OVERVIEW OF REFERENCE REGION GROUP MOBILITY MODEL FOR AD HOC NETWORKS

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ABSTRACT

In this paper, we present and visit the limitation of reference point group mobility model. It assumes that nodes in the same group always stay together throughout the simulation process. However, in many real life applications, the nodes's movement within a group is not always common. In particular, in a military operation, initially there is only one group. With multiple missions assigned to it, the group may be divided into a number of subgroups with each subgroup moving to a different location for accomplishing its task. A subgroup may be further divided into smaller groups or merge with other subgroups after completing its task. Therefore, in many scenarios it is necessary for a group to partition itself into smaller groups or a number of smaller groups to merge. Some recent researches present mobility models, which model possible group partitioning and group merging. We call this kind of mobility model a reference region group mobility model for ad hoc networks.

Keywords: Group, partition, Merging, MANET, review.

1 INTRODUCTION

Node mobility is one of the inherent characteristics of mobile ad hoc networks (MANET). It is also one of the parameters that most critically affect the performance of network protocols (e.g., routing). Today, in most simulation experiments, node movement is modeled as an independent random walk. One such model is the Random WayPoint mobility (RWP) model, which is the most popular mobility model used in the literature [2]. However, in real military scenarios, node mobility is not always independent. Mobility correlation among nodes is quite common. One typical example is group mobility. In battlefield, nodes with the same mission usually move in group such as tank battalions. For the modeling of military assets, group mobility models have drawn a lot of interest recently. The mobility models proposed so far in the literature assume some kind of permanent group affiliation. Also they require that each node belongs to a single group. In reality in a typical military scenario, a much more complex mobility behavior is observed. Some nodes move in groups; while others move individually and independently. Moreover, the group affiliation is not permanent. The mobile groups can dynamically re-configure themselves triggering group partition and mergence. All these different mobility behaviors coexist in military scenarios. A good realistic mobility model must capture all these mobility dynamics in order to yield realistic performance evaluation results, which, unfortunately, is not satisfactorily captured in any of the existing models [1]. In this paper, we present group mobility model, which includes all these "heterogeneous" mobility behaviors. We discuss in section 2, group mobility model; called Reference Point Group Mobility model RPGM. It assumes that a group of nodes always move together [10]. Section 4 presents the Reference Region Group Mobility (RRGM) model, which models possible group partitioning and group merging [3, 4].. The remainder of the paper is organized as follows. Section 5 presents a group partition and merging processes. Sections 6, 7, and 8 provide firefighters operating in a building, room searching or exhibition hall visiting, and battlefield, respectively. Section 10 analyzes the impact of mobility model on the performance evaluation of various routing protocols. Conclusions and References appear in sections 11 and 12, respectively.

2 REFERENCE POINT GROUP MOBILITY MODEL: RPGM

Group movements are based upon the path traveled by a logical center for the group. The logical center for the group is used to calculate group motion via a group motion vector, GM. The motion of the group center completely characterizes the movement of its corresponding group of Mobile Nodes (MNs), including their direction and speed. Individual MNs randomly move about their own predefined reference points, whose movements depend on the group movement. As the individual reference points move from time t to t+1, their locations are updated according to the group's logical center. Once the updated reference points, RP (t+1), are calculated, they are combined with a random motion vector, RM, to represent the random motion of each MN about its individual reference point [6]. Figure 1 gives an illustration of three MNs moving with the RPGM model. The figure illustrates that, at time t, three black dots exist to represent the reference points, RP (t), for the three MNs. The RPGM model uses a group motion vector GM to calculate each MN's new reference point, RP (t+1),

