as a measure of the strength of social ties, can also be read as a measure of the likelihood of geographic co-location, though the relationship between these quantities is not necessarily a simple one, as will become apparent. They [4] model the degree of social interaction between two people using a value in the range [0, 1]. 0 indicates no interaction; 1 indicates a strong social interaction.

The model also allows for the definition of different types of relationships during a certain period of time (i.e., a day or a week). For instance, it might be important to be able to describe that in the morning and in the afternoon of weekdays, relationships at the workplace are more important than friendships and family one, whereas the opposite is true during the evenings and weekends. Interaction Matrix is used to store the information of interaction between two nodes. One example may be the following:

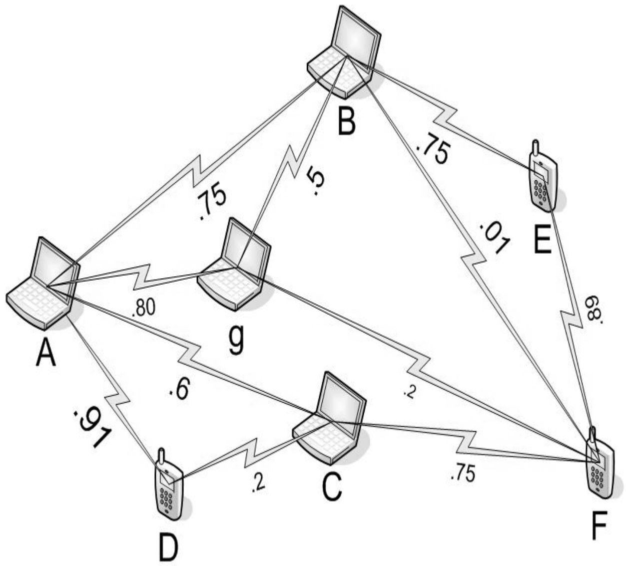

Fig. 2 Example of Social Network

$$m = \begin{bmatrix} 1 & 0.75 & 0.6 & 0.91 & 0 & 0 & 0.80 \\ 0.75 & 1 & 0 & 0 & .75 & 0.1 & 0.5 \\ 0.6 & 0 & 1 & 0.2 & 0 & 0.75 & 0 \\ 0.91 & 0 & 0.2 & 1 & 0 & 0 & 0 \\ 0 & .75 & 0 & 0 & 1 & 0.89 & 0 \\ 0 & 0.1 & 0.75 & 0 & 0.89 & 1 & 0.2 \\ 0.80 & 0.5 & 0 & 0 & 0 & 0.2 & 1 \end{bmatrix}$$

Fig. 3 Example of Interaction Matrix representation of the above Social Network

The generic element $m_{i,j}$ represents the interaction between two individuals i and j. We refer to the elements of the matrix as the interaction indicators. The diagonal elements represent the relationships that an individual has with himself and are set, conventionally, to 1. If the interaction indicator between two individuals i and j is less than 0.25, they are considered socially disconnected. The choice of the value 0.25 is arbitrary and it is only used to provide a clearer graphical representation of the important connections between people.

3 URM introduction

URM, is used improve the quality and utility of information from heterogeneous Groups by representing the relationship between them. To prove this, we have focused our research on a specific application.

The underlying hypothesis is that: Relationships can be represented through adjacency weighted matrices accurately, as like [4]. Matrices representations of different types of relationships are sometimes complementary. A matrix representation of a single relationship may be sparse, but when reinforced by other types of relationships represented in complementary matrices, the information it contains may be more dense and helpful. We contend that matrix representation and matrix processing are effective approaches for combining relationships from difference groups. Note that as a result of our methods, the Unified Relationship matrices, which can be used for various applications, is presumably of higher quality (e.g., less sparse, due to the addition of accurate new values, and so more effective).

