

A Novel Mobility Model for the Military Operations with Real Traces

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Abstract— Mobility modeling is important to analyze the network performance of protocols since it determines the network topology inducing the network performance. In this paper, we analyze the real trace data in military operations, and design a new mobility model for military units. Based on the military training trace data of the KCTC (Korea Combat Training Center) in Hong-Cheon, Korea, we investigate the structural, spatial, and temporal characteristics. After investigations, the proposed mobility model of military units in military operations is presented. Simulation results and evaluation show that our proposed mobility model generates very similar mobility trace with real field trace of military units.

Keywords— mobility model, military operation, group mobility

I. INTRODUCTION

Modern warfare aims to achieve the purpose of the war by dominating information over the enemy and avoiding the war of mass attrition. Network Centric Warfare (NCW) has been derived in accordance with this tendency of modern warfare. NCW is the concept that maximizes the efficiency of military force by ensuring the situation awareness and rapid information circulation by connecting weapons platforms and units through the network, and focusing and operating the most appropriate military force for the right time and place immediately. Therefore, NCW is to monitor and detect before enemy does, make a quick decision on attack and strike the targeted point and object without delay. There are four main areas that NCW can be applied to.

First of all, NCW increases the amount of shared information by connecting the broad military forces systematically through network. Second, NCW improves the quality of information and common situational awareness by sharing information. Third, operational durability and the commanding speed can be advanced by ensured collaboration and self-unification. Finally, those processes improve the efficiency of accomplishing mission.

As a result, the role of communication has been amplified to perform NCW. It is certain that all of assets, equipments and human resources should be well prepared. However, considering that everything mentioned earlier requires the assumption of information sharing, it is obvious that

communication's responsibility is bigger in this context to ensure the "networking".

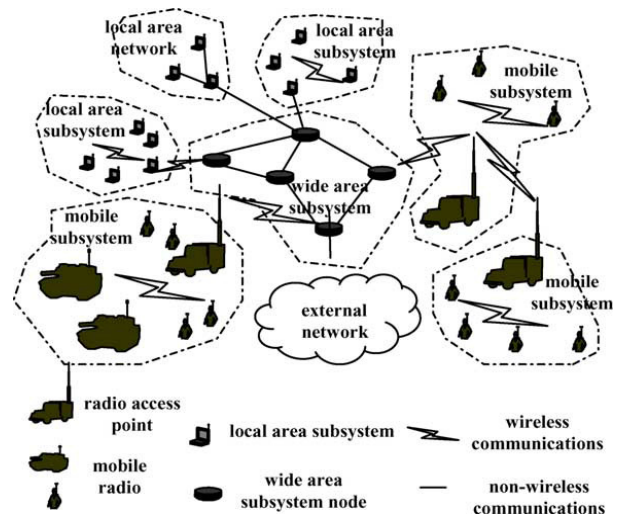


Figure 1. Military Tactical Communication

The wireless mobile ad hoc network is a good chance to gratify the growing desire for mobile computing [1]. Simulation is a very effective method to evaluate the protocol of the research. Simulation provides lots of merits compared with actual deployment of mobile nodes. It can be carried out very fast, also repetition. And it is possible with simulation to isolate parameters affecting the performance of the design. In simulating mobile system, to use a real mobility model is important so that simulation result is to do with the result of real world.

Therefore, using a realistic mobility model is an important factor to trust this network simulation result's reliability. In this research, we approached novel military mobility modeling using trace data. The rest of the paper is organized as follows. In section II, the proposed mobility models are described. The structural, temporal and spatial characteristics we researched and extracted from the trace data are described in section III, IV, V. The novel military mobility model is introduced in section VI. And section VII concludes the paper and presents future work.

II. RELATED WORKS

There are many mobility models proposed in mobile wireless networks. Mobility models are used to express the mobility pattern of mobile nodes. In this section, many proposed mobility models are introduced and described. The entity models are used to model the movement behavior of an individual mobile node. In Random Walk model [2], a mobile node moves from its current location to a new location by randomly choosing a direction and speed. The new speed and direction are both chosen from pre-define ranges. When this time ends, the mobile node repeats this motion. The Random Waypoint model [3] is widely used random mobility model. In this model, each node individually chooses a random destination and also chooses a random speed from pre-define speed ranges. Once the node reaches the destination, the node pauses for a pause time period. After the pause period, that process repeats. The drawback of this model is density wave which is the clustering of nodes in the part of the simulation area. Random Direction model [4] is created to overcome this density waves in the average number of neighbors produced by Random Waypoint model. In this model, a mobile node travels to the border of the simulation area in that direction. When the simulation boundary is reached, the mobile node pauses for a specific time and chooses another angular direction.

