Flaws Validation of Maze Mobility Model using Spatial-temporal Synthetic Mobility Metrics

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Abstract: Mobility modeling represents a critical task in mobile wireless networks to improve the overall throughput. This paper evaluates relevant spatial-temporal stochastic properties of the most frequently used synthetic mobility models compared to a new efficient mobility model named Maze Mobility Model (Maze MM). It imitates a real-life movement according to diverse mobility features, as spatial and temporal dependencies with also geographic restrictions. To demonstrate the efficiency of this new model, various metrics were validated such as; the speed decay problem, the density wave phenomenon, the spatial node distribution, the average neighbor percentage, and mobile neighbors range. Each mobility pattern may bear from diverse mobility flaws, as shown by network simulations. So, numerous metrics are employed to describe mobility features. The current research aims to deeply understand mobility features of Maze MM with the aim to deduce a definite judgment of each mobility metric, given that further this fact affects the whole network performances. The validation results are discussed to remark the effectiveness and robustness of Maze MM according to the validated mobility metrics.

1 INTRODUCTION

Mobile devices become ubiquitous in all our daily life activities. Among the principal challenging issues of this recent revolution is how to provide protocols and applications adequate to a highly dynamic mobile network. Researches objectives lean to deeply innovate in all fields of expertise related to wireless communications, that have achieved an unpredictable growth of traffic applications. They permanently suggest and implement new mobility designs responding to diverse mobility requirements for a high quality of services. It must take into consideration speed, distance and time to reflect a real-life situation. The precision of these mobility decisions further conduct to maximum save energy and moderate consumption of mobile devices. Under assorted limitations, the mobility Models (MMs) predict nodes movement from one position to another within a given period. They expect devices motions by changing speed and direction with time. Mobility models are implemented in the ground, airborne, space, and undersea where nodes are mobile as for as mobile opportunistic network, Mobile Ad Hoc Network (MANET), and vehicular ad hoc network. Mobility modeling field is principally splitted into several major tracks;

- Evaluating performances of mobility models under diverse scenarios,
- studying mobility traces of real human world deployments,
- suggesting new mobility models
- Or, validating the robustness of synthetic mobility models.

Each stumble of the adopted motion strategy occurs one or several serious mobility flaws, as an inadmissible fluctuation of neighbors' number, an irregular distribution of mobile nodes inside the net-

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work field, or the unsteadiness average speed within the simulation time. These problems have firstly been validated for only Random Waypoint Mobility Model (RW MM). And then, they are verified for many other mobility models, like: Manhattan Grid MM (MG MM), Reference Point Group MM, Nomadic MM, SLAW and SMOOTH example:

- The speed decay problem, depicted in (Pramanik et al., 2016).
- The spatial node distribution, described in (Wang et al., 2016).
- The density wave phenomenon, introduced in (Noguchi and Kobayashi, 2017).
- The average neighbor percentage, proposed in (Almomani et al., 2015).
- The mobile neighbors range, suggested by Ibadah in (Ibadah et al., 2018).

Those mobility metrics are mandatory for the network performance analysis. Network analysis is primary proceeded to evaluate the total network simulation basing on suitable performance metrics to only present a general view. However, mobility metrics make possible to judge a specific simulation of a mobility model without needing to implement it on a real mobile wireless network. A correct mobility validation can strictly detect the real reasons of network impairment without analyzing performances of the mobile network. For these purposes, in this paper we validate the previously suggested mobility metrics for Maze MM comparing with some well-know synthetic mobility models. Then, we verify the novel mobility metric called the 'node neighbors range' for this new mobility model. That profoundly exposes the no equilibrium of mobility models during the experiment time.

The rest of this paper is organized as follows. In Section 2, we validate Maze MM according to some mobility metrics. In Section 3, we present the Maze MM features. And finally, we discuss a brief conclusion.

2 MOBILITY MODELS VALIDATION

This section will mainly focus on mobility metrics; as spatial node distribution, speed decay problem, density wave phenomenon, Average node neighbor percentage and mobile neighbors range in order to describe more exact features of our current new model. We compare Maze MM with RW MM and MG MM.