3.1 Definition and Examples

3.1.1 Definition

We first give simple definitions for key terms, as they will be used in the rest of this paper:

- **MN Type:** A MN Type refers to a class of objects, defined by a set of characteristic features (e.g., MN user has a set of features including name, relationship etc.). A Mobile Node (MN) object is an instance of a MN Type.
- **Group:** A Group is a set of MN objects with the same MN Type (e.g., MN's in office). Table 1 gives examples of related Groups and MN objects.
- **Homogeneous/Heterogeneous:** Each group is homogeneous within itself, but heterogeneous with respect to other groups.
- **Intra-type relationship**: connects information objects within a homogeneous group (e.g., hyperlinks within web pages).
- **Inter-type relationship:** connects information objects across heterogeneous groups.

Table 2. Some relationships in our applications

Groups	Examples of MN objects
Family	**Father, Mother, Son, Daughter etc...**
Office	**Manager, Accountant, Typist, programmer, etc…**
Friends	**Girl friends, boy friends, lover and all other friendship**
College	**Principal, Professors, Students, etc…**

The formal definition of the Unified Relationship Matrix (URM) that represents both inter-type and intra-type relationships among heterogeneous MN objects in a unified manner is given below.

Suppose there are N different groups S_1, S_2, $S_3 \ldots S_n$. Mobile Node objects with in the same group are connected via intra-type relationships $R_i \subseteq S_i \times S_i$. MN objects from two different groups are connected via inter - type relationships $R_{i,j} \subseteq S_i \times S_j$ $(i \neq j)$. The intra-type relationships R_i can be represented as an m×m adjacency matrix L_i (m is the total number of objects in group S_i). Inside matrix L_i cell l_{xy} represents the inter-type relationship from the x^{th} object to the y^{th} object in the group S_i. The intertype relationship $R_{i,j}$ can be represented as an m×n adjacency matrix L_{ij} (m is the total number of objects in S_i, and n is the total number of objects in S_j), where the value of cell l_{xy} represents the inter-type relationship from the x^{th} object in S_i to the j^{th} object in S_j. If we merge N groups into a unified group U, then previous inter and intra type relationships are all part of intra type relationships R_u in group U. Suppose L_u is the adjacency matrix of R_u, then L_u is a square matrix. We define the Unified Relationship Matrix L_{urm} as a matrix that combines all the relationship matrices, as given in Equation (1).

$$L_{urm} = \begin{bmatrix} L_x & L_{xy} \\ L_{yx} & L_y \end{bmatrix} \quad (1)$$

Using the notations in the first paragraph of this section, Equation (1) can easily lead to the definition of the Unified Relationship Matrix L_{urm} for N interrelated data spaces, as shown in Equation (2).

$$L_{urm} = \begin{bmatrix} L_1 & L_{12} & \ldots\ldots & L_{1N} \\ L_{21} & L_2 & \ldots\ldots & L_{2N} \\ : & : & & : \\ & & \ldots\ldots & \\ : & : & & : \\ L_{N1} & L_{N2} & \ldots\ldots & L_{NN} \end{bmatrix} \quad (2)$$

