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An Improved Group Mobility Model for Mobile Adhoc Network based on Unified Relationship Matrix

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Abstract—**Most of the MANET protocols are evaluated by simulation environments. The validation is meaningful when they use realistic mobility models. 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. Most of the mobile nodes are directly or indirectly handled by human beings so mobility model based on social network theory predicts the node movements more realistic. Major challenges of these models are identifying the community and predicting the behavior of each node and each community.**

Our paper reinforces the model and overcome the challenges by using Unified Relationship Matrix which identifying the community structure more accurately and helps to predict the behaviour of a MANET. Unified Relationship Matrix helps to represent the relationships of inter and intra type of nodes among the various community groups with in the given terrain. It solves the node duplication among various heterogeneous community groups and identifies the correct community structure.

Index Terms—**Adhoc networks, Mobility, Social Networks, Unified Relationship Matrix, Mobile Nodes, Mobile Groups.**

I. Introduction

In MANET many research scholars use simulation to evaluate their protocols and routing algorithms. GloMoSim [9] and NS-2 [10] are the popular simulators used for this. In order to thoroughly simulate the wireless environment, the movement of mobile nodes should be predicted more accurate and realistic. A simple abstract mobility model, such as random waypoint model or random walk model fails to provide realistic node movements because the average nodal speeds 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 behaviour.

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 rarely move randomly, for example in a typical public park, different Park users move different speeds to reach their different attraction point such as snack bars, play areas, etc... The route that user take will not be random. These sort of human behaviors are mostly handled by social network mobility models that predict the more realistic node movements [2, 5].

In MANET social network concept represents the Mobile Nodes (MN) by social relationship matrix which 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 introducing the Unified Relationship Matrix (URM) concept. Input to this mobility model is social network matrix, which has the links of individuals carrying the mobile devices. Based on the results we generate realistic synthetic network structures for GloMoSim [9] and NS-2 [10].

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 URM to represent relationships from multiple and heterogeneous Mobile Groups. We further claim that, iterative computation over the URM will categorize community group structures and improve the 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; conclusion and future works are discussed in the last section.

II. Social Network Representation for MANET

Recent research in Social Network Theory brings the more realistic mobility model for mobile adhoc networks. Social network analysis is the mapping and measuring of relationship among peoples, groups, organizations, animals, computers and other knowledge processing entities. Representation of this relationship in Social Network model is as follows [8],

- Descriptive methods, also through graphical representation
- Analysis procedure, often based on a decomposition of adjacency matrix

- Statistical model based on probability model.

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). Interaction Matrix is used to store the information of interaction between two nodes. One example may be shown in Fig. 1.

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 0.4, they are considered socially disconnected. The choice of the value 0.4 is arbitrary and it is only used to provide a clearer graphical representation of the important connections between people.

III. URM Introduction

URM, is used improve the quality and utility of information from heterogeneous Groups by representing the relationship between them. It helps to identify the duplicated nodes among the various heterogeneous groups. To prove this, we have focused our research on a specific application family and friends groups. Before that, we presume an underlying hypothesis and introduce some important terms.

The underlying hypothesis is that: Relationships can be represented through adjacency weighted matrices accurately, as like [3, 4]. Matrices representations of

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

Figure 1. Example of Interaction Matrix representation of a Social Network.

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).

A. Important Terms

We give simple definitions for some of the 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) or Mobile Node object is an instance of a MN Type. In this paper the words MN and node are interchangeable.
- *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.

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 $G_1, G_2, G_3 \ldots G_n$. Mobile Node objects with in the same group are connected via intra-type relationships $R_i \subseteq G_i \times G_i$. MN objects from two different groups are connected via inter - type relationships $R_{i,j} \subseteq G_i \times G_j$ $(i \neq j)$. The intra-type relationships R_i can be represented as an m×m adjacency matrix L_i (m is the total number of MN objects in group G_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 G_i. The intertype relationship $R_{i,j}$ can be represented as an m×n adjacency matrix L_{ij} (m is the total number of MN objects in G_i, and *n* is the total number of MN objects in G_j), where the value of cell l_{xy} represents the inter-type relationship from the x^{th} MN object in G_i to the

TABLE I.
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

j^{th} MN object in G_j. If we merge all 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. We define the Unified Relationship Matrix L_{URM} as a matrix that combines all the relationship matrices, as given in equation (1).

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

URM defined in equation (1) gives all inter and intra type of relationships. In some cases, if two or more group areas are mapped or super imposed together; then L_{URM} has duplicated nodes entry. To overcome this problem we calculate Duplicated Unified Relationship Matrix (DURM), which definition is given below.