All the above mobility models do not represent real world. They are memory-less and have no continuity of the former behavior. This model causes frequent sharp change in speed and direction of movement which is not reasonable in a real world. The Boundless model [5] is an example of memory model but it has no geographical restriction.

There have been some researches about realistic group mobility model. Column Mobility model, Nomadic Mobility model, Pursue Mobility model [6] are good examples. In Column Mobility model, the set of mobile nodes form a line and are uniformly moving forward in a particular direction. In Nomadic Mobility model, a set of mobile nodes move together from one location to another location. A set of mobile nodes in Pursue Mobility model follow a given target. The most general of these models is the Reference Point Group Mobility (RPGM) model [7]. These three mobility models can be implemented as special cases of RPGM model.

Recently, there are number of researches on mobility models on real mobility traces [8, 9]. Minkyong et al. constructed a WLAN mobility model from real-world wireless user traces in Dartmouth College [8]. And David Kotz et al. tried to understand patterns of activity in the network [9]. Because the users in the campus don't have same purposes, their mobility can't be called group mobility in the strict sense.

Some researchers studied military traces [10]. They studied the military trace data that was collected from a MANET consist of jeep vehicles and Unmanned Aerial Vehicles (UAVs) in Lakehurst, N.J., U.S.A. They analyzed the structural, spatial, temporal characteristic from the trace data. They proposed the mobility model based on these

characteristics. But these trace data included only movement situation (patrol phase). Therefore, the model didn't represent the combat phase.

III. STRUCTURAL CHARACTERISTICS

In our trace data, nodes form a group and they move together to complete their endowed mission in contrast with common groups which have lots of works to do. Therefore, after long time, the distances between the nodes of the military group are shorter than those of other common groups [10]. Moreover, the nodes of the military group have similar mobility patterns. If some nodes are close each other and they have similar mobility pattern, we regard that they are in the same group. As you know, an army is composed of many structural groups. To accomplish a group's mission, the members behave in strict order, and the leader of the group usually positions in the center of the group.

Thus, we tried to find out a movement rule of members with a leader, not an individual movement rule in the group. Furthermore, the leader of the group will be a member of a high level group. Then we are able to design the military mobility models in this manner.

First of all, we are going to begin the platoon group that has 1 platoon leader, 3 squad leaders (In this paper, we call the squad leader follower).

In structural characteristic, we consider the distances between the leader and the followers. Figure 2 shows the analysis results.

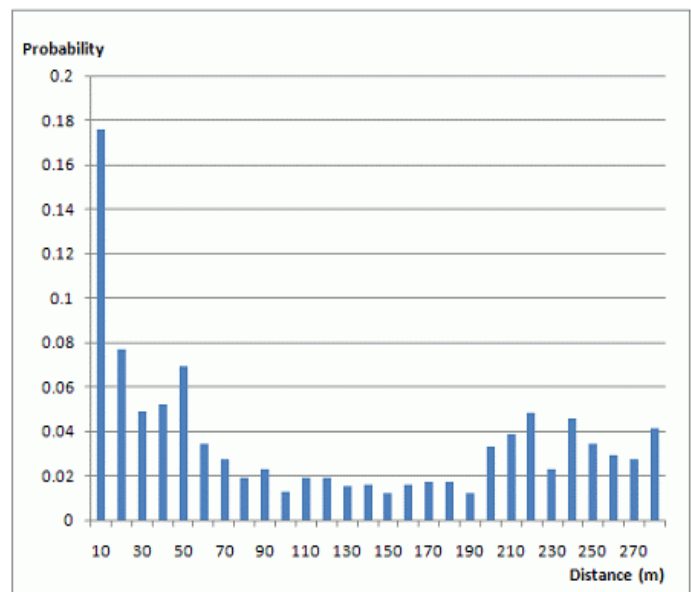


Figure 2. Distribution of distance between the leader and followers.

And we also consider the relative location of followers. The relative location is that what distribution of followers located in the center of leader. The result is shown in Table 1.

