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SELF-ORGANIZED BEHAVIOR BASED MOBILITY MODELS FOR AD HOC NETWORKS

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ABSTRACT

Among the aspects that require a major interest in the simulation of mobile ad hoc networks (MANETs) is the mobility of nodes in the network. Several mobility models have been proposed. In this paper, we study the impact of self-organized behavior based models on the mobility of nodes in the network, through two models, namely: Flock Mobility model and Leadership mobility Model. The results are then compared to those provided by the Random Walk Mobility model. The analysis points to the relationship between two important and interdependent concepts: mobility of nodes in the network and communication/interference between nodes.

Keywords: *Self-Organized Behavior, Mobility Models, Cellular Automata, Interference/Communication Between Nodes*

1. INTRODUCTION

Mobile ad hoc Networks (MANETs) are created on the fly. No fixed infrastructure is included in the configuration of the network. An important component of the ad hoc network simulator is the mobility model, since it has a direct impact on the network topology. Once the nodes are initially placed, the mobility model dictates how the nodes move within the network. A variety of mobility models have been proposed for ad hoc networks [1]. These models differ in their movement characteristics. For example, the Random Walk Mobility model described in [2], assumes that a node moves from its current location to a new location by randomly choosing a direction and a speed in which to travel. The new speed and direction are both chosen from pre-defined ranges, [speedmin, speedmax] and [0, 2π] respectively. Each movement in the Random Walk Mobility model occurs in either a contant time interval t or a constant distance travelled d, at the end of which a new direction and speed are calculated.

A number of variations of the Random Walk Mobility model have been proposed. Among them the Random Direction model [3] and the Random Waypoint model [4]. In the Random Direction model, each node moves until it reaches the boundary of the simulation area. It then selects a new direction in which to move. The Random Waypoint model in turn, assumes that each node selects a random point in the simulation area as its destination, and a speed from an input range [speedmin, speedmax]. The node then moves to its destination at its chosen speed. When the node reaches its destination, it rests for some pause time, before selecting a new destination and speed, and resumes movement.

While each of these models generates random mobility and can be used for simulation study for ad hoc networks, none of them attempts to model the behavior of nodes in a realistic way. Birds, fish and crowds of people coordinate their movement to achieve coherent displacement. Other mobility models based on natural phenomena are then proposed. Such phenomena can represents coordinate animal motion such as birds fly in flocks, fish swim in schools, and sheep move as a herd.

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Flocking behavior was first simulated on computer in 1987 by Craig Reynolds [5] with his simulation program. This program simulates simple agents that are allowed to move according to a set of basic rules. In its initial version, the flocking behavior is controlled by three simple rules: Collision avoidance (avoid collisions with nearby flockmates), Velocity matching (attempt to match velocity with nearby flockmates), and Flock centering (attempt to stay close to nearby flockmates). The basic model proposed by Reynolds has been extended in several different ways. These include, for example, the works of [6-7].

Another model based on natural phenomena is the Leadership Mobility model [8]. In this model one or more special nodes, called Leaders, directing the other nodes. The leaders move according to Random Walk Mobility model, while the other nodes follow one of the leaders.

Several research studies have examined the impact of mobility on the performance evaluation of ad hoc network [1, 9], on the spreading of worms in an ad hoc network [10-19].The aim of this paper is to propose a cellular automaton [20, 21] based simulation model to study the communication/interference in mobile ad hoc networks (MANETs) whose nodes move according to three mobility models, namely, Random Walk Mobility model, Flock Mobility model and Leader Ship Mobility model. The choice of cellular automata models is because they are simpler, and can be easily implemented compared with other dynamical approaches. In cellular automata models, the space, the time and the velocity of hosts are assumed to take discrete values. When applied to MANETs, cellular automata uses a set of cells, each of them has two states to indicate if it is occupied or not by a host.

The paper is organized as follows. Section 2 is devoted to the description of our model. We will focus essentially on two important elements, namely, the mobility of nodes in the network, and the communication/interference between nodes in the network. The analysis of the results is given and compared in section 3. Finally, the conclusion and future works are given in section 4.