The previously mentioned metrics have already been carried out for only RW MM. And newly, they have been analyzed for other mobility models by (Ibadah et al., 2018). In this section, we inquire to validate the movement steadiness for Maze MM compared to other synthetic mobility models. Using those mobility metrics, we can put up and understand an accurate judgment of each mobility flaw. The adopted strategy of mobile nodes chiefly further affects the whole network performances. These metrics will offer precise explanations of models' dissimilarities from each other. The validation parameters are presented in Table 1.

Table 1: Validation settings.

Parameters	Values
Number of nodes	50
Speed	5 m/s
Pause time (s)	0
Mobility models	Maze MM RW MM and MG MM
Mobility metrics	Speed decay problem Spatial node distribution Density wave phenomenon Average neighbor percentage mobile neighbors range
Area	$1030m \times 1030m$
Simulation time	1000 sec
Iterations	20 times

The aforementioned experimental settings are correlated to rectify all possible scenarios with the aim to deduce a deep and precise knowledge of each mobility unbalance. The simulation outcomes are displayed and examined by Figures 1 to 6 in the next sub-sections.

Models themselves do not offer precise explanations of how MMs are different from each other. Hence, this part will be a hard task which will mainly focus on mobility metrics in order to describe more exact features of our current new model. Using Matlab, we make the average of 20 MMs for each pattern to have more rigorous results. Random Waypoint MM as a reference of mobility modeling, suffers from several problems. In this section, we must make sure to learn more about Maze MM and compare it with RW MM and MG MM.

2.1 Speed Decay Problem

Firstly, we start with 'speed decay problem'. Yoon and al.(yoo,) showed that average node speed consistently decreases over time. And therefore, it should not be used for simulation. It decays over time before reaching a steady-state, which contradicts the assumption of having the same average speed during a simulation time, as proved with the red line chart of Fig. 1. We remark that RW MM obviously suffers from speed decay problem. Speed is not steady during simulation time, due to selecting randomly speed and waypoint independently.

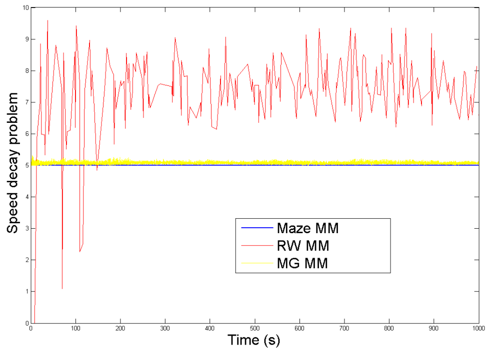


Figure 1: The Speed Decay Problem.

From the same Fig. 1, we observe that MG MM is less steady comparing with Maze MM which have stable speed during all simulation time. We conclude that Maze MM does not suffer from this problem. Due to every mobility decision is taken according to the distance traveled, speed adopted and motion time. If these three parameters are dependent by respecting each other, we almost avoid speed decay problem in a mobility pattern; as demonstrated for Maze MM in Fig. 1.

2.2 Density Wave Phenomenon

Secondly, another mobility metric is validated which is called 'density wave phenomenon'. It represents the average number of neighbors for a particular node. Royer, Melliar-Smith and Moser(Royer et al., 2001) were observed this pathology of RW MM which periodically fluctuates along with time as exactly proved in Fig. 2.

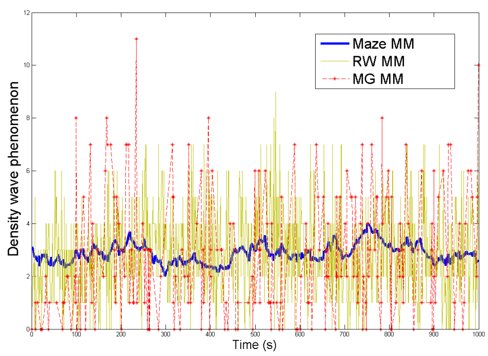


Figure 2: The Density wave phenomenon.

From Fig. 2, MG MM suffers too from this trouble as shown with green line chart. We observe that, RW MM and MG MM fluctuate in a big range from 0 to 11 and from 0 to 9 respectively, and frequently without any neighbor. But, this range is more precise (2-4) with Maze MM which all the time has at least two neighbors. This metric is too important, mostly, if we applied for a MANET. If a mobile node send traffics without any intermediate node, that will mainly influence the Packet Delivery Ratio (PDR) in such network.

