Characterization & Evaluation of Mobility Metrics for Levy walk using MobiSim

1Hemal Shah, 2Yogeshwar Kosta, 3Darshana Patel
1, 3Ganpat University, 2Marwadi Education Foundation, Gujarat, India.
1Hemal.shah@ganpatuniversity.ac.in, 2ypkosta@gmail.com, 3darshanapatel27@gmail.com

Abstract—In mobile adhoc networks, mobile node and its movement patterns has significant impact on network protocols & its performance. Therefore, it is required to analyze and understand node mobility specific to scenario such as disaster management, village area network, etc. and or in general. Mobility models are based on setting out different parameters related to node movements. These parameters are the starting location of mobile nodes, their movement direction, velocity range, speed changes over time. Various matrices can be evaluated to the mobility models. This synthetic data can be given as input to suitable network routing protocols for performance analysis. In this paper authors has evaluated performances matrices of various mobility models using MobiSim simulator. Further, levy walk mobility model’s metrics are compared with random families, group & geographic models and social model. Our observation results indicate that the levy walk features are important in characterizing the performance of mobile ad hoc network.

General Terms- Mobility metric, Mobility Model, routing protocol, delay tolerant network (DTN)

Keywords- Levy walk, temporal dependency, spatial dependency

I. INTRODUCTION

A mobile ad hoc network (MANET) is an autonomous, self-configuring network of mobile nodes that can be formed without the need of any pre-established infrastructure or centralized administration. MANETs are extremely flexible and each node is free to move independently, in any random direction. Each node in MANET maintains continuously the information required to properly route traffic. Due to the ease of deployment, many practical applications have been developed for these networks. Mobile classrooms, battlefield communications and disaster relief are some applications that use MANETs [1]. One of the inherent characteristics of these networks is the movement patterns of nodes. This characteristic has significant impact on the performance of protocols in MANETs. This enables to emulate movement patterns and conceptualize the mobility models. These models determine how nodes change their speed, direction and other parameters with respect to time. A wide range of mobility models have been proposed in recent years. Each of them describes the movement pattern of mobile nodes in a specific scenario and captures some of the mobility characteristics of the nodes. Therefore, it is essential to do analyze the various metrics of mobility models, ink behavioral characteristics under given simulation setup and comment on fitment of these characteristics in designing the routing protocol in MANET. Authors contribution pin pointed as 1 Simulation of various metrics for range of models 2 Characterization, Evaluation and Comparison of Levy walk mobility model against temporal dependency, relative speed, behavior and average distance.

The rest of paper is organized as follows. Section II categorizes mobility model and briefly describes each mobility class and levy walk model Section III discusses mobility metrics. Section IV presents simulation setup, results and observation, Section V is devoted performance analysis & characterization. Finally, conclusion and future works are presented in section VI need to create these components, incorporating the applicable criteria that follow.

II. MOBILITY MODELS

Based on mobility characteristics / patterns, mobility models have been classified [2] into Entity based models, Random variants model, Group models, Geographic models and social models as shown in figure-1.

- **Random Models**: Node moves randomly and independent of their neighbor. Random walk [3], Random way point [3], Random direction [3] and levy walk are examples of Random families.


- **Group Models**: The movement of a node is influenced by the nodes around it. Reference Point Group Mobility model [6], Column [3], Pursue [3] and Nomadic Community [3] are examples of Group Models.

- **Geographic Models**: The area in which the node is allowed to move is restricted. Manhattan [1], Freeway [1] and Obstacle [7] are examples of Geographic models.

- **Social Models**: A social relationship between nodes is realized. Orbit [9], CMM [10] and Slaw [8] are examples of social models.
Levy Walk Model

The term Levy walks (LW) was first coined by Schlesinger et al to explain a typical particle diffusion not governed by Brownian motion (BM). BM characterizes the diffusion of tiny particles with a mean free path (or flight) and a mean pause time between flights.[15]

A *flight* is defined to be a longest straight line path from one place to another that a node makes without a directional change or pause.