2. THE MODEL

The model presented in this paper represents the ad hoc network as a square grid of n x n cells, with nodes placed at each intersection (cell) as illustrated in figure 1. Each node communicates with its direct vertical and horizontal neighbors, such that each node has exactly eight neighboring nodes. Each cell can be occupied by exactly one host. Initially, N hosts are randomly distributed on the network.

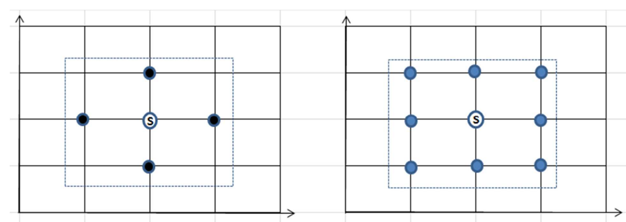

Figure 1. A square grid model for the MANET.

The central node (node S) has two types of neighborhood, the Von Neumann neighborhood (on the left) and the Moores neighborhood (on the right)

For any given host S at time t, the model uses two types of neighborhoods [22]:

- The Von Neumann neighborhood of S includes only the four cells immediately neighboring the cell occupied by the host S. These four cells are namely North, South, East and West.
- The Moores neighborhood of S is an extended Von Neumann neighborhood which includes, in addition, the four diagonally neighboring cells North-West, North-East, South-West and South-East.

A. Mobility of hosts

In this section, we describe in detail the mobility of hosts in the network. The hosts move on a square grid of n x n cells with periodic boundary

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conditions (number of hosts remains constant). The direction of each host is chosen according to Von Neumann neighborhood. Thus, each of the N nodes in the network moves in one of the four directions: north, south, east and west. Let $pos_i(t)$ = $(x_i(t),y_i(t))$ denote the position of the ith node at time t.

1. Random Walk Mobility Model

As mentioned in the introduction, the Random Walk Mobility model assumes that a node moves from its current location to a new location by randomly choosing a direction in which to travel. Starting from a given configuration at time t, the configuration at the next time (t+1) can be obtained as follows: each host starts with choosing the direction in which to travel in the next time step. This direction is randomly selected among the four directions, namely, north, south, east and west. The new position is then calculated based on the actual position and the new direction found previously. If this new position is unoccupied by another node, the host is moved according to this new position with probability p_{move}, else the host remains in its place.

2. Flock Mobility Model

For sake of simplification, in this model we have considered the flock in its simplest form. Thus we have retained only the third rule of the original version of the flock model. This rule reflects the fact that hosts, like birds flying within a flock, are attracted to each other as long as they are within the detection range. The detection range in our case is represented by the Moores neighborhood.

The only difference with the Random Walk Mobility model is the choice of the direction of hosts. In this model the direction is chosen according to the flock behavior. This behavior can be summarized as follows: at each time step, a host gets the list of its Moores neighborhood. From this list, the host can have an idea about the tendency of its neighboring nodes. This tendency constitutes the new direction.

In real flocks, a bird can move away from the group for various reasons, like avoiding predators or obstacles, for example. To translate this, we introduce a probability θ. Thus, at each time step, a host is moved in the network according to the flock mobility model with probability θ. This can be written formally as:

```
If θ > random then
        Moves the host using Flock Mobility model
Else
        Moves the host using Walk Random Mobility model
End if
```

Algorithm1: Hosts in the network move according to the flock behavior with probability θ.

3. Leader Ship Mobility Model

Although leaders and leadership are classical and recurrent topics that have inspired philosophers and writers for centuries, it was only in the last century that they began to be studied in a more systematic manner and become a main topic in several disciplines such as sociology, political science, business management and social psychology.

Once the nodes are initially placed on the network, the Leadership Mobility model selects one or more nodes as leaders. At each time step, the leaders move in the network according to Random Walk Mobility model, while the other nodes follow one of the leaders previously selected. This behavior can be summarized as follows: a node begin by getting the list of its Moores neighborhood, MNL. If there is only one leader in the MNL, the node follows this leader with probability θ (according to algorithm1). If there is more than one leader in MNL, the actual node chooses a leader randomly. Otherwise, the node moves according to Random Walk Mobility model.

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B. Communication and interference between hosts

The Moores neighborhood is adopted for the communication/interference between hosts in the network. That is, a given host S can communicate only with hosts located in his Moores neighborhood, and hosts of this neighborhood are the set of nodes that contribute towards interference with radio reception for node S.