at time t+1; as stated, GM may be randomly chosen or predefined. The new position for each MN is then calculated by summing a random motion vector, RM, with the new reference point. Figure 2 is an illustration of three MNs moving together as one group. The movement of the logical center and the random motion of each individual MN within the group are implemented via the RWP mobility model. One difference, however, is that individual MNs do not use pause times while the group is moving. Pause times are only used when the group reference point reaches a destination and all group nodes pause for the same period of time [9].
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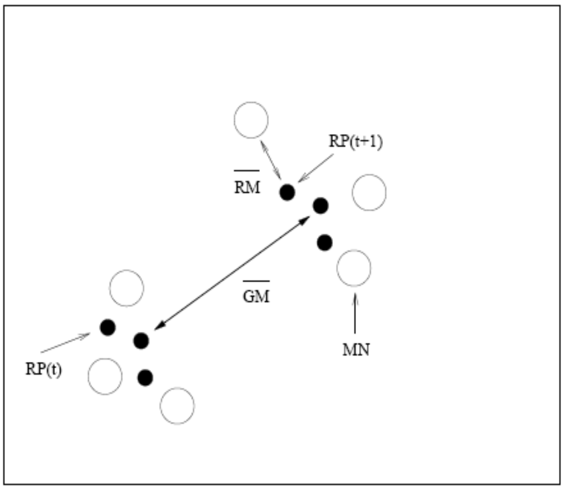

Figure 1: Movements of three MNs using the RPGM model

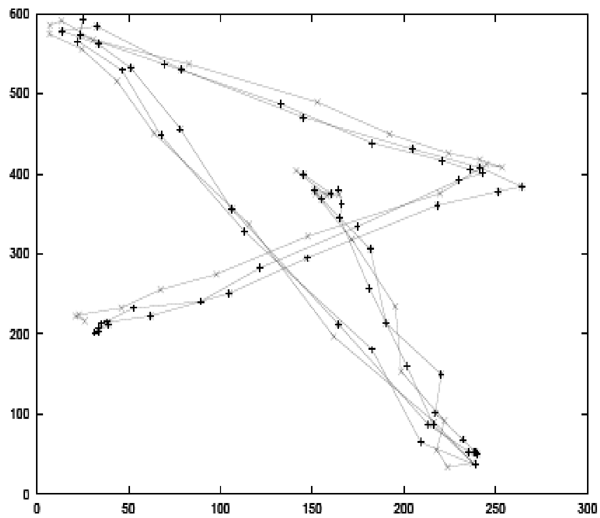

Figure 2: Traveling pattern of one group (three MNs) using the RPGM model

3 DISCUSSION

The RPGM model was designed to depict scenarios such as an avalanche rescue. During an avalanche rescue, the human guides tend to set a general path for the dogs to follow, since they usually know the approximate location of victims. The dogs each create their own “random” paths around the general area chosen by their human counterparts [9]. The RPGM model can generate topologies of ad hoc networks with group-based node mobility for simulation purposes, but for mobility or partition prediction purposes, it has two disadvantages. First, this model is used in the scope of an omniscient observer or a God, where the complete information about the mobility groups including their member nodes and movements are known. Given the distributed nature of the ad hoc network, such global information about the mobility groups are not conveniently available to any mobile nodes at run-time. For example, a mobile user traveling to a destination does not know all the other users that are heading in the same direction. Therefore, the lack of prior knowledge about the mobility groups make the RPGM model inapplicable for run-time partition prediction. Second, the RPGM model represents the mobile nodes by their physical coordinates. Given only the instantaneous physical locations of the nodes, it is difficult to discern the nodes' group movement patterns and the trend in the network topology changes [6]. Moreover, because the RPGM model is based on RWP model, it still cannot overcome the shortcomings caused by the characteristics of the RWP model, such as non-uniform network density, and it is not adequate to simulate the group movement in reality, such as group partition and mergence. Thus, several other mobility models such as RRGM model were proposed. We shall discuss this model in this paper.

