Social Based Mobility Model with Metrics for Evaluation of Social Behaviour in Mobility Models for MANET-DTN Networks

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Abstract. *In this paper, are described the basics of Social Based Mobility Model inspired by mobility of students alongside with Metrics for Evaluation of Social Behaviour in Mobility Models for MANET-DTN networks. These networks are mobile networks, where mobile devices are carried by humans. For simulation purposes, it is useful if mobility models designed to evaluate and tests performance of routing protocols are using mobility patterns and behaviour of humans. For these reasons, Students Social Based Mobility Model (SSBMM) was proposed as simulation tool with social mobility of nodes. To prove that SSBMM is really using social behaviour of nodes, Metrics for Evaluation of Social Behaviour in Mobility Models was designed. These metrics were adapted to the mobility of nodes in order to be able to reveal if the mobility of nodes in used mobility models is social. The performed simulations prove deviation of SSBMM from random mobility models. Described metrics reveal that SSBMM has strong social ties among nodes in comparison with random mobility models.*

Keywords

Evaluation method, MANET - DTN, mobility model, social behaviour, students.

1. Introduction

A Mobile Ad Hoc NETwork (MANET) and Delay Tolerant Networks (DTN) are in general a group of wireless mobile devices that communicate without any fixed infrastructure. These wireless mobile devices could be different electronic devices such as cell phones, PDA or laptops. But they have one significant common attribute and that is their mobility. Researchers and scientist are still always investigating MANET-DTN networks and they are trying to create effective and well-functioning routing protocols in term of message delivery ratio, network throughput and much more. The main problem is that they deal with the mobility of wireless mobile devices, also knows as nodes. Authors in [1] claim that node mobility has a significant impact on routing protocol performance. In order to evaluate the performance of proposed routing protocols, researchers and scientists need to use proper simulation tools. One of these tools is mobility model. From reason that wireless mobile devices are carried by humans in real life, it is useful if mobility models designed to evaluate and tests performance of routing protocols are using mobility patterns and behaviour of humans. But many researchers use random mobility models as simulation tools to verify the correctness and functionality of the protocols. Therefore, we decided to create social based mobility model inspired by the mobility of students in university campus. Humans are social individuals and they move and organise themselves in social groups. For that reason, it is useful if the movement of nodes in the mobility models follows such behaviour of humans. Most of the current social-based mobility models give nodes freedom in terms of movement because they move as they want according to social feeling and attractivity to other nodes or places. The main idea of adapting mobility of students into mobility models is that people have their duties and responsibilities such as going to work or school. This part of life is mandatory and not a free choice. Student Social Mobility Model (SSBMM) follows the routine of student's daily life and also takes into account the mandatory part of human life. Social mobility models are popular simulation tools today. However, many researchers are still used random mobility model, as was mentioned above. In order to show differences between random models and social models and also in order to reveal the level of social behaviour among nodes in social mobility models, we decided to adapt commonly known metrics into mobility of nodes in mobility models. These metrics are then able to reveal the level of social ties among nodes in used mobility of nodes.

The article is organised as follows. In Sec. 2. is described Students Social Based Mobility Model. Section 3. describes Metrics for Evaluation of Social Behaviour in Mobility Models. Then Sec. 4. describes the simulation of proposed SSBMM model and main results that are analysed and compared with random mobility models such as Random Walk and Matis by described evaluation metrics. At the end, we conclude this paper in Sec. 5.

2. Description of Social Based Mobility Model SSBMM

2.1. Overview

The main idea of this research was a creation of social based mobility model of nodes - SSBMM, that capture usual day or week of the students. Generally, creators of social mobility models give nodes freedom in terms of movement because they move as they want according to social feeling, attractivity to other nodes or places. This idea was extended by restrict node's freedom. In real life, every person has responsibilities and duties. For example, adults need to go to the work or students to the school. A time when people are at work or students are at school is mandatory for them. In our research we will focusing on student's routines during the week. They are not able to choose when they want to go to the school or when they go home from school. These times are defined for them by the system, for example, mandatory time for students is defined by the schedule. Every student is supposed to follow a schedule defined by his school. A mandatory time is one part of the day. Another part is a time when students travel to the school at morning or evening. This part of our life was also added into SSBMM in order to simulate public transport. After all that duties, they have a free time. In this part of the day, they are able to behave as they want according to social feeling, attractivity to other nodes or places. For thus reasons, the day was divided into three parts, travelling, school and free time. Furthermore, days was divided into 5 business days and 2 weekend days of the usual week. Based on those assumptions, we are able to simulate customary movement pattern of people, that tends to repeat by the time.