At a slotted time t, let Pi(t) ∈ [0, Pmax] be the transmit power of node i, and g(xi(t) – xj(t)) be the channel gain function in the wireless medium, such that the signal emitted by node i and received by node j is Pi(t)g(xi(t) – xj(t)), where xi(t) and xj(t) are the positions of node i and node j respectively.

On the other hand, we have assumed that at time t, node i can transmit data to node j if the signal received by node j is strong enough compared to the thermal noise and interference. This can be written formally as:

$$\text{SNR} = \frac{\text{Pi(t)g(xi(t)-xj(t))}}{\sigma^2 + \sum_{k\neq i,j} P_k(t)g(xk(t)\text{-}xj(t))} \geq \beta \qquad (1)$$

Where SNR is the signal-to-interference ratio, β the SNR threshold requirement for successful communication and $\sigma 2$ is the background noise power. The term $\sum_{k\neq i,j} Pk(t)g(x_k(t)-x_j(t))$ is the interference contribution from nodes within the neighborhood of the receiving node j.

In this paper we have made some assumptions for sake of simplification. First, Pi(t) = P_{max} for all i, i.e. every node emit a maximal power which correspond to the worst case for interfering communications. Then, g(xi(t) – xj(t)) is distance-based and its value is given by $\frac{1}{d_{ij}^{\alpha}}$ where dij is the distance between node i and node j, α is the path loss exponent. Equation (1) becomes:

$$\text{SNR} = \frac{P_{rec,j}}{\sigma^2 + Pother} \geq \beta \qquad (2)$$

Where $P_{rec,\,j} = \frac{P_{max}}{d_{i,j}^{\alpha}}$ the signal power received by host j. The quantity $P_{other} = \sum_{k\neq i,j} {P_{max}}/{d_{kj}^{\alpha}}$ represents the interference contribution from nodes within the neighborhood of the receiving node j.

3. RESULTS AND ANALYSIS

In this section we present the simulation results of the communication/interference between nodes in the wireless ad hoc networks comprising N (=80) mobiles hosts distributed randomly in a square grid of 20 x 20 cells with periodic boundary conditions. The simulation uses one of the three mobility models, namely, Random Walk Mobility model, Flock Mobility model and Leadership Mobility model to move the nodes in the network.

Each point is simulated for T=2000 time steps, of which the first half (1000) were discarded to let transients die out and for the system to reach its asymptotic steady state.

We considered different values of the SNR threshold β to examine the effect of nearby nodes on the signal strength between node i and node j. β = 0 is used where a connection is always possible between two nodes in a given neighborhood regardless of other nodes in the neighborhood. On the other hand and in order to see the effect of other nodes within neighborhood of the transmitting pair of nodes, the values of β must be positive (β > 0). In this latter case, a connection is only possible if the signal strength between node i and node j is greater than the SNR threshold β.

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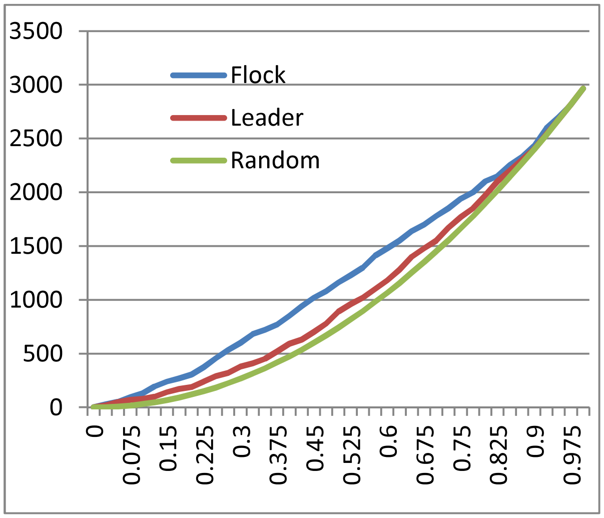

Figure 1. Number of active connections versus the density ρ in the case of β=0 for the three mobility models

