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Movement model for battlefield with confrontation characteristic

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Abstract-**In this paper we propose a mobility model derived from real-time strategy game's replays which can reflect confrontation & collaboration characteristic of nodes movement in military scenario. This mobility model covers several units' characters, including the velocity distribution, mutual synergies, creation/destruction and terrain effect. Game players' human decision is also involved, which makes this mobility model completely different from previous ones. We analyze how the confrontation &collaboration characteristics are reflected in our mobility model. We also evaluate the AODV protocol on the proposed model and traditional Random Waypoint model, and simulation results show that the network performances and topologies are significantly different when different mobility models are adopted. According to these results, this model could generate more realistic simulation scenario than the traditional mobility model, and the simulation results are more credible.**

Keywords: confrontation environment, simulation, mobility model, real-time strategy game

I. INTRODUCTION

Due to the cost of deploying and implementing real large-scale mobile ad hoc environments in the real world, most research such as developing network protocols and services relies on simulation for evaluation.

Currently, there are two types of mobility models used in the simulation of networks: traces and synthetic models. Synthetic Models attempt to realistically represent the behaviors of mobile nodes (MNs); the widely used ones represent multiple MNs whose actions are completely independent of each other, such as Random Walk and Random Waypoint models [3]. All the models assume that the mobility nodes move in an ideal environment and in a random way; effects of other objects are not considered. Traces collect the tracks of MNs in real world, and provide accurate information, especially when they involve a large number of participants and an appropriately long observation period. Many researches are on the topic of modeling mobility using the traces method [4-11]. In [4], the introduction of roles allows different objects to uniquely and realistically react to events. Paper [5] develops a model that utilizes application level aspects of networked game traces to statistically model online game Quake II. Paper [7] [8] collect data about human movements. The mobility patterns using trace of wireless network activity are analyzed in [9]. [10] takes the influence of obstacles into consideration. These models, while adequate to study environments for which they are designed, fails to capture the confrontation & collaboration characteristic of MNs' movement in military scenario. The community is increasingly interested in developing network protocols and services for military ad-hoc networks, this paper proposes a mobility model which can reflect confrontation & collaboration characteristic of MNs' movement in military scenario. The Real-time strategy game is operated by persons, so man's decision-making which corresponds with tactics in battlefield is blended with. To prove the effectiveness of the proposed model, we sum up the confrontation & collaboration characteristics which include velocity distribution, mutual synergies, creation /destruction and terrain factor of the military scenarios, and analyze how these characteristics are reflected in the proposed model. We compared the AODV protocol performance in the proposed model with the traditional model. Simulation results show that the network performances and topologies are significantly different when different mobility models are adopted.

The remainder of this paper is structured as follows. Section II introduces mobility model derived from real-time strategy game. In section III, the characteristics of the model that reflects characteristics of military scenario are analyzed. In section IV, generated network topology is demonstrated and characteristics of the model are analyzed. Section V concludes the paper, summarizing the original contribution of our work.

II. MOBILITY MODEL GENERATING PROCESS

As shown in fig. 1, the process to generate the model is consisted of two parts: Game Ordain Module (GOM) and Data Process Module (DPM). GOM creates a virtual battlefield environment in Real-time Strategy game. The mobile traces are extracted and processed by DPM. Then mobility model is used to simulate routing protocols and assess the performance.

GOM creates virtual battlefield environment based on Real-time Strategy game at a very low cost, which is consisted of two blocks: Define Map and Ordain Kind of Units. At first, The Define Map Block prepares a map for the game. The map includes a corresponding terrain taking into consideration obstructions, such as the mountains, lakes, buildings and so on which would affect the units tracks in the war. The Ordain Kind of Units Block ordains the kinds of allowing combat arms for each player. Finally the player as the military leader gathers the resources, expands his forces and leads them to victory in a virtual battlefield. The game is operated by persons, so

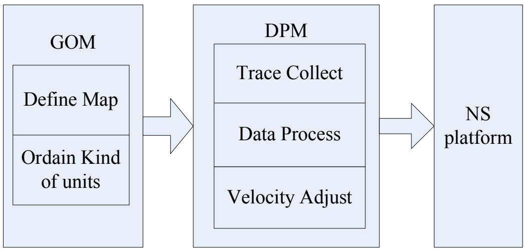

Figure 1. Mobility model Generating Process

man's decision-making which corresponds with tactics in a real battlefield is combined, which makes the model completely different from previous models.