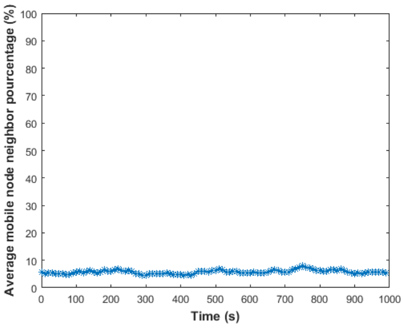
From all these results, we conclude that RW MM and MG MM have apparently this problem. However, Maze MM is more stable with slight fluctuation in a reasonable range with some neighbors all the time.

2.3 Average Neighbor Percentage

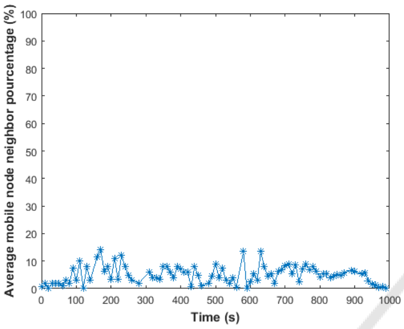
Thirdly, we validate another mobility metric which called 'average neighbor percentage'. In general, high variability in average mobile node neighbor percentage will produce high variability in performance results (Almomani et al., 2015). In order to highly be certain of the outcomes displayed in Figure 2, this metric will give more rigorous view of neighboring nodes changes in Figure 3.

- According to Figure 3b, the RW MM knows the worst results. It oscillates in a range of 0–16% with several existing moments of any neighbor. That means any intermediate node will be detected to forward packets which are sent by a definite mobile node. This flaw further raises the lost packets which will reduces the packet delivery ratio of this validated model.
- From Figure 3c, the MG MM presents small fluctuations in the range of 4–9%, in addition to more than two neighbors are always present among the total experimented nodes. This fact permits to this pattern to outperform than the RW MM.
- Nevertheless, from Figure 3a, Maze MM have a range of 3–6%. It produces the best obtained results, with a continuous presence of neighbors during the whole validation time. This particularity lets them to highly outperform than other models (Ibadah et al., 2019). This mobility model is *more steady* than the other models.

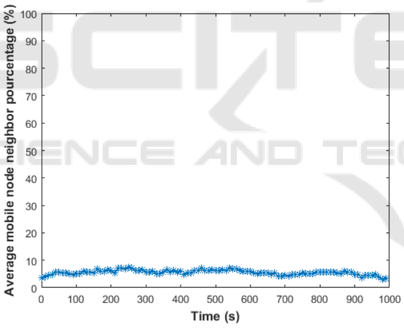
This property accords a global sight of the density wave phenomenon within the validation period. That mightily confesses the results depicted in Figure 2, as outlined in Table 2.



(a) Maze MM

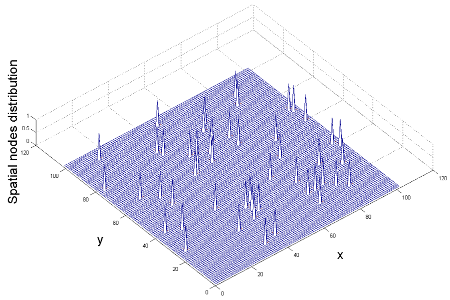


(b) RW MM

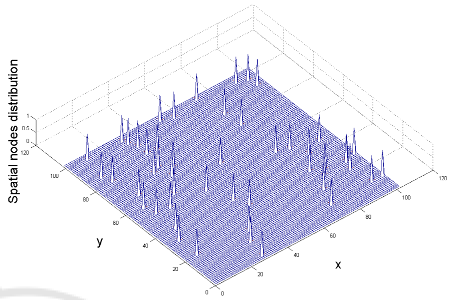


(c) MG MM

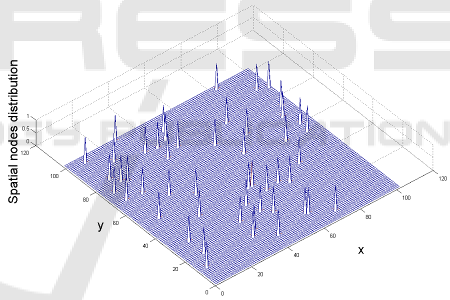
Figure 3: The Average neighbor percentage. (a) Maze MM (b) the RW MM; (c) the MG MM.