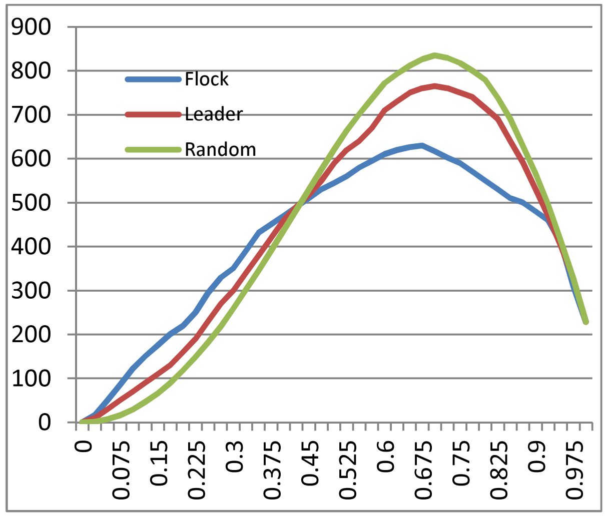

Figure 2. Number of active connections versus the density ρ in the case of β>0 for the three mobility models

The results of the figure 1 display the number of active connections as a function of the density of the network ρ for three mobility models: Random Walk Mobility model, Flock Mobility model and Leadership Mobility model. We can see clearly that for β=0, the relationship between the number of active connections and the density of the network appears to be exponential in nature. This is obvious since for this case, i.e. for β=0, all nodes of the neighborhood communicate with the actual node, regardless to the interference between nodes in the network.

On the other hand, for the three models, the Flock Mobility model is the one who shows more active connections than the others. This is due to the nature of the mobility of nodes in the network. But all the curves tend to the same value, when the density becomes more serious (about ρ>0.8).

For β>0 (figure 2), the number of active connections (NoC) increases, reaches a certain value NoC_c for the densityρ_c, and then decreases as the network approaches saturation state. This result is expected, since increasing the number of nodes in the network increases the number of neighbors and therefore the number of active connections. But once the network approaches the saturation state, the number of interferences increases, causing then a reduction in the number of active connections.

As one can see clearly, the value of NoC_c is affected by the nature of the mobility of nodes. In fact, for the Flock Mobility model, the value of the NoC_c is smaller compared to the other models. This result can be interpreted as follows: with the Flock Mobility model, the nodes tend to be concentrated quickly causing interference between nodes.

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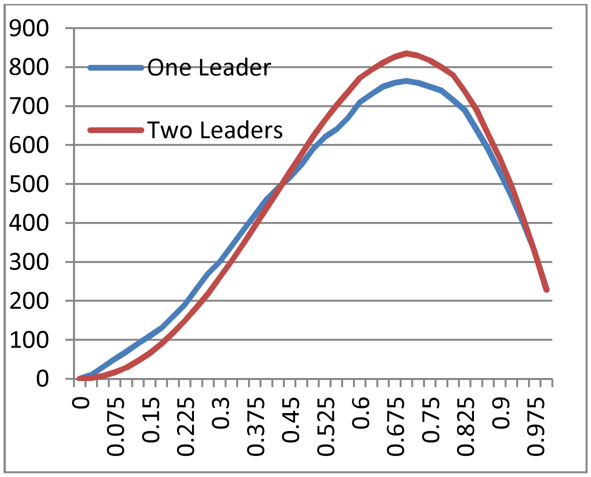

Figure 3. Number of active connections versus the density ρ in the case of $\beta>0$ for the three mobility models

Finally, as one can see from figure 3, the number of leaders has an impact on number of communications between hosts in the network. If we increase the number of leaders, the number of active communications decreases. This result is immediate since, many leaders promote the formation of many groups of nodes, while for one leader; the hosts tend to follow it to form a single group.

4. CONCLUSION AND PERSPECTIVE

In this paper we have studied the communication/interference between nodes in mobile ad hoc networks using thee different methods of mobility: Random Walk Mobility model, Flock Mobility model and Leadership Mobility model. Our results show that the communication/interference between mobile nodes of an ad hoc network is greatly affected by several factors, such as, the way by which hosts move in the network and the value of the Signal to Interference Ration (SNR) threshold.

With the absence of collision detection in this work, collisions are more likely to occur and causing, then, more interferences between nodes in the network. In future works, we plan to integrate the mechanism of collision avoidance CSMA/CA (Carrier Sense Multiple Access/Collision Avoidance) to explore how it affects communication/interference between mobile hosts in the network.

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