3.1.2 An Example

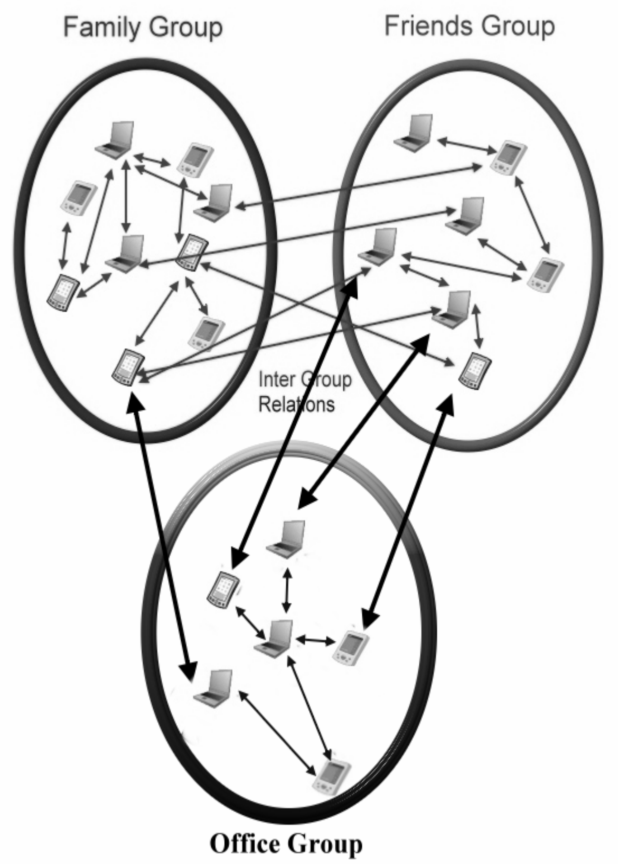

Fig. 4 Example scenario of MANET

The URM can be used to explain a lot of many real-world MANET scenarios. For example, considering a family party conducted by a company, we take three different groups: family group, friends' group and office group. That means three intra type relationships with three inter type relationship. Figure 3 depicts the situation.

Based on the attraction value initial adjacency matrix is formed. That can be derived to URM. Equation 3 represents the URM for the above example.

$$L_{urm} = \begin{bmatrix} L_{family} & L_{mix1} & L_{mix2} \\ L_{mix1}^{T} & L_{friend} & L_{mix3} \\ L_{mix2}^{T} & L_{mix3}^{T} & L_{office} \end{bmatrix} \quad (3)$$

Where L_{family} is the interaction matrix of family group, $L_{friends}$ is the interaction matrix of friends' group and L_{office} is the interaction matrix of office group. Inter group relationship between family and friends; family and office; friends and office are represented by L_{mix1}, $L_{mix2,}$ and L_{mix3} respectively. $L_{mix1}{}^{T}$, $L_{mix2}{}^{T}$ and $L_{mix3}{}^{T}$ are the transpose matrices of L_{mix1}, $L_{mix2,}$ and L_{mix3} respectively.

4 Implementation

4.1 Position Selection and Update

In this section, we discuss the mechanisms that form the basis of the evolution of the simulated scenarios after the initial establishment phase.

Initially all the Mobile Nodes are randomly placed inside the Group. Movement of the nodes are based on the following rules.

Rule 1: gives the movement of nodes based on their attraction velocity.
Rule 2: avoids the collision of nodes by maintaining small distance among the nodes.
Rule 3: groups the nodes and calculate the group velocity with the help of URM.
Rule 4: gives the movements of groups based on the rule 3.

4.1.1 Rule-1

A node that belonging to a group moves inside and outside the corresponding group area towards a goal. This point is chosen by its attraction value in the Social relationship matrices. Initially each node moves with a randomly generated different speed (a predefined range). New position of node i is calculated by adding it's current position and velocity V.

$$_{New}P_{n\_i} = {}_{Old}P_{n\_i} + V_{n\_i} \quad (4)$$

Velocity V is the sum of current velocity; it's attraction velocity; and the velocity calculated by rule 2.

$$V_{n\_i} = V_{n\_i} + {}_{Attr}V_{n\_i} + V_{rule2} \quad (5)$$

Attraction velocity is calculated by subtracting the position of current node with attraction node. The equation for attraction velocity $_{attr}V_{n\_i}$ is following:

$$_{attr}V_{n\_i} = (P_{attr} - P_{n\_i}) / 100 \quad (6)$$

Velocity to the attraction point is 1% that is given by dividing the equation by 100 in equation (6).

4.1.2 Rule-2

Every node tries to keep a small distance from its neighbours. The purpose of this rule is avoiding collision of nodes. We take the small distance as 100 units. Positions of all the nodes are updated by their velocity. Equation for calculating this velocity is following:

$$V_{rule\ 2} = V_{rule\ 2} - (P_n - P_i) \quad (7)$$

The algorithm for calculating $V_{rule\,2}$ is as following:

1. *FOR EACH NODE*
2. *IF N! = Ni THEN*
3. *IF (PN – Pi) < 100 THEN*
4. $v_{rule\ 2} = v_{rule\ 2} - (P_n - P_i)$
5. *ENDIF*
6. *ENDIF*
7. *ENDFOR*

4.1.3 Rule-3

Initially Groups are formed by collection of similar nodes. Their boundary values are assumed by their member nodes geographical values. Group movement depends on the group velocity values. Here all the values of velocity are measured in terms of (x, y) coordinates. Group velocity $V_{g\_i}\Delta t$ is calculated based on two factors: One is cumulative velocity of nodes in that group; second one is calculated by attraction velocity from URM.