DPM extracts and processes tracks of the combat units in game and provides nodes' mobility traces for the simulation, which is consisted of three blocks: Trace Collect Block, Data Process Block and Velocity Adjust Block. Trace Collect Block collects location information of all nodes at a regular time interval through analyzing and scanning the memory structure of the game, and then writes them into files. These files include the position information and other attributes of the game units, collected result of game units at a certain time is expressed as Tuple Information (TupleInfo): entity=<TIME, OBJECT-ID, OBJECT-POS, PLAYER, OBJECT-TYPE>, where TIME is the current game time, OBJECT-ID is the only entities logo, OBJECT-POS is the location information of entity, PLAYER embodies which team the combat units belong to, and OBJECT-TYPE is information of object types. Entities with different types have diverse sizes and velocities.

Data Process Block reads files generated by Trace Collect Block, then removes unwanted information according to the demand of simulation and generates mobility model which are required by Network Simulation Platform. In addition, further demand can be met by the Data Process Block, 1) we can use units' type information. In the simulation, different units types' signal transmitting power can be set at different levels, so MNs can have wireless communications equipment of various transmission range. 2) The MNs can be classed into several groups according to the side which the node belongs to or the types of units (such as infantry, armor, and other combat arms). The simulation nodes traces are sent to Network Simulation Platform. Network simulation parameters and Communication modes of different groups can be different.

For the balance of game, combat units' velocity distribution in the real-time strategy game keeps relatively uniform which is far different from that in the real battlefield environment. Velocity Adjust Block is used to adjust velocity proportion. Velocity Adjust Block can adjust the velocity of game units by modifying the TupleInfo's TIME of nodes. Game units are classed according to the type at first. Then the TupleInfo's TIME of each type's nodes can be compressed according to corresponding velocity rate we need. Of course, velocity in the map of the game is a relative concept. We can also adjust speeds according to various requirements through expanding (narrowing) offset of nodes obtained from map or modifying the TupleInfo's TIME. Here, the Network Platform is NS2 and the GOM is based on the StarCraft Game.

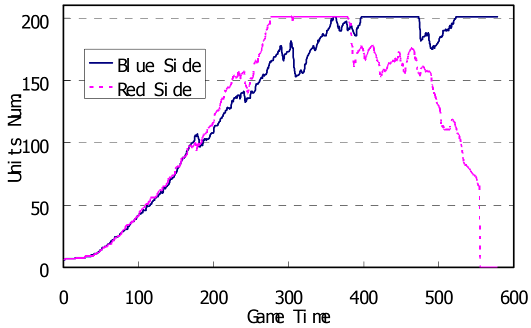

Figure 2. Node Numbers Varies with Time Changing

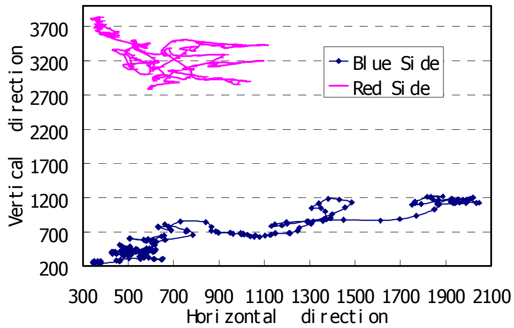

Figure 3. Location Centers of the Two Sides in the model

III. Confrontation Characteristics Analysis of the Mobility Model

In military environment, the node has its own mobility behavior. The characteristic of nodes behaviors different from general ad hoc network is listed below [1] [2]: 1) Damage. The node can be damaged because of the other side's assault; 2) Activity Scope. The node in battlefield scenario has a definite objective, which prescribe rough route to some extent; 3) Speed. Different kinds of individual entities have various speeds in the military environment; 4) Terrain. The mobility of nodes is greatly influenced by the environment.

A. Node Destruction

Confrontation of nodes is reflected by the destruction, as well as communications interference which might be adopted between the different groups. The destruction of node caused by antagonizing in our simulation process can completely simulate the damage of combat units in the state of fighting. Fig. 2 gives the change of number of nodes with the time proceeding. At the beginning, which is the preparation stage, nodes number of two sides continuously increase, but it has not yet entered war confrontation stage, nodes almost have no damage at the time. With the time proceeding, the war gradually goes into the state of confrontation, nodes constantly get damaged, the two sides increase troops resources at the same time, but nodes of the side which gives ground get seriously damaged, resulting in rapid decline in the number of nodes; while the nodes of the side which triumphs over gets a little damaged. In the final, the nodes of one side are all destroyed, which means the end of the war, the nodes of the winner remain unchanged in the period of time.