Table 1. Relative Location of followers (No order)

1 st Quadrant	2 nd Quadrant	3 rd Quadrant	Percent (%)
1	1	1	31.1
2	2	2	0.6
3	3	3	2.4
4	4	4	1.5
1	1	2	17.9
1	1	3	13.3
1	1	4	5.1
2	2	1	2.6
2	2	3	0.6
2	2	4	0.4
3	3	1	1.3
3	3	2	2.9
3	3	4	5.6
4	4	1	0.9
4	4	2	1.2
4	4	3	1.1
1	2	3	3.5
1	2	4	3.4
1	3	4	0.7
2	3	4	3.7

IV. TEMPORAL CHARACTERISTICS

The speed of nodes is very important component in the temporal characteristics. Moreover, movement duration time and pause duration time are also important components to represent mobility temporal characteristics.

If the distance between two points that a node moved one point to the other point is too short in comparison with the duration time, we regard that the node paused for that time. The distribution of nodes' speed varies from 0.01 m/s to 2.2 m/s.

We define the scale of pause 0.04m/s. Because the data that has less than 0.04m/s continues more than 300 sec, and the distance within that time can be called pause. We also obtained the platoon leader probability on pause or move by using this criterion. The following tables show the probability on pause or move, temporal characteristics distribution like speed, movement duration time and pause duration time.

Table 2. Probability on Pause and Move (leader)

State	Pause	Move
Percent (%)	36.5	63.5

Table 3. Distribution of movement duration (leader)

Duration (sec)	60	120	180	240	300	360
Percent (%)	71.9	16.4	7.0	1.8	1.8	1.1

Table 4. Distribution of speed for movement duration (leader)

Speed (m/s)	0.04 ~ 0.6	0.6 ~ 1.0	1.0 ~ 1.4	1.4 ~ 1.8	1.8 ~ 2.2
Percent (%)	59.6	19.3	11.7	6.1	3.3

Table 5. Distribution of pause duration (leader)

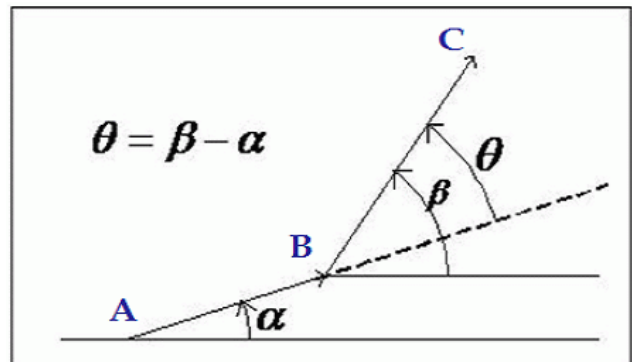
Duration (sec)	60	120	180	240	300	360
Percent (%)	27.1	3.8	3.6	3.4	59.5	2.6

Table 6. Distribution of speed for pause duration (leader)

Speed (m/s)	0 ~ 0.01	0.01 ~ 0.02	0.02 ~ 0.03	0.03 ~ 0.04
Percent (%)	46.2	23.4	14.3	16.1

V. SPATIAL CHARACTERISTICS

We analyze the spatial characteristic especially in terms of the directional characteristic. To analyze directional characteristics, we employ the relative angle metric which is the difference between the current direction angle and the formal direction angle. We let the former absolute direction angle α and let the latter absolute direction angle β . Then, we can obtain relative direction angle θ by subtracting α from β as shown figure 3.

**Figure 3. Method to obtain Relative Direction Angle****Table 7. Absolute Angle and Relative Angle**

Point	Absolute Angle	Relative Angle
A	α	α
B	β	$\beta - \alpha$

When the node changed the directional angle, we calculate the absolute angle, and then we subtract the formal absolute angle from the current absolute angle. We calculated the node's relative direction angle respectively (Move phase and Pause phase). After pause duration, the relative direction angle is calculated with the former angle before then pause. The obtained relative angles in this way are classified in figure 4.