$$V_{g\_i}\Delta t = {}_{attr}V + \sum V_{n\_i} \quad (8)$$

$$_{Att}V = (P_{attr} - P_g)/100 \quad (9)$$

4.1.4 Rule-4

Each group moves with a cumulative speed of velocity (value obtained by the velocity value of MN's in the group range). The equations used to update the position of the host are as following,

$$_{New}X_{groupi} = {}_{current}X_{groupi} \pm V_{g\_i}\Delta t \quad (10)$$

$$_{New}Y_{groupi} = {}_{current}Y_{groupi} \pm V_{g\_i}\Delta t \quad (11)$$

If any group does not have an attraction to other groups its position will not be updated. This is calculated by unified relationship matrix. It is worth noting that Groups also move towards chosen goals in the simulation space with the help of URM.

4.2 Modeling Hosts and Groups Dynamics

In the previous section, we presented a general overview of the model. In this section, we describe how social network relationships influence the evolution and the dynamics of the simulated mobile scenario. Let us consider the case of a host inside a group. When a host reaches a goal, it implicitly reaches a decision point at which it must decide whether to remain within the group, to move to another group, or to escape outside all groups. This process is driven by the Sociability Factor of the host. More specifically, a threshold is generated using a uniform random distribution; if the Sociability Factor of the host is higher than the threshold, a new goal is chosen outside the areas of any group. If this does not happen, a new goal inside one of the groups (including the current one) is chosen. More specifically, the attraction intensities exerted by the groups towards the host are calculated. The host will join the group that exerts the highest attraction. If the group, of which the host is currently a part, exerts the greater attraction, the host will not leave the group.

The case of a host starting outside group areas is symmetric. When the host reaches its goal, a threshold is generated and if the Sociability Factor of the host is lower than the threshold, the host will join the group of hosts that exerts the greatest attraction.

4.3 Evaluation

In order to extract quantitative information about the structure of the generated mobile scenario, the mobility model was implemented using OMNet++ [17] and GloMoSim [16], a discrete event simulator. We used uniform distributions to generate the Interaction Matrices and the connection threshold was set to 0.25.

We defined a square simulation area with a side of 1 km and group areas with a side of 200 m. The simulation was set to run for 1 hour of simulated time (10 inter-type relationships for each mobile scenario) in order to obtain a statistically meaningful set of results. Each group moves with a random speed (with a value in the range 1-2 m/s) and each host moves with a randomly generated different speed (with a value in the range 1-3 m/s). As described above, the movement of a host is the result of the composition of these speeds.

We considered three scenarios characterized by different numbers of hosts and groups. The first scenario was composed of 30 nodes grouped into 5 geographically separate groups, whereas the second was composed of 60 nodes grouped into the same number of groups and third scenario was composed of 120 nodes. In all the cases, all the hosts were initially placed inside the groups. From the simulation results, we extracted the distribution of the average degree of connectivity. The average is computed using a sample interval equal to 1 second. Figure 4 and Figure 5 show the distributions of the degree of connectivity related to the scenarios composed of 30 and 60 nodes respectively, each with five groups.

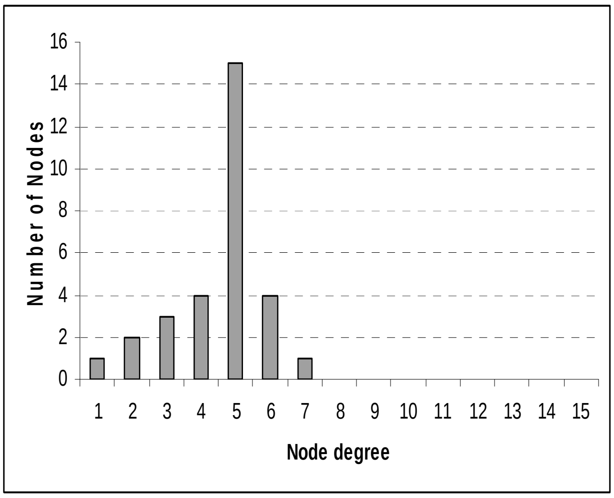

Fig. 5 Distribution of Degree of Connectivity. (Scenario one: 30 nodes grouped into 5 groups).