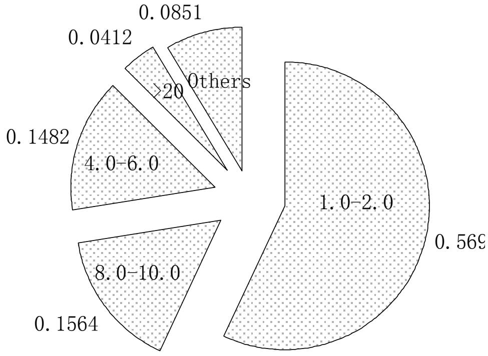

Figure 4. Velocity Distributions of Combat Units


Figure 5. Mobile Node's Track

Shown as Fig. 2, if nodes in a group are destructed greatly, inter-node communication will be seriously affected, which reflects the confrontation characteristics. In addition, because of the pretreatment process that nodes are classed into several groups by DPM, communication of confrontational mode could be adopted among nodes of different groups.

B. Node Activity Scope

In the start of a battle, combat units should set out from its own camp, with the battle proceeding, although some units go deep into enemy's combat scope, most units still move around the vicinity of their own camp. So the location center of two sides' combat units is located within their own controllable territorial limits. Related statistical information of game combat units will be analyzed. Assuming units of the same combat side were ($n_1, n_2, ..., n_n$), the TupleInfo's OBJECT-POS of node i is expressed (x_i, y_i). Taking the blue side for example, location centre (**P**) at a moment is defined as:

$$\mathrm{P} = \left(\frac{\sum_{i=1}^{n} x_i}{n}, \frac{\sum_{i=1}^{n} y_i}{n} \right) \tag{1}$$

Fig.4 shows location center distribution of the red and blue side in the whole process of fighting in the proposed model. It is shown that location center distribution of the red side is in the scope of [2700, 4000] * [500, 1100] , and the blue side is in [500, 2000] *[200, 1200], compared with the map scope of [0, 4096]*[0, 4096], armed forces has always been mainly distributed in their own vicinity of camps and has their own activity scope. Nodes of the same group centralize together.

C. Velocity Distribution &Terrain Affect

A war assigns the roles and distributes specific task in accordance with the characteristics of arms. Different arms have speeds of big difference. This characteristic can

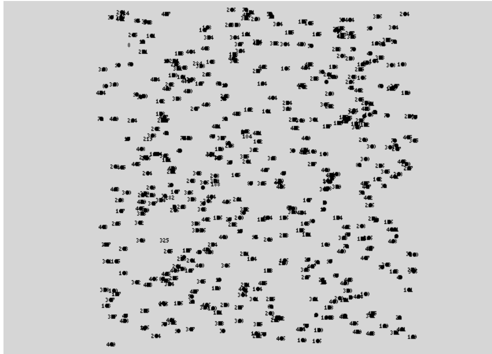
Figure 6. (a) Network Scene Constructed by Game

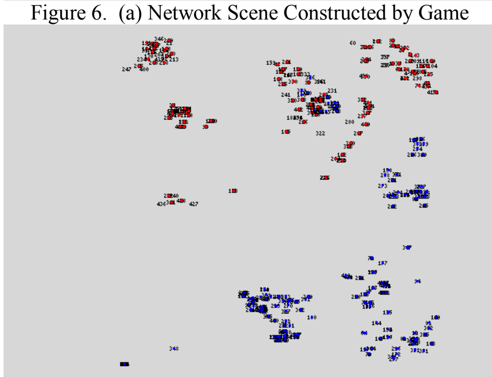
Figure 6. (b) Network Scene Constructed by RWP

also be reflected in our model. The nodes velocity is defined as:

$$\bar{v}_i = \frac{\sum_{1}^{l} \sqrt{(x_{j+1}-x_j)^2 + (y_{j+1}-y_j)^2}}{T_e - T_b} \tag{2}$$

Where l is the number of a node's collected locations, Tb, Te are respectively the times of nodes joining and leaving for node damage. (x_j, y_j), (x_{j+1}, y_{j+1}) is respectively the TupleInfo's OBJECT-POS of node i in j time and at a next collecting time of the same combat unit. Based on the velocity adjusting method described in section II, we stipulate velocity of soldier is the same as that in game, the speed of the heavy weapons is 3 times as that in game and the air force is 30 times and so on. Fig. 4 gives distribution of nodes velocity, the nodes whose velocity is between 3 and 4 takes 56%, which can be regarded as foot soldiers; the ones takes about 15% which can be regarded as rocket launcher in battlefield environment; the ones is 15%which can be regarded as tanks; the ones above 60 which can be regarded as planes. The difference in the types of arms will show corresponding different velocity. Compared to the existing mobile model, this velocity distribution can more realistically reflect MNs scene in battlefield environment.