4 REFERENCE REGION GROUP MOBILITY MODEL

In this section, we present Reference Region Group Mobility (RRGM) model. In this model, every group is associated with a reference region which is an area that nodes will move towards to a once they arrive, the nodes will move around within the region waiting for the arrival of others. After a reference region has been stationary for some time at an intermediate location, a new location for the reference region will be generated. As such, the reference region moves gradually towards the destination with its path defines the trajectory of the movement of the group. The size of the region is defined based on the node density as given by the user according to the specific scenario. In RRGM, new destinations may be created at times so that if multiple destinations are assigned to a group, this group will be partitioned into a number of smaller subgroups, each with a new reference region associated to a different destination. When a group has reached its destination, the group could merge with another group. RRGM also defines two group types: active groups and standby groups. Active groups are those that have destinations assigned to them and nodes are actively either moving toward their reference region or moving within the regions. Whereas standby groups have no destination assigned yet and nodes only move within the stationary reference regions. The standby groups model situations where some groups are waiting for their task assignments or where nodes have reached the destination and are waiting for a new task [3]. Two group-partitioning modes have been designed:

4.1 Group partition when a new destination is generated (First mode)

In some applications it is necessary for a group to partition itself into a number of smaller groups to accomplish different tasks at different locations. For instance, when an army unit is moving towards an enemy's citadel, a command is received that a team of soldiers has to be separated from the main force to accomplish another task. A new team would then be formed and partitioned from the current team. To support group partitioning in RRGM, new destinations will be generated and placed at some time interval as specified by the users. Once a new destination is generated, the distance from the destination to every standby group is calculated. Again, the closest standby group is selected and becomes active and will move towards the destination. If no standby group exists, the active group that is closest to the new destination is chosen, and a number of nodes are randomly selected to form the new group. Thereafter, a new reference region is generated between the original group and a newly created destination. Members of the newly formed groups will than change their directions and move towards the new reference regions. To ensure each group has a minimum number of nodes, a threshold n_{min}, this group cannot be chosen for partition. In RRGM, if a group has reached its destination for some time, the group will become a standby group and will merge with another group. Two conditions need to be satisfied before a group could merge into other groups. Firstly, the number of nodes in the standby group is less than $n_{min.}$ This is to ensure that we have either two small groups merge with each other or a small group merges into a large group. Secondly, the group has paused at the destination for a period of time τ as specified by users. This is to ensure that the nodes have spent some time at the destination to complete their assigned tasks before the group becomes a standby group. Once the two conditions are met, the group will select the nearest reference region as its new reference region, and its nodes become members of the target group [4].

4.2 Group partition when a group passes by a destination (Second mode)

The second mode of group partitioning is useful in scenario such as building search where locations of the destinations (e.g. rooms) are in general predefined by the user. Under this mode of operations, generating a reference region for each destination will not initialize the model. Instead, only one reference region for the whole group will be created initially. A set of coordinates pairs $\{(d_{x1}, d_{y1}), (d_{x2}, d_{y2}) \ldots (d_{xk}, d_{yk})\}$ will be used to define the intermediate checkpoints for the path of the reference region. Such checkpoints represent turnings in a building where the group may turn left or right to move into another corridor. The initial reference region will be placed along the path between the initial group position and the first checkpoint [4].

5 GROUP PARTITION AND MERGING

Figure 3 shows us a general group mobility scenario where a group may partition and merge.