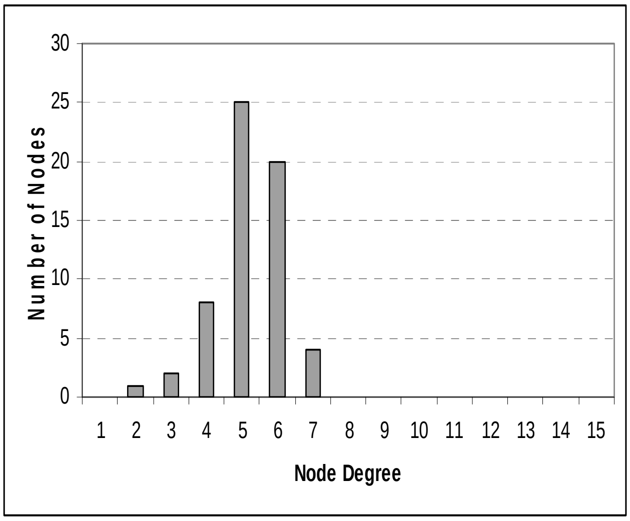

Fig. 6 Distribution of Degree of Connectivity (Scenario two: 60 nodes grouped into 5 groups)

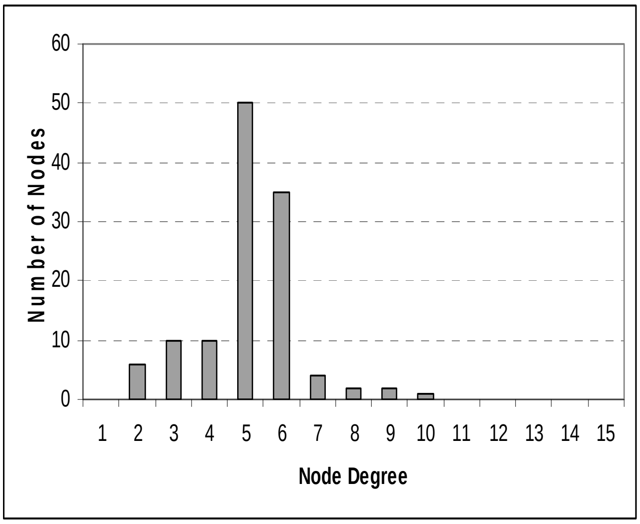

Fig. 7 Distribution of Degree of Connectivity (Scenario two: 120 nodes grouped into 5 groups)

We plotted this graphs against the degree of nodes with respect to number of nodes with that degree. Moments of hosts are based on their social attraction value [3] and moment of the groups based on the URM attraction value. However, the social clustering influences the dynamic network topology and, consequently, the average node degree, as it can be seen by comparing the range of values of k corresponding to the peak of the bar values in Figures 4 and 5. The value of peak in Figure 5 roughly doubles with respect to Figure 4 (from the range 4 to the range 6), indicating that, approximately, double the number of the nodes are now clustered in the group areas.

5. Conclusions and Future Works

All mobility models, which exist, based on highly simplistic random movement models. Since these models are patently unrealistic, the practical applicability of much current ad hoc networks research must be considered highly suspect. In the absence of trace data, the best that can be achieved is to base synthetic mobility models on realistic models of human socialization.

We believe that it is possible to design mechanisms based on the evaluation of the social network that connects the individuals carrying the mobile devices, in order to build more efficient and, at the same time, more reliable systems. For example, in order to reduce the number of inter-type relationships that are presented in the system, it is possible to consider the likelihood of the co location of certain nodes.

In this paper, we have presented a novel group mobility model for mobile ad hoc networks research, founded on social network theory. Since mobility models can only be judged on the basis of behavior that emerges as a consequence of their dynamic evolution, we have discussed the emergent properties of the networks generated using our model. We have shown, in particular, that the degree of the simulated network based on URM is strongly influenced by the grouping mechanisms.