Another division was performed on nodes (students). Because of their mandatory part, which is school, is defined by schedule, they also need to be divided into study groups. It is more efficient if the schedule is defined for study groups rather than for each student separately. Furthermore, students are divided into two groups based on their origin, which means that some of them live in the college dormitory. Some of them are inhabitants of the particular city where the school is located, so they live in city settlement area. This two areas (settlement, dormitory) will be a part of the simulation area of the model in different locations. These areas are important because students will travel to the school and back from the area of their origin location every business day. This movement is simulated by travel traces. All mentioned areas and travel traces with their locations in the simulation area are displayed in Fig. 1.

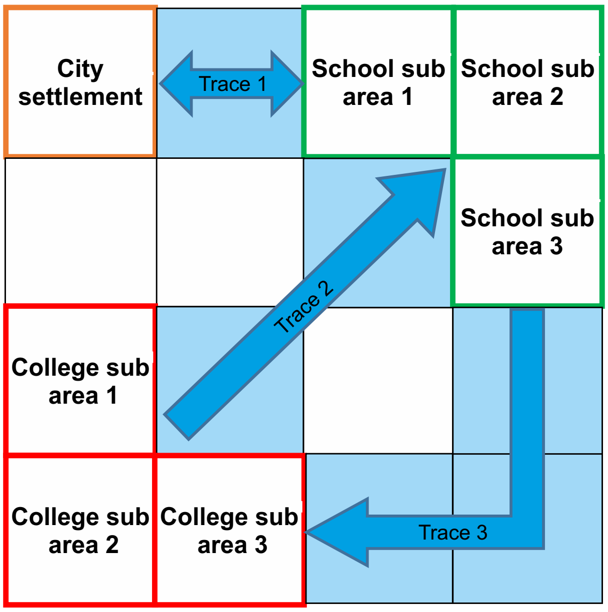

Fig. 1: Simulation area of SSBMM.

At the end, it is possible to see, that school and dormitory are divided into three sub-areas. These sub-areas can be interpreted as the library, laboratory, and lecture hall and so on in the case of school. Student's position in these sub-areas will be affected by schedule. In the case of the dormitory, these sub-areas can be interpreted as the gym, rooms or pub. These sub-areas will be used to simulate attractivity of nodes to the other nodes and sub-areas.

2.2. Behaviour of Nodes in Different Areas

In this Section and in the following subsections, behaviour and movement of students in all areas of SSBMM will be described. These areas are separated from each other and behaviour of the nodes in these areas are different.

Behaviour of Nodes in City Settlement

This is the area where students that are inhabitants of the city where the school is located live. In this area, students spend most of their free time. From the observation, we assumed, that they move along their apartment, which is basically the small range of movement. At the initial phase, the positions of students with city settlement origin are randomly generated inside settlement area. Than new goal in new time slot is generated as follows:

$$\begin{aligned} x_{t+1} &= x_t + \mathrm{rand}[x_{\min}, x_{\max}], \\ y_{t+1} &= y_t + \mathrm{rand}[y_{\min}, y_{\max}]. \end{aligned} \tag{1}$$

In the Eq. (1), variables x_t, y_t represent coordinates in the current time slot and x_{t+1}, y_{t+1} are coordinates of the node in the time slot $(t+1)$. These coordinates are computed from current positions plus small ranges $[x_{\min}, x_{\max}]$ and $[y_{\min}, y_{\max}]$. This is simulation of the small range of movement in the apartment.

Behaviour of Nodes in School

The positions of nodes or students in particular school sub-area at particular time slot are generated according to the schedule (structure will be explained later). Basic idea is, that every student knows his schedule and study group affiliation. So, if student A has chemistry in sub-area 1 at 7:00 a.m., the node that represents this student just randomly generate his position inside of this sub-simulation area. Assume that student B has physics in the sub-area 2 at the same time. Then, if student A has physics in the sub-area 2 at 8:00 a.m. and student B has chemistry in the sub-area 1 at the same time according to the schedule, they just change their sub-areas by randomly generating positions inside sub-areas that correspond to the cells of the simulation grid. The schedule is defined for every study group. That implies that for every study group are defined times when students of particular study group should be in particular school's sub-area. The schedule is defined for every business day differently. The weekend days are all free time, so there is no schedule defined for these days and nodes are moving according they social feeling or by random movement.