(a) Maze MM



(b) RW MM



(c) MG MM

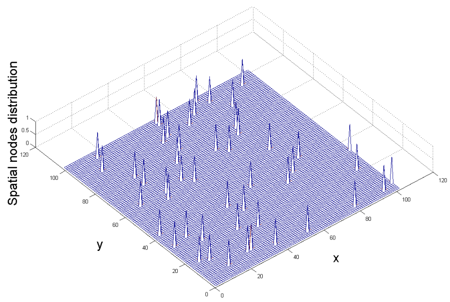
Figure 4: The Spatial node distribution at $t = 0s$. (a) Maze MM (b) the RW MM; (c) the MG MM.

2.4 Spatial Node Distribution

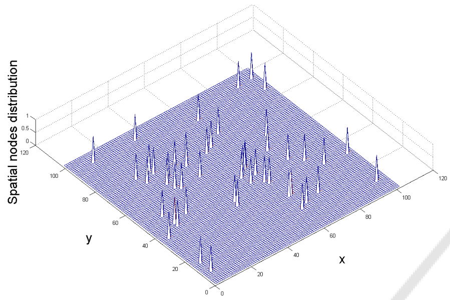
Fourthly, we validate another mobility metric, as the 'spatial node distribution'. Bettstetter (Bettstetter et al., 2002), Blough and al. (blo,) respectively observed the non-uniform spatial distribution of RW MM as proved in Fig. 4(b). At the steady state, the node density is extreme in the center region, whereas, it is almost few around the boundaries, as shown in Fig. 4(b). We analyze this mobility metric at t = 0 and when simulation time elapses.

In Fig. 4(a) at t = 0, we observe that Maze MM is well distributed in the simulation field when mobile nodes are located at the boundaries with some few empty spaces comparing with Fig. 4(b) and Fig. 4(c). That will be more obvious if we use a high mobile node number.

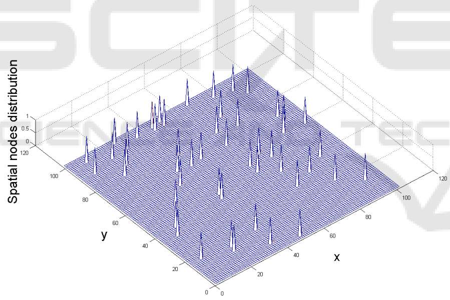
We analyze this mobility metric when simulation time elapses. In Fig. 5(a), we observe that Maze MM has always the best spatial distribution. It is well distributed in the simulation field with some mobile nodes at the boundaries. It has some few empty spaces comparing with Fig. 5(b) and Fig. 5(c). If a MM has this phenomenon during simulation time, nodes will suffer from 'Density wave phenomenon' all the time, as shown in Fig. 2.



(a) Maze MM



(b) RW MM

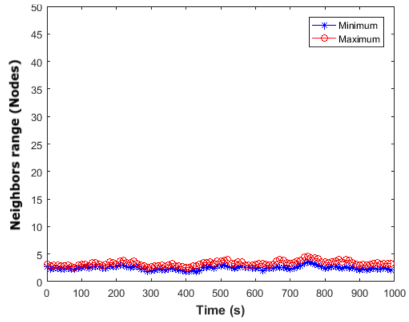


(c) MG MM

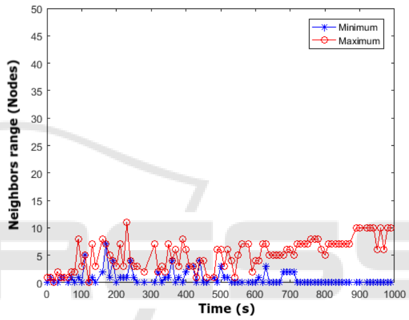
Figure 5: The Spatial node distribution at $t = 1000s$. (a) Maze MM (b) the RW MM; (c) the MG MM.