We are now investigating other properties of networks generated by our model from a theoretical point of view. The mobility model presented in this paper will be used in our current investigation about the design of efficient routing protocols and systems (especially in terms of the use of the available resources) for mobile ad hoc networks. In this paper we are not dealing obstacles and path redirection concept, which is under research.

Finally, we plan to refine the model both by making dynamic changes in the number of groups and by allowing the definition of obstacles within the simulation environment.

References

[1] Jungkeun Yoon, Mingyan Liu, and Brian Noble, “Random Waypoint Considered Harmful”, *IEEE INFOCOM*, IEEE 2003.

[2] Michael Feeley, Norman Hutchinson, and Suprio Ray, “Realistic Mobility for Mobile Ad Hoc Network Simulation”,*ADHOC-NOW 2004*, pp.324–329, Springer-Verlag Berlin Heidelberg, 2004.

[3] Mirco Musolesi, and Cecilia Mascolo, “A Community Based Mobility Model for Ad Hoc Network Research”, *REALMAN’06*, May 26, 2006, Florence, Italy.

[4] M. Musolesi, S. Hailes, and C. Mascolo. “An Ad Hoc Mobility Model Founded on Social Network Theory”. *In Proceedings of MSWiM’04*, pages 20–24. ACM Press, October 2004.

[5] A. Jardosh, E. Royer, K. Almeroth, and S. Suri, “Towards realistic mobility models for mobile ad hoc networks.” *In MobiCom’03*, September 2003.

[6] X. Hong, M. Gerla, G. Pei, and C.-C. Chiang. “A Group Mobility Model for Ad hoc Wireless Networks”. *In Proceedings of the ACM/IEEE MSWIM’99*, *Seattle, WA*, August 1999.

[7] James M. Cargal, “Social relationship as Algebraic Relationship”, *Proceedings of the 1980 Winter Simulation Conference*, copyright IEEE 1980.

[8] C. Bettstetter, G. Resta, and P. Santi, “The node distribution of the random waypoint mobility model for wireless ad hoc networks”, *IEEE Transactions on Mobile Computing*, 2(3):257–269, July-September 2003.

[9] Wensi Xi, Benyu Zhang, and Zheng Chen, “Sim Fusion : Measuring Similarity using Unified Relationship Matrix ”, *SIGIR’05*, August 15–19, 2005, ACM Press ,2005.

[10] S. Basagni, I. Chlamtac, V. R. Syrotiuk, and B. A. Woodward, “A distance routing effect algorithm for mobility (DREAM)”. *In ACM/IEEE International Conference on Mobile Computing and Networking (Mobicom98)*, pages 76-84, 1998

[11] Mohsen jamali and Hassan Abolhassani, “Different aspects of socials network analysis”. *In IEEE/WIC/ACM International Conference on web intelligence, (WI’06)*, 2006.

[12] X. Zeng, R. Bagrodia, and M. Gerla, “Glomosim: A library for parallel simulation of large-scale wireless networks”. *In Proceeding of PADS Workshop*, May 1998.

[13] C. E. Perkins and E. M. Royer, “*The Ad hoc on-Demand Distance Vector Protocol in C”* E. Perkins, editor, Ad hoc Networking, pages 173–219. Addison-Wesley, 2000.

[14] B. Karp, “Geographic Routing for Wireless Networks”, PhD thesis, Harvard University, 2000.

[15] M Sanchez, Mobility models, http://www.Disca.upv.es/misan/mobmodel.htm., Page accessed on May 30th, 2007.

[16] Glomosim Project work details, http://pcl.cs.ucla.edu/projects/glomosim

[17] OMNeTpp. 2007. Available online via <http://www.omnetpp.org/> [accessed Feb. 15, 2006]

[18] V. Davies, “Evaluating Mobility Models within an Ad Hoc Network”, Colorado School of Mines, Master’s thesis, 2000.

[19] N. Fuhr and T. Rolleke, “A Probabilistic Relational Algebra for the Integration of Information Retrieval and Database Systems,” ACM Transactions on Information Systems, vol. 15, pp. 32-66, 1997.