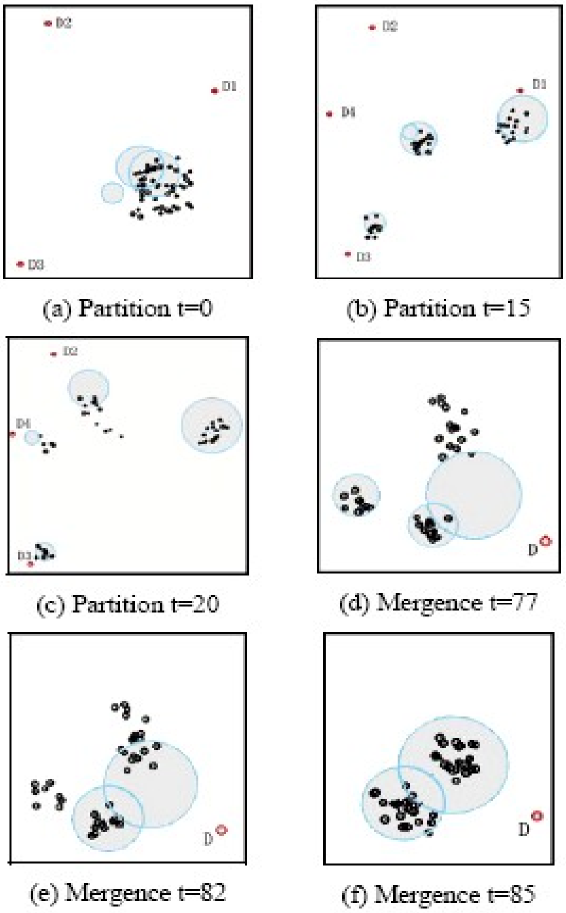

Figure 3: General Group Mobility Pattern with Group partition and merging.

As shown in figure3 (a), initially at time 0, for the three destinations, D_1, D_2 and D_3, three reference regions are generated. The initial group is partitioned into three subgroups and they gradually move into their corresponding reference regions. Figure 3(b) shows that at time 15, while the groups are moving towards their destinations, a new destination D_4 has been generated. The closest subgroup, which is moving towards D_2, is now partitioned into two subgroups with the newly formed subgroup moves towards D_4 as shown in figure 3(c). At time 20, the biggest group on the right side in figure3(c) has arrived its destination and became a standby group, while other subgroups are still moving towards their destinations. Figure3 (d) to (f) illustrate the process of mergence. Figure 3(d) shows that the two smaller groups are standby groups while the third one is an active group moving toward the destination D. In figure3(e), one of the smaller standby groups starts to merge into its nearest reference region, and the merging is completed at time 85 as shown in figure3(f). The scenario given above can be used to model application scenario such as search and rescue. Destinations represent the areas where rescue teams move towards the destinations, some members may be called upon to provide help in other areas. Another application is to model battlefield scenario where a number of enemies' defenses are deployed around. After the units get to their destinations and finish their tasks, they may reassemble again and be deployed to other areas [4].

6 FIREFIGHTERS OPERATING IN THE BUILDING

As firefighting agencies become more advanced, they are using sophisticated location determining, tracking and communications systems that are often based on packet radio networks. Firefighting teams themselves are typically small elements of not more than five firefighters, operating in concert with other small teams as they enter buildings and attack the fire. Group structure and control is critical. Individual nodes stay fairly close together in this scenario, but barriers and node failure can easily lead to link breakages that will stress the routing protocol. It is also common for two members to break off from the group to clear a room or search an obscured area, for example. Figure 4 depicts a typical tactic employed by firefighting teams, wherein a command element of a team stations itself at the entrance to a room and a smaller clearing team moves through the room to search for fire and victims [7].

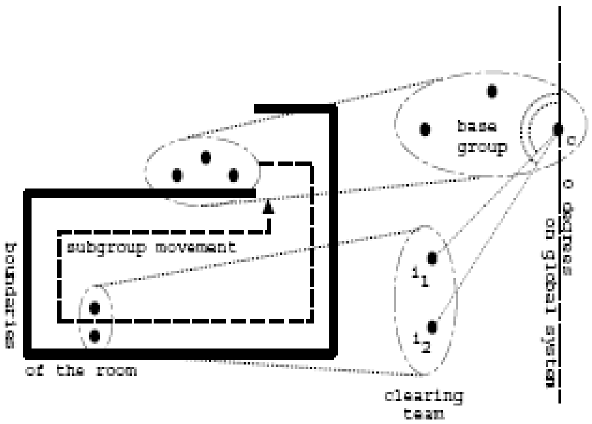

Figure 4: Firefighting team in a building: clearing a room

The destinations shown on the two sides of the figure 5 represent rooms or exhibition counters. During a building search, the police officers will move along the corridor, and a small team will be formed to search the rooms as they pass by. After searching a room, the team will join back the main force to move toward. Similarly, in an exhibition hall, delegates from a company may gather together when they enter an exhibition hall. When the group passes by a counter that some may be interested in, the small group may visit the counter while others may continue to walk forward. After visiting a counter for a while, the members will rejoin the main group again. The circles with arrows indicate the movement direction of each subgroup [4].