In battlefield areas, the mobility of vehicles and soldiers are greatly influenced by the environment (e.g., terrain factors) as well as by interaction with other nodes. For example, on a billabong, tanks cannot travel at their desired speed. Furthermore, the location of trees, hills, lakes, etc. restricts the position of nodes and other buildings impact the flow of nodes. In this paper, simulation of propagation and mobility for urban wireless networks is addressed. The combat units (except air force) would avoid obstacles to proceed if they encounter mountains, lakes, buildings or other obstructions in the game. As shown in Fig. 6, the nodes' mobile track in the plane is not evenly distributed, because the combat units bypass the obstacles to go ahead, which is very similar to real battlefield where terrain needs to be considered. The space in Fig. 5 can be obstacles that combat equipment can not cross through.

IV. Simulation Results and Analysis

In our simulation, we choose the AODV routing protocol. 100 nodes are distributed in a region of 500 * 500 units. All the MNs have the same maximal communication distance, set to 250 unit, and 2Mbps for link bandwidth. The largest number of concurrent connections is 30, total simulation time is set to 900 seconds and packet size is 512 bytes. The velocity range of MNs is from 4.8 to 8.0 unit/s, no pause time in RWP model. Then the generated topologies derived from different mobility models are demonstrated.

A. Distribution of Nodes

The nodes distribution in the proposed model is not uniform. The MNs in the same side will exhibit structured movement to achieve a certain objective, and nodes may be damaged. Player's intention and interaction are executed by MNs, which make their behavior have more relevance. The nodes in different camps also have confrontation, defensive, rescue and other interactive characteristics. One of the node distribution snapshoot is shown in Fig. 6(a). To be compared, Fig. 6(b) in RWP mode is a uniform distribution.

Clearly, the proposed mobility model reflects the key characteristics in a military scenario; it's more suitable for simulating such kind of mobile ad hoc network.

B. Simulation Results

Packet delivery ratio (PDR) is shown in Fig. 7 with the speed changing. When the nodes' speed is low, the proposed model has a lower PDR compared with RWP mainly due to the nodes damage. When the speed increases, network performance of the two models all decrease because the faster the MNs' velocity is, the greater the changes of the network topology. At the same time, the PDR of RWP's drops faster than ours. It's because that the RWP is based on random directions and speeds, while, nodes in our proposed model would complete a task by mutual synergies, which exhibits collaboration characteristic. The PDR is mainly affected by the relative speed of nodes but not the absolute speed. Nodes have confrontation & collaboration characteristics in our model, which make the distribution of nodes in the same side is denser, and the relative movement speed is lower than nodes in RWP model. Simulation results indicates that the routing protocol performance has significant different when adopting different mobility model.

V. Conclusion

The paper proposes a mobility model for battlefield scenarios. Nodes exhibit structured movement based on

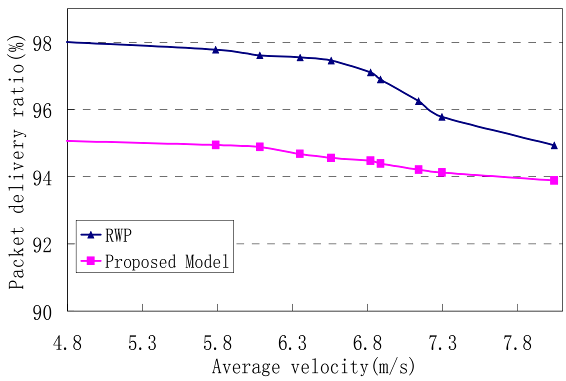

Figure 7. Comparison of AODV Packet Delivery Ratios

tactics like that in battlefield scenarios. Mutual synergies, interacting, velocity distribution, nodes creation/destruction and terrain effect in our model more realistically reflect real confrontation environment, which has a guiding role in the research on many respects in the battlefield environment. The human intention and interaction of game players are also involved in this model, which make it much more realistic than previous models. These specific characteristics do also have an impact on the results of performance evaluation.

Acknowledgements

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