[20] V. Tolety, “Load reduction in ad hoc networks using mobile servers.”, Master’s thesis, Colorado School of Mines, 1999

[21] T. A. Snijders, P. E. Pattison. G. L. Robins, and M. S. Handcock, "New specifications for exponential random graph models." 2004.

[22] G. Robins, P. Pattison, and S. Wasserman. "Logit models and logistic regressions for social networks," Psychometrika. vol. 64, pp. 371-394. November 1999.

[23] P, Hoff, A. Raftery, and M. Handcock, "Latent space approaches to social network analysis," Journal ofthe American Statistical Association, vol. 97, pp. 1090-1098. 2002.

[24] M. Handcock. "Assessing degeneracy in statistical models of social networks," December 2003, working paper, University of Washington.
[25] P. Smyth. "Statistical modeling of graph and network data." in Proceedings of IJCAI Workshop on Learning Statistical Modelsfrom Relational Data, Acapulco, Mexico, August 2003.
[26] D. S. Johnson and M. A. Trick, Cliques, Coloring, and Satisfiability: Second Dimacs Implementation Chollenge. American Mathematical Society, October 1996.
[27] H. Kautz, B. Selman and M. Shah, "Referral Web: Combining Social Networks and Collaborative Filtering", in Communications of the ACM (CACM), Vol (40) 3:63-65, 1997
[28] E. M. Royer, P. M. Melliar-Smith, and L. E. Moser, "An Analysis of the Optimum Node Density for Ad hoc Mobile Networks." In Proceedings of the IEEE International Conference on Communications, pages 857–861, Helsinki, Finland, June 2001.
[29] G. Resta and P. Santi,"An Analysis of the Node Spatial Distribution of the Random Waypoint Mobility Model for Ad hoc Networks." In Proceedings of the 2nd ACM International Workshop on Principles of Mobile Comptuing (POMC), Toulouse, France, October 2002.
[30] Kadushin, Charles. "A Short Introduction to Social Networks: A Non-Technical Elementary Primer" Accessed: October 29, 2003. Online. Internet. <http://construct.haifa.ac.il/~cerpe/papers/kadushin.html>.
[31] Moses Boudourides (2002). "A Review of Network Theories On The Formation of Public Opinion". Contributed paper at the EURICOM Colloquium: Electronic Networks and Democratic Engagement, Nijmegen, the Netherlands, October 9-11, 2002
[32] "The Promise and Pitfalls of Social Networking", Accessed: December 1, 2003. Online. Internet. http://www.darwinmag.com/read/110103/pitfalls.html
[33] "EFF Review Of May 20 Report On Total Information Awareness", Accessed: December 1, 2003. Online. Internet. <http://www.eff.org/Privacy/TIA/20030523_tia_report_review.php>.
[34] "Report to Congress regarding the Terrorism Information Awareness Program", In response to Consolidated Appropriations Resolution. May 20, 2003. Pub. L. No. 108-7, Division M, 111(b).
[35] Jordi Sabater, Carles Sierra(2002). "Reputation and Social Network Analysis in Multi-Agent Systems". International Conference on Autonomous Agents. July 2002, pp. 475-482.
[36] Phillip Bonachich(2001). "The Evolution of Exchange Networks: A Simulation Study". Journal of Social Structure. Volume 2, number 5, November 8, 2001.

Authors

S.Gunasekaran received his M.E. degree and B.E., degree in Computer Science and Engineering from Anna University and Bharathiyar respectively. He is currently working towards the PhD degree in ANNA University, Coimbatore. His research interests accumulate in the area of Mobility, Routing, Network management in MANET and Sensor Networks.

Email: - gunaphd@yahoo.com

Dr.N.Nagarajan received his B.Tech and M.E. degrees in Electronics Engineering at M.I.T Chennai. He received his PhD in faculty of information and communication engineering from Anna University, Chennai. He is currently working as Dean, Computer science and engineering department, Coimbatore Institute of engineering and information technology, Coimbatore. He is member of board of study of faculty of information Technology at Anna University, Coimbatore. His specialization includes optical, wireless Adhoc and sensor networks. He is guiding assorted research scholars in optical networks and adhoc networks.

Email: - swekalnag@rediffmail.com