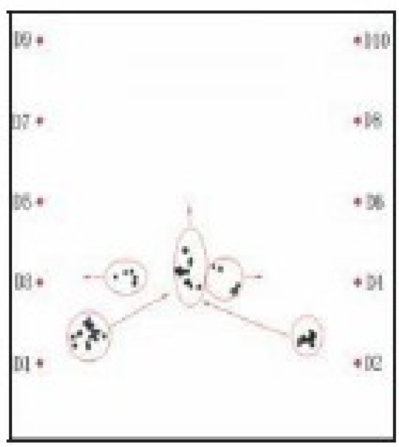

Figure 5: Building search

7 ROOM SEARCHING OR EXHIBITION HALL VISITING

8 BATTLEFIELD

During battlefield planning, topographical teams and support staff are responsible for conducting thorough terrain analyses to support commanders in battlefield planning. This analysis can range from elevation calculations and specifications of restricted and unrestricted terrain, to soil and vegetation data depending upon the specific needs of the commander and the battle situation. The commander's task of terrain analysis for the purpose of battlefield planning is usually two fold: 1) the analysis of the military aspects of the terrain, and 2) evaluation of the terrain's effects on military operations. On the battlefield, RRGM model is very useful. Each vehicle or in some cases each soldier represents a node in a larger tactical internet. Military units are fundamentally hierarchical, and they deploy, move and operate in groups that display tight adherence to a group structure that is known a priori [8].

Many other application scenarios, such as a fleet of warships or fighter planes in a combat maneuver, can also be modeled using RRGM. As such, all nodes will move within the area based on the random waypoint mobility model.

9 DISCUSSION

In this section, we have discussed a Reference Region Group Mobility model that is used in the description of group movement in mobile wireless ad hoc networks. As ad hoc network is most likely to be deployed to support group communication, such as in search and rescue, battlefield operations, etc., it is very unlikely that the mobile nodes will move around independently. Furthermore, in-group operations, groups may frequently sub-divide or merge whenever necessary. As most mobility models fail to describe such mobility patterns, our mobility model attempts to provide a better reflection of the group movement pattern with group partition and mergence. Examples have been provided to illustrate the applications of the model for different scenarios. With this mobility model, the effectiveness and the efficiency of group communication routing protocols could be evaluated under a more realistic environment. There are a number of ways to extend this initial work. The first of these relates to the size of coverage region. By using the density-based approach, our model can control the size of the region to be covered by a group. Density-based routing is of particular interest in mobile and unstable networks. In mobile networks, the closest node might leave or move to another location. In such scenarios, density-based routing increases the probability of successful packet delivery. This work can also be improved through further investigation on network disconnect prediction. Network disconnection causes the network to separate into completely disconnected portions. It is a widescale topology change that can cause sudden and severe disruptions to on-going network routing and upper layer applications. Using this model, we can predict the future network partitioning, and thus minimize the amount of disruptions. Finally, according to the fact that multicasting, in general, works well if the density of group members is sparse and in low mobility, this work can be improved through multicast routing based on cluster formation information in-group communications.