Behaviour of Nodes When They Travel

In the Fig. 1 blue arrows represent the traces. Some traces are two-way and others are just one-way. Travelling in this model is realised by moving nodes along traces that corresponds to the cells of simulation grid. On the node's way through trace 2, randomly generate its position in time slot t inside the first cell (light blue) that crosses this trace. On time slot $(t+1)$ its position inside the first cell are just shifted to the second cell on that trace. These positions are not randomly generated again, they are shifted by the cell size in x-direction and y-direction described by Eq. (2):

$$\begin{aligned} x_{t+1} &= x_t + s, \\ y_{t+1} &= y_t + s, \end{aligned} \tag{2}$$

where s is the size of the cell in simulation grid. From this description is clear, that node needs one time slot to pass through one cell of grid along the trace. The idea is that node knows its schedule and then the time when it needs to be in school. So before travel, it needs to calculate the departure time from its area of origin to the school and vice versa, in order to be in school or home at the time.

Behaviour of Nodes in College Dormitory

Students, which are not inhabitants of the city, spend their free time in this area of city. There they move according to their social feeling, attractivity to other nodes or to one of the dormitory sub-areas.

Relationships between nodes in this model are realised by weighted graph [2]. Nodes in this weighted graph represent students and the edges and their weights are representing the strength of relationships among nodes. This strength is represented by the value in the range [0,1], where 0 indicate no relationship between the pair of students and 1 indicate the strongest relationship. The weighted graph can be interpreted by the symmetric Social Relationships (SR) matrix. Equation (3) shows SR matrix of five students.

$$\mathbf{SR} = \begin{pmatrix} 1 & 0.55 & 0.23 & 0.45 & 0.15 \\ 0.55 & 1 & 0.92 & 0.78 & 0.87 \\ 0.23 & 0.92 & 1 & 0.30 & 0.63 \\ 0.45 & 0.78 & 0.30 & 1 & 0.95 \\ 0.15 & 0.87 & 0.63 & 0.95 & 1 \end{pmatrix} \tag{3}$$

The element $sr_{i,j}$ of SR matrix represents the strength of the relationship between individuals i and j. This matrix is symmetric because the same strength of relationship from both sides of individuals is considered.

Mobility of Nodes Based on Relationships in College Dormitory

The mobility of nodes in the college dormitory is performed based on described relationships among nodes. Positions of nodes are calculated by following mechanism:

- *First goal selection* - in the initial phase, nodes that belong to dormitory origin are equally divided into three groups in order to spread nodes equally into the dormitory sub-areas. Each group belongs to its own dormitory sub-area. The first goal in time slot t of every student from each group will be randomly generated inside of sub-area where his group belongs.

- *Subsequent goal selection* - after first goal in time slot t is generated, new goal in the time slot $(t+1)$ is selected by the mechanism presented by authors in [2]. A certain number of nodes is associated with each sub-area cell C_k. Each cell exerts a certain social attractivity for a certain node. The social attractivity of a cell is a measure of its importance in terms of the social relationships for the node taken into consideration. For the each node is calculated social attractivity of all three cells (Eq. (4)). This calculation is based on evaluation the strength of the relationships of nodes from particular cells with the node taken into consideration. So the social attractivity for the cell C_k and for the node i is defined as follows:

$$SA_{C_{k_i}} = \frac{\sum\limits_{\substack{j=1 \\ j \in C_k}}^{n} sr_{i,j}}{w}, \tag{4}$$

where w is the cardinality of cell C_k (number of nodes in C_k) and $sr_{i,j}$ is the element of SR matrix between node i and j. In other words, the social attractivity of a cell for node i is defined as the sum of the elements of SR matrix that represent the relationships between node i and the other nodes that belong to that particular cell, normalised by the total number of hosts associated with that cell. If the cell C_k is empty then $w = 0$ and $SA_{C_{k_i}} = 0$. The new goal for node i is then randomly generated inside the cell with the highest social attractivity for that node [2].