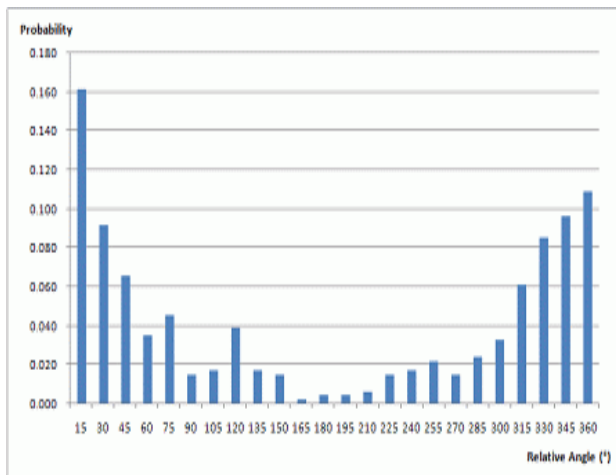


Figure 4. Distribution of relative angle change in move phase (leader)

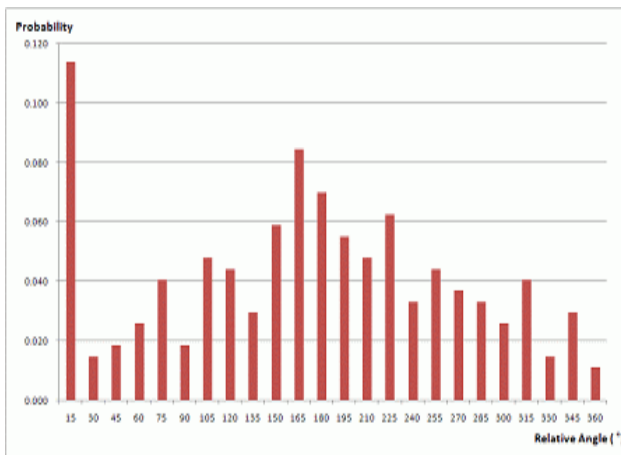


Figure 5. Distribution of relative angle change in pause phase (leader)

VI. MOBILITY MODEL

Based on above characteristics we propose a new mobility model in military operations. In our model, nodes are organized in a group. We considered the mobility models classifying leader and followers. We assume that all nodes in a group move around a leader (Platoon leader). Moreover, the followers in a group have a same distribution of location, distance, speed. Lastly, nodes in a group start with the given beginning positions.

A. Mobility Model for a Leader node

Step1. A node decides whether the node move or pause. If the node decides to pause, go to Step2. Otherwise, go to Step4.

Step2. Pick out the time duration from a distribution of a pause time duration.

Step3. After the picked duration time, go to Step1.

Step4. Pick out the movement time duration, movement speed, relative movement angle from distributions of the movement phase.

Step5. Generate the node's destination with combinations of picked movement time duration, movement speed, relative movement angle.

Step6. Move to the generated destination for the picked duration time, go to Step1.

B. Mobility Model for Follower nodes

Step1. If the leader node (Platoon leader) decides to pause, go to Step2. Otherwise, go to Step3.

Step2. After the picked duration time of leader, go to Step1.

Step3. Generate the destinations of the follower nodes around the leader based on follower's statistics (Relative location of followers, Distances between the leader and followers).

Step4. Move to the generated each destination for the picked movement duration time, go to Step1.

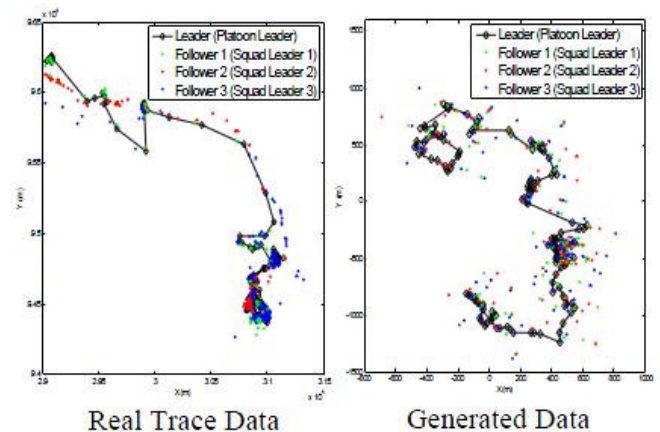


Figure 6. Plots of real trace and generated data by proposed mobility model

VII. CONCLUSION

To design realistic mobility model in military operations, we analyzed the structural, spatial, temporal characteristics from the real trace data. And then, we proposed a new military mobility model based on these characteristics. As shown in Figure 6, our mobility model presents whole characteristic of real trace data like structural, spatial, and temporal characteristics. This mobility model can be utilized for generating long time and large scale artificial data to analyze the behavior of the network. These kinds of experiments need high cost to implement, so our model can be the fundamental work for future research.

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