LW can reproduce similar power-law inter-contact time (ICT) distributions of human walks observed in [16]. Inter-contact Time (ICT) is an important factor of DTN (delay tolerant networks) routing performance [17] and LW model provides facts on power-law trend.

The DTN network simulation using the model shows unique routing performance characteristics unobserved in RWP and BM: while RWP shows overly optimistic routing performance because its high occurrences of long flights intensify the chance of meeting destinations, and BM shows overly pessimistic routing performance because its high occurrences of short flights diminish the chance of meeting destinations, LW shows performance somewhere in-between the performance seen from these two models [18].

The following defines a Levy distribution [18] with a scale factor $c$ and exponent $\alpha$ in terms of a fourier transformation,

$$f_X(x) = \frac{1}{2\pi} \int_{-\infty}^{+\infty} e^{-i\xi x - |\xi|^\alpha} \, d\xi$$

For $\alpha = 1$, it reduces to a Cauchy distribution and for $\alpha = 2$, a Gaussian[5] with $\sigma = \sqrt{2c}$. Asymptotically, for $\alpha < 2$, $f_X(x)$ can be approximately by $1/|x|^{1/\alpha}$. Here $c$, $\alpha$ and $\beta$ to be simulation parameters.[3]

Important steps for implementation

- Consider a 2-dimensional random walk defined by a sequence of *steps* that a walker (node) makes.
- A step[4] is represented by a tuple $S = (l; 0; \Delta t_f; \Delta t_p)$. $0$ is the direction of that flight, $l > 0$ is the length of the flight, $\Delta t_f > 0$ is the time duration of the flight or *flight time* (*flight duration*), $\Delta t_p >= 0$ is the time duration of the pause or *pause time*.
- At the beginning of each step, a node chooses a direction randomly from a uniform distribution of angle within $[0, 360]$, a finite flight time randomly based on some distribution, and its flight length and pause time from probability distributions $p(l)$ and $\psi (\Delta t_p)$, respectively.
- Choose alpha parameter (flight length factor) in between 0.1 and 2. Choose beta parameter (pause time factor) must be in [-1, 1].
- During a pause, a walker node does not move from the place where the current flight ends. The time elapsed during a step is called a step time $\Delta t_s$, which is the summation of its flight time and pause time. The walker starts its first step at the origin at time $t = 0$.
- After some time $t$, the distance $\text{dis}(t)$ of the random walker from the origin follows a Gaussian distribution with its width proportional to $\sqrt{t}$ if the variance of flight lengths and the mean of step times are both finite.
- The position $x$ of a random walker after $N$ steps can be described as a total sum of each flight.
- Using the $\Delta t_f$ and $l$ calculate speed of flight. $\Delta t_p$ specifies pause time at the end of a flight and it will be calculated using a configurable distribution $\psi (\Delta t_p)$.
III. MOBILITY METRICS

In order to analyze synthetic mobility traces, for each model needs some common minimum input parameters: No. of nodes, Max. Speed, Min Speed, border height, border width, height, width, walking time etc. Also, mobility metrics have been introduced. Metrics [2] which capture mobility characteristics of each node independently and in group.

- **Degree of temporal dependency**: This metric measures the similarity of the velocities of a mobile node during the times that are not too far apart [1]. This metric reflects the smoothness of mobile nodes movement.

- **Repetitive behavior**: In real world scenarios the movement behavior of mobile nodes is repeated frequently. In [11], a method has been proposed to evaluate repetitive behavior. This method measures the average ratio of time during which a node is inside the transmission area of its initial position.

- **Relative speed**: The relative speed measures the difference between velocities of two nodes that are not too far apart [12]. This metric differentiates the movement patterns based on relative motion.

- **Degree of spatial dependency**: The degree of spatial dependency measures the similarity of velocities of two nodes that are not too far apart [1]. This metric represents the correlation degree of node velocities with its neighbors.

IV. SIMULATION SETUP

We used our previously developed mobility simulator called MobiSim [14] to generate mobility traces. MobiSim is an open source java based simulator which can generate mobility traces for various mobility models.