3. Metrics for Evaluation of Social Behaviour in Mobility Models

Researchers use many different mobility models with different parameters without analysis of movement. In authors' simulations with social movement is important to know, how strong relations ties among nodes are, how the nodes behaviour influence functionality of mobile network and how evaluations of mobility models and results of routing protocols interrelate between each other. Without that information, successful message transfer through the mobile network can be misrepresented.Therefore, Metrics for Evaluation of Social Behaviour in Mobility Models was created. Authors in [3] observe that clustering level in models with social behaviour is usually far greater than in models with non-social behaviour. This is due to the fact, that humans usually organise themselves into communities. Therefore, one of the metrics expresses how many communities was created by the movement of nodes in particular mobility model. To obtain such information, Louvain method for community detection [4] was used.

3.1. Louvain Method for Communities Detection

In order to use Louvain method for community detection, the proper output must be used. For example, the method was previously used on the Twitter social network to explore the problem of partitioning Online Social Networks onto different machines. This method worked with static networks. In order to evaluate the mobility of nodes, contacts among nodes through the whole simulation was calculated. Using different radio ranges it is possible to define if nodes are in their ranges and thus in contact or not. The numbers of contacts between all pairs of nodes are stored in the Meeting matrix. This matrix is symmetric and expresses, how many times the particular pair of nodes met each other during simulation. From Meetings matrix is possible to create a weighted graph. This weighted graph will be used as social networks where nodes are vertices of these graphs and edges represents a number of contacts among nodes.Than, Louvain method is possible to use for discover social communities. This method uses the parameter called Modularity quality in order to make a decision about into which social community particular node belongs. Modularity quality measures how well a given partition of a network compartmentalizes its communities. The modularity of a partition is a scalar value between -1 and 1 that measures the density of links inside communities as compared to links between communities. The modularity can be either positive or negative. Positive values indicate that there is some community structure. To look for the best divisions of a network, it is good to have positive, and preferably large, values of the modularity [4]. Therefore, when using social mobility models, values of modularity quality should be positive and also larger. Along with the number of communities, this parameter can provide further information about how strong social communities are.

3.2. Average Weighted Degree

Another parameter that could be used as metric to describe social aspect is the average weighted degree [5]. The weighted degree of a node is similar to a node degree. It's based on the number of edges that incidents with the particular node. But furthermore, it

Tab. 1: Number of communities results

Radio Range [m]	50 nodes			100 nodes			200 nodes		
	RW	Matis	SSBMM	RW	Matis	SSBMM	RW	Matis	SSBMM
20	3	4	5	6	5	12	7	6	25
50	3	3	7	4	5	13	5	6	14
100	3	3	7	4	3	6	5	4	8
300	2	2	2	3	3	2	4	4	2

also considers the weights of these edges. Basically, it is the sum of the weight of the edges that incidents with the particular node. Meetings matrix is basically a weighted graph that expresses a number of contacts among nodes. Classic node degree, therefore, does not express the entire problem. On the other side, while node degree just expresses how many nodes particular node met during simulation, weighted node degree also expresses how often. From average weighted degree parameter can be expected, that bigger values should represent more frequent contacts among nodes.

4. Simulations and Results

To prove, that SSBMM really uses social behaviour of nodes, simulations using Metrics for Evaluation of Social Behaviour in Mobility Models were performed. Random Walk (RW) [6] and Model Matis [7], which are random mobility models, were used in comparison to the SSBMM. This comparison provides differences between social and random models and also prove the correctness of described metrics. All results of simulations are performed in simulation area 1500 × 1500 meters with different radio ranges (20, 50, 100, and 300). Simulation duration was set up on 28 days, divided by 48 slots per day. Parameters were set up based on settings in SSBMM model in order to reveal mobility patterns of humans in comparison to the random movement of nodes.

4.1. Number of Communities Results

The results of the number of communities are shown in Tab. 1. In radio range of 20 meters radio range, the SSBMM outperform random mobility models in term of the number of communities when 100 and 200 nodes were in simulations. It also performs better in the simulation with 50 nodes, but only by one community. This is related to the fact, that network created by 50 nodes with the radio range of 20 meters on 1500 × 1500 area-wide is sparse. It means that nodes weren't in contact so often than in simulations with the higher number of nodes and bigger radio ranges.