10 THE IMPACT OF MOBILITY MODEL

It has been shown that mobility patterns can affect the performance of ad hoc network routing protocol significantly. In this section, we will evaluate the performance of two routing protocols, AODV and DSR, under the Random WayPoint mobility model and the Reference Region Group Mobility model. The performance metrics collected include packet delivery ratio, average control packets per data packet delivered, end-to-end delay and average jitter. As shown in figure 6, as speed increases, the packet delivery ratio for RRGM degrades rapidly for both AODV and DSR as group partitioning occurs more frequently. For RWP, DSR's performance deteriorates rapidly as speed increases as DSR relies on the information stored in the route cache that may become invalid very soon when the node mobility is high. As a result, such invalid route information will cause the generation of route errors and initiate new route requests resulting in the relatively higher overhead than AODV as show in figure 7. It is worth noting that the amont of control packets generated by DSR under RRGM is much less than that under RWP, as paths generated for intra-group and inter-group communications for RRGM will mostly likely remain valid as long as the groups are not partitioned. Figure 8 shows that the end-to-end delay of DSR under RRGM is lower than that under RWP. Again, the lower delay is achieved with the possible intra-group communications and less control packets being generated under RRGM. Similarly, figure 9 shows that DSR has a smaller jitter under RRGM. On the other hand, the end-to-end delays and jitters of AODV under the two models do not differ significantly. This illustrates that AODV performs rather stable under different environment and is not very sensitive to group physical changes. Note that as velocity increases, the jitter of DSR is much greater than that of AODV. Figure 10 shows that when the group density is low, nodes are moving randomly around in a larger region and DSR performs badly. The performance of DSR improves as the density increases because information in the route cache will remain valid for a longer period of time with the area covered a group reduces. However, with further reduce in the group coverage area; the overlapping area among groups is reduced resulting in group partitioning. Hence, the packet delivery ratio reduces as group density further increases. As AODV does not rely on the cache information, it manages to achieve a higher delivery ratio. Similarly, figure 11 shows that the end-to-end delay of DSR decreases as density increases initially. This is because at low density, the overlapping area among groups is so large that even intra-group communication may employ members from other groups' as relays and the lifetime of routes constructed with nodes from different groups would not last long. As a result, the end-to-end delay at low group density is high. As the group density increases, the overlapping area becomes smaller and shorter routes for intra-group communication are more readily available resulting in the decrease in delay. However, with further increase in density, transient network partition occurs frequently resulting in a graduate increase in delay. On the contrary, AODV is not affected much by the change in density and the end-to-end delay is stabilized at a low value. Although AODV out performs DSR in the studies showed here, we can see that under RRGM, the difference in performance between DSR and AODV is not as drastic as in the case of RWP. With nodes moving in a smaller region covered by a group, the cached information kept by DSR remains valid for a longer while. Furthermore, if the group density is high, using DSR for intra-group communication will even outperform AODV [5].