We selected a Random walk (RW), Random waypoint(RWP), Random Direction(RD), Random Waypoint(RWP-WR)(without reflection walls), Probabilistic random, Levy walk, Manhattan, Markov, Biased Markov, Pursue, RPGM, Row, String, Multi there. so that they do not adequately capture temporal dependency as well as spatial dependency.

Due to variety of mobility models, we just selected a few mobility models as representative of their mobility classes. Simulation time is taken 50000 sec for all scenarios. For Random Walk and Random variant models minimum speed is taken 15 m/s and maximum speed is taken 20 m/s.

Height and width of simulation area is kept 300 x 300. For Levy walk it is 800 x 800. Border height and border width is kept 10, 10. For Pursue, RPGM, Row, String and Multi model, Levy walk model is selected as a leader model.

Details of the parameters for simulation setup are given in Appendix shown in Table-1, Table-2 & Table-3

V. Performance Analysis

As shown in Appendix - Table-1 and figure-2, RW, RWP, RWP-WR, RD and RPGM have the lowest average degree of temporal dependency. Because in these models the movement pattern of each node is independent of its previous movement. Manhattan and Gauss-sudden stops due to pauses in the intersection of streets lead to reduction of temporal dependency. In Gauss-Markov, frequent changes of velocity and direction of mobile nodes at each time reduce the temporal dependency [14]. Therefore, Manhattan has highest and Gauss-Markov have medium values. Levy walk has the second highest value for temporal dependency. In these models a velocity is selected according to the path length of movement at each step. In Levy walk, the path length of movement is selected randomly from levy distribution [4]. This causes most of the selected path lengths fall into a limited range. Some limited range of path lengths Levy walk leads to similarity between velocities of mobile nodes during the time. Therefore Levy walk has second highest value of temporal dependency. For probabilistic random, pursue, RPGM, Row, String and Multi model has zero impact of temporal dependence. Since, most them are group mobility model.
dependency of a node with its neighbors in the opposite direction. As a result, Manhattan has low values of spatial dependency like Random models. In RPGM the leaders of each group determine the movement pattern of group members. Therefore, RPGM should have highest degree of spatial dependency but in our reading it comes to zero. Investigations are under process for findings.

The RW, RWP, RD and (Gauss) Markov models, have the higher value for relative speed –figure-3, due to lack of similarity between velocities and directions of neighbor nodes. RPGM and Manhattan have medium values. In RPGM, nodes move together so the velocity difference between neighboring nodes is low. In Manhattan, mobile nodes must consider the safety distance so the neighbor nodes have similar velocities and directions. Since, in Slaw and Levy walk the selected path lengths fall into a limited range, the velocity difference between neighboring nodes is too low. As seen in Table I, Slaw and Levy walk have the lower value of relative speed.

Vast variation observed in location distribution for Manhattan mobility model. In Manhattan, a node's movement is influenced by nodes behind it in the same lane. As shown in figure-5, values are medium for pursue, RPGM, Row and string model.

As random models are not so realistic, and all nodes work independently, so, less relative behavior than a group mobility models & levy walk(human mobility behavior) as shown in figure-4

As shown in figure-6, average distance between nodes remains almost unchanged in random families' models. It is lower in group mobility models and lowest in Manhattan and Row. Its value observed highest in Levy model due vast variability in movements of nodes.
CONCLUSION

Although in Levy walk each node selects mobility parameters such as pause time and path length randomly, this model is not similar to other random models such as RW, RWP and RD. In Levy walk model mobility patterns lead to more realistic network. Levy walk features are important for representing the performance of mobile network routing strategy. Thus using this model, we evaluate the performance of routing protocols when mobile network carried by humans. We do not claim that human walks are Levy walks; although our human mobility traces contain striking statistical resemblances to Levy walks, there are still some significant deviations between pure Levy walks and our human walks.