Among N different groups G_1, G_2, G_3…G_n, the intra-type relationships $R_i \subseteq G_i \times G_i$, which can be represented as an m×m adjacency matrix L_i is 0 (because it may contain duplicated nodes relations values). The intertype duplicated relationship $R_{i,j}$ can be represented as an n×n adjacency matrix L_{ij} (n is the number of duplicated MN objects belong to both G_i and G_j) where the value of cell l_{xy} represents the inter-type duplicated relationship from the x^{th} MN object in G_i to the j^{th} MN object in G_j. If we merge all groups into a unified group U, then previous inter and intra type duplicated relationships are all part of intra type duplicated 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 duplicated Unified Relationship Matrix L_{DURM} as a matrix that combines all the duplicated relationship matrices, as given in equation (2).

$$L_{DURM} = \begin{bmatrix} 0 & L_{12} & ...... & L_{1N} \\ L_{21} & 0 & ...... & L_{2N} \\ : & : & & : \\ & & ...... & \\ : & : & & : \\ L_{N1} & L_{N2} & ..... & 0 \end{bmatrix} \quad (2)$$

B. An Example

The URM can be used to explain a lot of many real-world MANET scenarios. For example, considering a party, we take two different groups Family relationship and friends' relationship. That means two intra type relationships with one inter type relationship. Figure 2 depicts the situation. In this example some of the MNs' belonging to family group may act as a member of friends' group and vice-versa. These nodes are known as duplicated nodes. D-URM can identify these nodes and assists to discover the precise group behaviors.

Each node may or may not be associated with attraction values. Based on these attraction values initial adjacency matrix is formed as like figure1 and this can be derived to URM. An equation (3) represents the URM for the example shown in figure 2

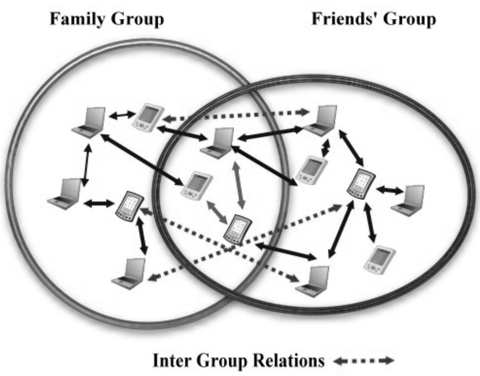

Figure 2. Example scenario of MANET

$$L_{urm} = \begin{bmatrix} L_{family} & L_{mix} \\ L_{mix}^{T} & L_{friend} \end{bmatrix} \quad (3)$$

Where L_{family} is the interaction matrix of family group, $L_{friends}$ is the interaction matrix of friends group and L_{mix} is the interaction matrix between the family group and friends group. DURM for the above example is given below:

$$L_{DURM} = \begin{bmatrix} 0 & L_{DMIX} \\ L_{DMIX}^{T} & 0 \end{bmatrix} \quad (4)$$

L_{DMIX} is the interaction matrix formed by duplicated MNs between family and friends' group. The 0 sub-matrices in the diagonal indicate that no duplicated nodes between group and itself.

IV. IMPLEMENTATION

A. 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 MNs' are randomly placed inside the Group. Movements of the nodes are based on the following rules.

B. Rule-1

A node that belonging to a group moves inside and outside the corresponding group area towards a goal. (i.e., a point chosen by its attraction value in the Social relationship matrices).

Every node tries to keep a small distance d from its neighbors. The purpose of this rule is avoiding collision of nodes. We take this small distance d as 10 units. Each node updates their position based on the velocity which is given below:

$$_{New}\ P_{n\_i} = _{Old}\ P_{n\_i} + V_{n\_i} \quad (5)$$

Here ${}_{New}\, P_{n\_i}$, ${}_{Old}\, P_{n\_i}$ are new and old positions of MN *i*. V_{n_i} is the velocity which is calculated by the following equation:

$$V_{n\_i} = V_{n\_i} + {}_{Attract}\, V_{n\_i} + V_{rule\_1} \quad (6)$$

Here ${}_{Attract}V_{n\_i}$ is the velocity from i[th] node towards its attraction node. V_{rule_1} is the velocity obtained by the *rule-1*.Initially each node moves with a randomly generated different speed (a predefined range). Let P_{n_i} and P_{attact} are the i[th] MN's position and its attracted MN's position. The equation for attraction velocity ${}_{Attract}\, V_{n\_i}$ is:

$$ {}_{Attract} V_{n\_i} = (P_{attact} - P_{n\_i}) / S_i \quad (7)$$

S_i is the speed of node *i*. Each node has different speed movement level based on their nature. The equation for calculating Rule1 velocity V_{rule_1} is,

$$V_{rule\_1} = V_{rule\_1} - [P_{n\_i} - \sum_{j=0}^{n} (P_j)] \quad (8)$$

Here *n* denotes the number of MNs which have small distance *d* from node *i*. The algorithm for calculating V_{rule_1} is following:

Algorithm 1: Calculating velocity for rule1

```
1.  FOR EACH NODE
2.    IF Node != Node_i  THEN
3.        IF(Pn_i – Pn) < 10 THEN
4.            V_rule_1 = V_rule_1 – (P_n_i – P_n)
5.        ENDIF
6.     ENDIF
7.  ENDFOR
```

C. Rule-2

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 groups are as following,

$$ {}_{New}\, P_{group\_i} = {}_{current}\, P_{group\_i} + \Delta V_{group\_i} \quad (9)$$

If any group does not have 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.