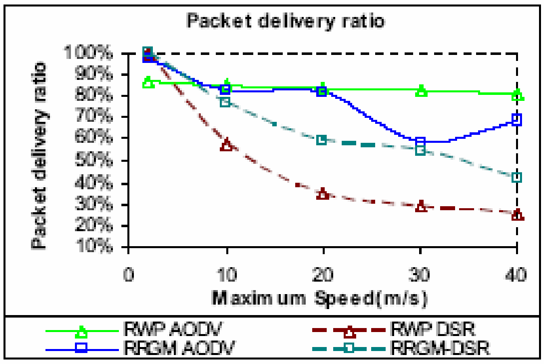

Figure 6: Packet delivery ratio vs. speeds

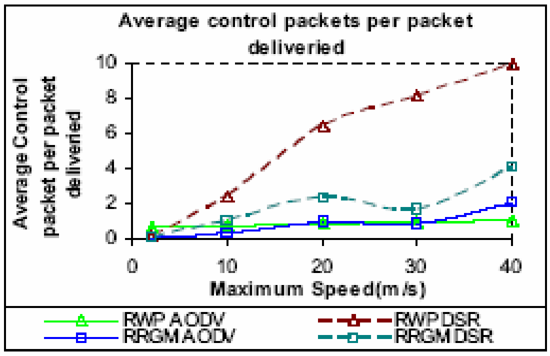

Figure 7: Average control packet overhead vs. speeds

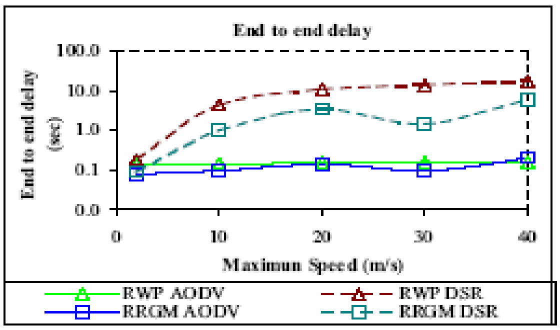

Figure 8: End-to-end delay vs. speeds

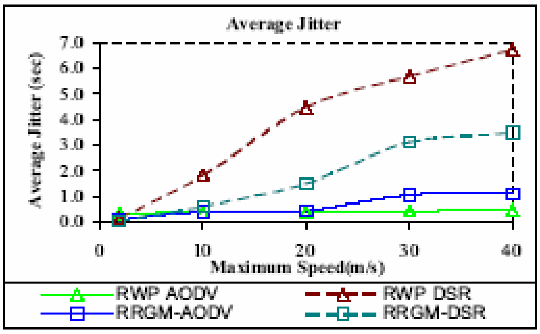

Figure 9: Average jitter vs. speeds

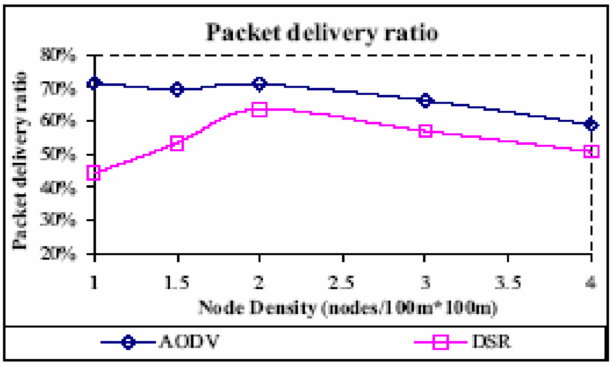

Figure10: Packet delivery ratio vs. node density

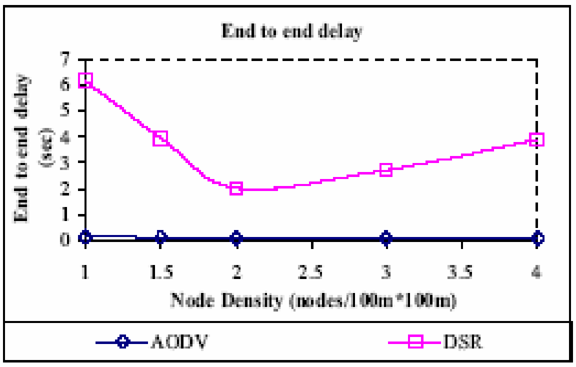

Figure 11: End-to-end delay vs. node density

11 CONCLUSIONS

The performance of an ad hoc network protocol can vary significantly due to the selected mobility model. It should be evaluated with the mobility model that most closely matches the expected real life system. Over the years, a number of group mobility models have been proposed for ad hoc networks. Most of them such as Reference Point Group Mobility model, model the movement of pre-defined groups, where nodes in the same group always stay together throughout the simulation process. Such models fail in modeling scenarios where groups may be partitioned and merged those are most likely to be found in ad hoc networks. These kinds of application scenarios can be found in search and rescue operations, conference seminar sessions, and conventional events. In this paper, in section 4 we presented RRGM model, which provides a better reflection of group movement behavior with possible group partition and mergence. Section 5 shows a group partition and merging processes. Some practical applications of RRGM model such as firefighters operating in a building, room searching or exhibition hall visiting, and battlefield are provided in sections 6, 7, and 8 respectively. In section 10 we have shown how two typical ad hoc routing protocols, AODV and DSR, perform in a group environment. From the simulation results, we see that AODV performs better than DSR in general, and for AODV, less data packets are delivered and more control packets are required under frequent network partitioning.

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