2.5 Mobile Neighbors Range

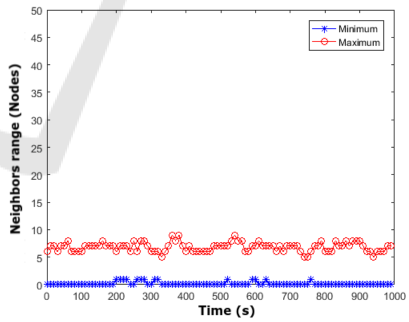
A new metric was recently suggested surmounting limitations of the other metrics which have been suggested previously, such as the spatial node distribution, density wave phenomenon and average neighbor percentage. This new metric is called 'mobile neighbors range'. It gives a right conduct of mobility models firmness for all mobile nodes within the validation period. It inspects neighboring changes basing on a specific propagation range whatever the time instant, the targeted model, and the inspected node, are. This feature is prosperous for each instant by showing a range of recorded neighbors for the mobility pattern. Meanwhile, this metric points out the advantages and disabilities of each mobility issue which has been highlighted previously. The validation outcomes of this mobility metric are shown in Figure 6.



(a) Maze MM



(b) RW MM



(c) MG MM

Figure 6: The Mobile neighbors range. (a) Maze MM (b) the RW MM; (c) the MG MM.

We remark that:

- According to Figure 6b, the RW MM reports the worst pattern based on this property. It bears perceptibly from the number of neighbors variation during time. That occurs a worse mobility pattern with an irregular gap of mobile neighbors range that reflects the unsteadiness behavior within time.

- The MG MM defines more appropriate fluctuations with a regular gap of 0–9, with several moments with no detected neighbors. That firmly endorses the previous results of prior validated metrics, as the density wave phenomenon and the average neighbor percentage.
- Figure 6 shows that RW MM and MG MM have obviously this issue. However, the Maze MM outperform at this feature where the calculated range is too promptly converges in a regular margin. In addition to during all validation time, mobile nodes detect some neighbors to forward packets to their destinations with no losses. This specificity is not spoted for the other validated model. That hugely reflects that the validated mobility model is more steady and stable which lead to satisfactory results in the performance analysis (Ibadah et al., 2017) .

This metric furnishes rise precision compared to the others. The mobile neighbors range reasons that it handles flaws of all prior mobility metrics by validating all deployed nodes within all validation period for all mobility models. We conclude that Maze MM offers the best results than RW MM and MG MM in the five analyzed mobility metrics. It keeps:

- The same speed during the simulation time, due to, its respecting to the motion laws, as shown for the 'speed decay problem' in Fig. 1.
- Maze MM has the best 'spatial node distribution' before moving, as confirmed in Fig. 4. And also, when the simulation time elapses, as proved in Fig. 5.
- All the time, Maze MM has a few fluctuations of density neighbors comparing to RW MM and MG MM, as demonstrated in Fig. 2, for the 'density wave phenomenon'.
- Maze MM maintains the same rhythm of the average neighbor percentage, as shown by Figure 3.
- Moreover, Maze MM offers the best recorded Mobile neighbors range with high satisfactory results, as exactly defined in Figure 6.

Based on these metrics, we can divine performances of the mobility models with no need to simulate them into a wireless network, as mostly done to judge the mobility model. This policy is more precise to only yield the correct behavior of only the motion strategy adopted. These metrics highlight integral aspects with the aim of correctly extract outlook of mobility issues. Due to these flaws, the choice of a wrong mobility model deeply affect the whole network performances with undesirable consequences. After simulating 60 files corresponding to the three mobility models, we deduce that we can classify them according to their results as recapitulated in Table 2. The best outcomes are shown in green cells(1), acceptable shifts are shown in yellow colored cells(2), and the worst results are shown in red colored cells(3).

Table 2: The validated mobility model classification.

Mobility Metrics	Mobility models		
	Maze MM	RW MM	MG MM
Speed decay problem	1 -	3 -	2 -
Density wave phenomenon	1 -	3 -	2 -
Average neighbor percentage	1 -	3 -	2 -
Spatial node distribution	1 -	3 -	2 -
Mobile neighbors range	1 -	3 -	2 -

These validations of the Maze MM is too sufficient to judge Maze MM robustness and effectiveness comparing to other patterns. The aim of this investigation is to prove that the realistic combination of Maze MM approach that take into consideration all parameters to perform an efficient and flexible mobility pattern which can be deployed in complex situations to afford the best performances, as proved by its high-performance outcomes (Ibadah et al., 2019).

3 MAZE MOBILITY MODEL FEATURES

The main faced challenge of Maze MM is how, we can deduce the most convenient trajectory to a definite destination into a complex field to lead nodes with to correctly move in presence of various mobility restrictions (paths, walls, and intersections). Some previously suggested mobility patterns mimic various real-life situations, but they are not flexible with environment.