Initially Groups are formed by collection of similar nodes. Group movements depend on the group velocity values. Here all the values of velocity are measured in terms of (x, y) coordinates. Group velocity ΔV_{group_i} is calculated by group attraction velocity ${}_{Attract}V_{group\_i}$.

$$\Delta V_{group\_i} = \Delta V_{group\_i} + {}_{Attract}V_{group\_i} \quad (10)$$

Group Attract Velocity is calculated from Group Attraction Matrix (GAM).GAM is derived by URM and DRUM which is given below,

$$GAM= L_{URM} - L_{DURM} \quad (11)$$

$$ {}_{Attract}V_{group\_i} = \sum_{i=1}^{m} [{}_{attract}V_{n\_i}] \quad (12)$$

Here *m* denotes the number of MNs moving towards the attracted group. Group attract velocity is calculated by summing attract velocity of all the nodes moving towards its attracted group, which is shown in equation (12).

D. 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.

E. Evaluation

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). We used uniform distributions to generate the Interaction Matrices and the connection threshold was set to 0.4.

We considered two scenarios characterized by different numbers of hosts and groups. The first scenario was composed of 30 nodes grouped into five groups, whereas the second was composed of 60 nodes grouped into the same number of groups. In both cases, all the hosts were initially placed randomly inside the groups and the threshold value set to 0.4. 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 3 and Figure 4 show the distributions of the degree of connectivity related to the scenarios composed of 30 and 60 nodes respectively, each with five groups.

We plotted this graphs against the degree of nodes with respect to number of nodes and number of duplicated nodes with that degree. Figures 3 and 4 composed of 30 and 60 nodes respectively, each with five groups. Nodes movements are based on their social attraction value [3] and the groups' movements are 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 corresponding to the peak of the bar values in Figures 3 and 4. The values of peak in Figure 3 roughly double with respect to Figure 4 indicating that, approximately, double the number of the nodes is now clustered in the group areas. Like this, Duplicated nodes also gets doubled when double the number of nodes.

V. CONCLUSION AND FUTURE WORKS

All mobility models which are existing based on highly simplistic random movement models. Since these models are patently unrealistic, the practical applicability of much current adhoc 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, in order to build more efficient and more reliable systems. This paper identifies and improves the community structures and behaviors for MANET mobility models with a help of Unified Relationship Matrix.

In this paper, we have presented a novel group mobility model for MANET research, founded on social network theory. We have shown, in particular, that the degree of the simulated network based on URM is strongly influenced by the grouping mechanisms. The empirical results show that our algorithms identify the correct community structure when the number of nodes and groups are increased inside the MANET terrain. In this paper we are not dealing obstacles and path redirection concept, which is under future research.

Finally, we plan to refine the model by making dynamic changes in the definition of obstacles within the simulation environment and support the GUI oriented visualizations.

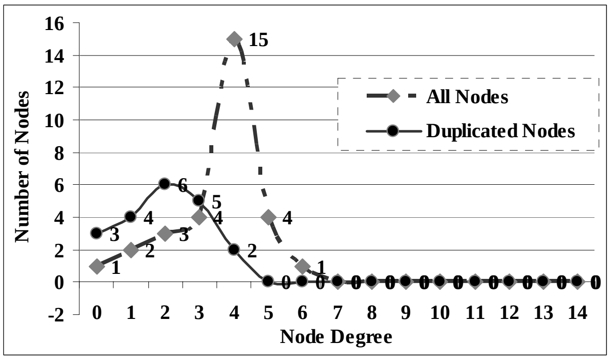

Figure 3. Distribution of Degree of Connectivity (Scenario one: 30 nodes grouped into 5 groups).

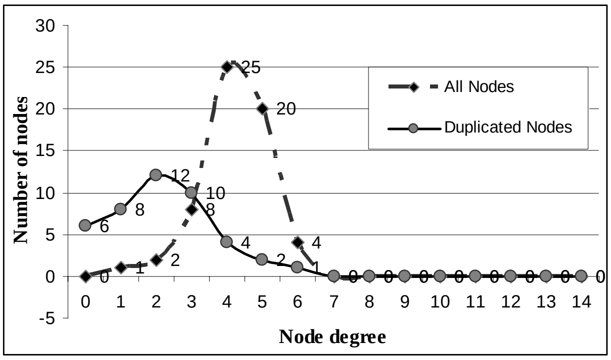

Figure 4. Distribution of Degree of Connectivity (Scenario two: 60 nodes grouped into 5 groups).

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