In the case, when 50 meters radio range was used, SSBMM also outperforms random models, but this time in all numbers of nodes. The nodes in SSBMM met each other in their study groups in school and they also met each other in their free time according social feelings. That causes more communities. In random models, movement of nodes is random, but there are still some communities. In the pure random model, the node should cover all cells of simulation grid equally.It means that in the pure random model should exist only one community. But in RW or Matis models, the random movement is not pure, so some contacts are a little bit more often than others. That causes more than one community.

SSBMM also perform better than random models in radio range of 100 meters. But in radio range of 300 meters, random models have more communities while SSBMM has only 2 communities. In such big radio range in 1500 × 1500 area-wide, the network is very dense. Louvain method, therefore, considers many contacts among nodes, that are maybe not even in the social relationship. But investigations of nodes in communities reveals, that 2 communities in case of SSBMM are actually nodes divided into 2 origin groups (dormitory, settlement). Louvain method correctly identifies the division of nodes into origins by SSBMM model based on the number of contacts in Meeting matrix.

4.2. Modularity Quality Results

The results of Modularity quality (Fig. 2) provides a better understanding of how strong discovered communities are. It is possible to see, that SSBMM totally outperforms random models. The values of Modularity quality in case of SSBMM were always higher. Authors in [8] declared, that nonzero values represent deviations from randomness, and in practice, it is found that values above 0.3 are good indicators of significant community structure in a network. In our results, SSBMM keeps values of Modularity quality under 0.4 which proves SSBMM deviation from randomness. Results show, that if random mobility models were used, small values of modularity quality were obtained. These values are nonzero which means deviation from randomness, but these values are also very close to zero, which means that this deviation is not significant.

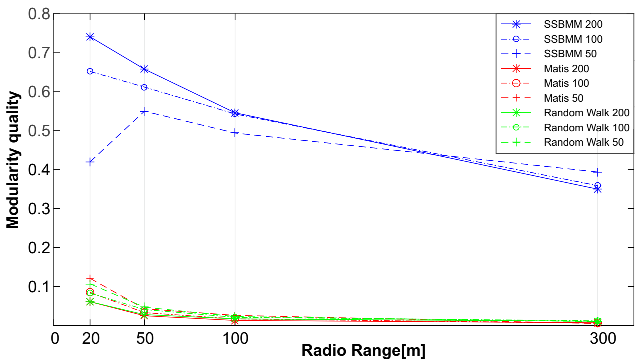

Fig. 2: Modularity quality results.

4.3. Average Weighted Degree Results

In Fig. 3 are depicted results of average weighted degree for 200 nodes. It is possible to see, that SSBMM again performs better than random models in all radio ranges. Since SSBMM uses movement pattern of students, that tends repeat after week, the frequency of contacts among some nodes in SSBMM was higher than in random models. This pushed average weighted degree values higher. The result of this is, that values of average weighted degree are twice as higher than values of random models. The similar behaviour was observed in simulations with 100 and 200 nodes.

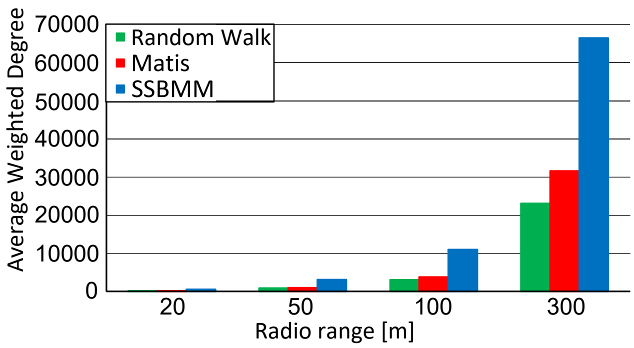

Fig. 3: Average Weighted Degree of 200 nodes.

5. Conclusion

In this paper, Student Social Based Mobility Model along with Metrics for Evaluation of Social Behaviour in Mobility Models for MANET-DTN networks, were described. Simulations show that SSBMM exerts social behaviour of nodes. Also, using Metrics for Evaluation of Social Behaviour in simulations proves, that this method is possible to show differences between social based and random based mobility models.

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