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REFERENCES


Table 4: Simulation readings


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**Appendix**

**Table-1 Common input mobisim parameter to all models**

<table>
<thead>
<tr>
<th>Models</th>
<th>no.of nodes</th>
<th>pause time</th>
<th>min speed</th>
<th>max speed</th>
<th>height</th>
<th>width</th>
<th>border h</th>
<th>b width</th>
<th>walking time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random walk</td>
<td>45</td>
<td>6</td>
<td>15</td>
<td>20</td>
<td>300</td>
<td>300</td>
<td>10</td>
<td>10</td>
<td>-</td>
</tr>
<tr>
<td>Random waypoint</td>
<td>45</td>
<td>6</td>
<td>15</td>
<td>20</td>
<td>300</td>
<td>300</td>
<td>10</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Random Direction</td>
<td>45</td>
<td>6</td>
<td>15</td>
<td>20</td>
<td>300</td>
<td>300</td>
<td>10</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Random Waypoint WR (without reflection walls)</td>
<td>45</td>
<td>6</td>
<td>15</td>
<td>20</td>
<td>300</td>
<td>300</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Probabilistic random</td>
<td>45</td>
<td>6</td>
<td>15</td>
<td>20</td>
<td>300</td>
<td>300</td>
<td>10</td>
<td>10</td>
<td>-</td>
</tr>
<tr>
<td>Levy walk</td>
<td>45</td>
<td>-</td>
<td>15</td>
<td>20</td>
<td>800</td>
<td>800</td>
<td>10</td>
<td>10</td>
<td>-</td>
</tr>
<tr>
<td>Manhattan</td>
<td>45</td>
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<td>15</td>
<td>20</td>
<td>300</td>
<td>300</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Markov</td>
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<td>-</td>
<td>15</td>
<td>20</td>
<td>300</td>
<td>300</td>
<td>10</td>
<td>10</td>
<td>-</td>
</tr>
<tr>
<td>Biased Markov</td>
<td>45</td>
<td>-</td>
<td>15</td>
<td>20</td>
<td>300</td>
<td>300</td>
<td>10</td>
<td>10</td>
<td>-</td>
</tr>
<tr>
<td>Pursue</td>
<td>45</td>
<td>6</td>
<td>-</td>
<td>-</td>
<td>300</td>
<td>300</td>
<td>10</td>
<td>10</td>
<td>-</td>
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<tr>
<td>RPGM</td>
<td>45</td>
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<td>300</td>
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<td>-</td>
<td>300</td>
<td>300</td>
<td>10</td>
<td>10</td>
<td>-</td>
</tr>
<tr>
<td>String</td>
<td>45</td>
<td>6</td>
<td>-</td>
<td>-</td>
<td>300</td>
<td>300</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**Table-2 Basic parameter to all Group models as well as Complex(Internal)model for Mobisim Simulation**

<table>
<thead>
<tr>
<th>Models</th>
<th>Leaders model</th>
<th>Leaders model offset</th>
<th>adr</th>
<th>max initial distance</th>
<th>sdr</th>
<th>groupsize</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pursue</td>
<td>Levy Walk</td>
<td>8.8,8,8</td>
<td>0.16</td>
<td>80</td>
<td>0.24</td>
<td>8,8</td>
</tr>
<tr>
<td>RPGM</td>
<td>Levy Walk</td>
<td>11.11,11.11</td>
<td>0.26</td>
<td>50</td>
<td>0.4</td>
<td>11.11,11.11</td>
</tr>
<tr>
<td>Row</td>
<td>Levy Walk</td>
<td>8.8,8,8</td>
<td>0.26</td>
<td>25</td>
<td>0.4</td>
<td>8.8,8,8</td>
</tr>
<tr>
<td>String</td>
<td>Levy Walk</td>
<td>8.8,8,8</td>
<td>0.25</td>
<td>24</td>
<td>0.25</td>
<td>8.8,8</td>
</tr>
</tbody>
</table>

**Table-3 Basic parameter to Manhattan model**

<table>
<thead>
<tr>
<th>Model</th>
<th>max acceleration</th>
<th>Positive ace ratio</th>
<th>Safe distance ratio</th>
<th>hlines</th>
<th>vlines</th>
<th>dir12lanespace</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manhattan model</td>
<td>16</td>
<td>5.5</td>
<td>4</td>
<td>120,280,296</td>
<td>120,280,296</td>
<td>16</td>
</tr>
</tbody>
</table>