The Maze MM owns a set of substantial characteristics that adjust the entire adopted motion policy. It is characterized by many remarkable aspects:

- Maze MM abides by the physical laws of motion. That considers the elemental relations between speed, time, and distance. As opposed to RW MM, for example, which randomly chooses speed and destination independently of each other. That further produces an unrealistic model.
- It is a mobility model with spatial dependencies, i.e., the next mobile node location can only be in one of the four directions (top, left, down, or right) basing on to the last position.
- It is also a mobility model with temporal dependencies, i.e., the present instant mainly related to

the previous time instant.

- Due to the uniform grids, the flight length is steady between two successive grids.
- The visiting frequency and return time are probabilistically distributed with relevance to the restituted trajectory.
- For the first period, it has a spatial distribution according to white grids. And subsequently, the obtained trajectory must be only shaped by pathways with no walls. This condition reflects a realistic motion of daily life behavior.

The outstanding outcomes offered by Maze MM have been resulted thanks to its logical process, its conception, and the consideration of real-life movements. These features make this model more efficient and stable, even in the presence of diverse mobility restrictions.

4 CONCLUSION

The noticeable results sown in this paper has remarked the relevance of mobility models in mobile networks to improve the overall throughput by supporting routing protocols. Given the results obtained in the proposed approach and shown and discussed in this paper, we conclude that a new flexible mobility model is developed which offers the best result at the most confronted mobility problems, like speed decay problem, spatial node distribution and density wave phenomenon, average neighbor percentage, spatial node distribution, and mobile neighbors range. Due to walls used inside the simulation area, Maze MM can be classified as a mobility model with geographic restrictions. And also, it can be considered as a hybrid entity synthetic mobility pattern. It combines a random distribution at the beginning, a temporal dependency based on the instant of the previous decision motion, and a spatial dependency while the next position depends on the last one. For all that, this pattern mimics real-life movement especially in a complex area without spending the time to move to a wrong destination. This pattern can be used for mobile devices like robots which have problems of energy consumption.

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REFERENCES

Almomani, O., Al-Shugran, M., Alzubi, J. A., and Alzubi, O. A. (2015). Performance evaluation of position-based routing protocols using different mobility models in manet. *International Journal of Computer Applications*, 119(3).

Bettstetter, C., Wagner, C., et al. (2002). The spatial node distribution of the random waypoint mobility model. *WMAN*, 11:41–58.

Ibadah, N., Minaoui, K., Rziza, M., and Oumsis, M. (2017). Experimental synthesis of routing protocols and synthetic mobility modeling for manet. In *Sensor Networks (SENSORNETS 2017), 6th International Conference on*, pages 168–173.

Ibadah, N., Minaoui, K., Rziza, M., Oumsis, M., and Benavente-Peces, C. (2018). Deep validation of spatial temporal features of synthetic mobility models. *Computers*, 7(4):71.

Ibadah, N., Rziza, M., Minaoui, K., Oumsis, M., and Benavente-Peces, C. (2019). Flexible synthetic mobility modeling to discover trajectories for complex areas of mobile wireless networks. *Journal of Ambient Intelligence and Humanized Computing*, pages 1–14.

Noguchi, T. and Kobayashi, T. (2017). Adaptive location-aware routing with directional antennas in mobile adhoc networks. In *Computing, Networking and Communications (ICNC), 2017 International Conference on*, pages 1006–1011. IEEE.

Pramanik, A., Choudhury, B., Choudhury, T. S., Arif, W., and Mehedi, J. (2016). Behavioral study of random waypoint mobility model based energy aware manet. In *Signal Processing and Integrated Networks (SPIN), 2016 3rd International Conference on*, pages 624–629. IEEE.

Royer, E. M., Melliar-Smith, P. M., and Moser, L. E. (2001). An analysis of the optimum node density for ad hoc mobile networks. In *Communications, 2001. ICC 2001. IEEE International Conference on*, volume 3, pages 857–861. IEEE.

Wang, W., Chen, Y., Chen, H., Kong, X., and Chen, J. (2016). Parameter characteristics of gauss-markov mobility model in mobile wireless sensor networks. *Adhoc & Sensor Wireless Networks*, 34.