A Novel Mobile Awareness Mechanism in Wireless Ad Hoc Networks without GPS

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Abstract

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A mobile Ad Hoc Network is a wireless multihop network without any existing infrastructure. In such a networking environment, each mobile node can move freely such that the network topology changes dynamically. This may frequently result in the link breakdown, thus causing network inefficiency and data loss. In this paper, we develop a simple heuristic mechanism to characterize the instant mobility of network nodes. We assume that all network nodes can move arbitrarily, and none of them is equipped with any positioning device (such as the GPS system). Each mobile node is (at any time) classified as either a low mobility node or a high mobility node. A mobile node estimates its own mobility type by comparing the signal strength of consecutive received messages sent by its low mobility neighboring nodes. It then broadcasts this mobility type information to its neighbors. The mobility estimation algorithm is thus fully distributed and self organized. Simulation results have revealed that such a mobility estimation algorithm can achieve a reasonably high degree of accuracy for a wide range of networking environments. Once the nodes can be classified as either high mobility or low mobility, we can take the advantage of characteristic of low mobility nodes for some applications, such as path setup, cluster head election.

Section I: Introduction

The appearance of Internet makes information exchange more quick and precise, and there exist more and more applications based on Internet. More and more users are expecting to connect to Internet all the time to get the information from all over the world. Wireless network provides the environment for people to connect to Internet freely without the limitation of wired networks. Currently, we can easily use an infrastructured wireless network architecture to connect to Internet. Such a network structure is characterized by a mobile node which utilizes the air interface to connect to a fixed infrastructure, such as the base station if the cellular network or the access point if the Wireless LAN structure. Many researchers, developments and products have appeared for these types of wireless networks[1][2][3][4].

For some special situation, it is difficult to setup the base station or if there does not exist any base station. Thus the study of Mobile Ad Hoc Networks without any existing network infrastructure is a trend in these years. The related research topics include fault tolerance, signal strength[5], signal interference, mobility[6][7], power saving[8] and so on. Therefore the self-oganized wireless ad hoc network without the base stations becomes a hot research topic in recent years[9][10]. It is usually called Mobile Ad Hoc Networks(MANET) or Wireless Ad Hoc Networks. In wireless ad hoc networks, each node moves freely in the network. Mobility is thus one of the important properties in MANET. If the nodes move very fast in the network, it usually cause the efficiency of the network downgrading and the probability of packet loss higher. High mobility nodes in the networks may cause significant performance degradations, such as the difficulty in path setup, link breakdown packet loss, etc.

Many researchers have studied the mobility problems and proposed a few corresponding algorithms. However, most of these research works use the GPS-like positioning system as an auxiliary tool to obtain the mobile characteristic of network nodes[11][12][13][14][15][16][17]. Some algorithms may not need GPS-like positioning system to operate but still need some fixed systems to act as reference points. Thus moving nodes get their positions with the help of the reference points.

In this paper, we propose and design a mobile awareness algorithm for mobile networks without the GPS-like positioning device and any fixed systems. The mobile characteristic of each network node falls into either high or low mobility type. A simple real-time mobility estimated mechanism is developed such that any single node can utilize the successive signals received from its neighbors to estimate its own mobility type. The node spontaneously broadcasts its mobility information to its neighbor nodes and there exists no central control unit. This is a truly self-organized wireless ad hoc network. With the mobility awareness, we favor the low mobility nodes than high mobility ones in some applications. For example, when we want to construct a path from node A to node B, we may want a long valid time of the path, at least longer than total data transmission time. The path composed of low mobility nodes may provide the required stability while that composed of high mobility may not provide one. In cluster algorithm, how to elect the cluster head is one of the important topics and there exist many election algorithms, like minimum id, maximum connection, and so on. A cluster head plays the role of communicating with its cluster member and sending messages to other cluster heads. Cluster head re-election is a complex and inefficient opeartion. After the cluster head is elected, the network topology changes and the path needs to reroute. If we can select the stable nodes as the cluster head to reduce the frequency of cluster head re-election procedure, the overall efficiency will arise. Hence, the study of mobile awareness algorithm will establish a foundation for many applications to achieve a higher level of correction and efficiency.

In Section II, we will describe our mobility awareness mechanisms in details. In Section III, the simulation environments and the associated node movement models are developed. Illustrative performance evaluation via simulations is carried out in Section IV. Finally, the conclusion is drawn in Section V.

Section II: Mobile Awareness Mechanism

In this section, we describe our proposed mobile awareness mechanism in detail. We asuume none of the network nodes is equipped with any positioning device like GPS receiver. Each node broadcasts a hello message (as the beacon signal) periodically to notify its own presence to all of its neighboring nodes. All of the hello messages(transmitted by different network nodes) are broadcast with the same transmission power. It is well known that for an isotropic radiator, the received signal power density is inversely proportional to the square of the distance between the transmitter and the receiver. Therefore, by measuring and comparing the consecutively received signal stengths, we are able to estimate the relative position displacement between the two nodes, under the sufficiently high signal-to-noise ratio network environment. Furthermore, each network node is (at any time) classified into a low mobility type or a high mobility type. We thus propose the following mobility awareness algorithm, employed by each network node to estimate its own instantly mobile behavior. Such a mechanism is thus fully distributed and is conducted through two phases. Take node (A) as an example. In phase one, node (A) measures the relative distance change between itself and each of its neighboring nodes, and then determines the effective number of useful links. In the second phase, node (A) utilizes the relative mobility information provided by those useful links and apply a simple majority rule (described later) to determines its own current mobility type. It will then broadcasts its own mobility type along with transmission of the hello message. The detail of these two phases are further described as follows.

Phase I: Receiving process for calculating useful distance information

As we described previously, a receiving node, denoted here as node (A), can measure the successive signals, transmitted by a transmitting nodes such as node (B), to determine the relative distance change between the pair of these two nodes. If such a distance difference is greater than a mobility threshold C_m, that means the distance between these two nodes changes a lot in a short period of time. It is worthwhile to notice that only the *relaive* distance change can be measured. Furthermore, any network node is simply classified into the high or low mobility type. If node (B) claims itself to be the high mobility one, the relative distance change information is not sufficient for node (A) to determine its own mobility type. Therefore, we discard such link information in our proposed mechanism. However, if node (B) claims itself to be the low mobility node, this means that node (B) is moving slowly or stands still currently. The relative distance change between these two nodes may provide useful information for node (A) to estimate its own mobility type. Therefore, we consider this as the effective distance information. Since a node may find more than one neighboring nodes at any time, a few effective distance data may be obtained. The detailed work flow for receiving process is provided in Figure 1 as follows.

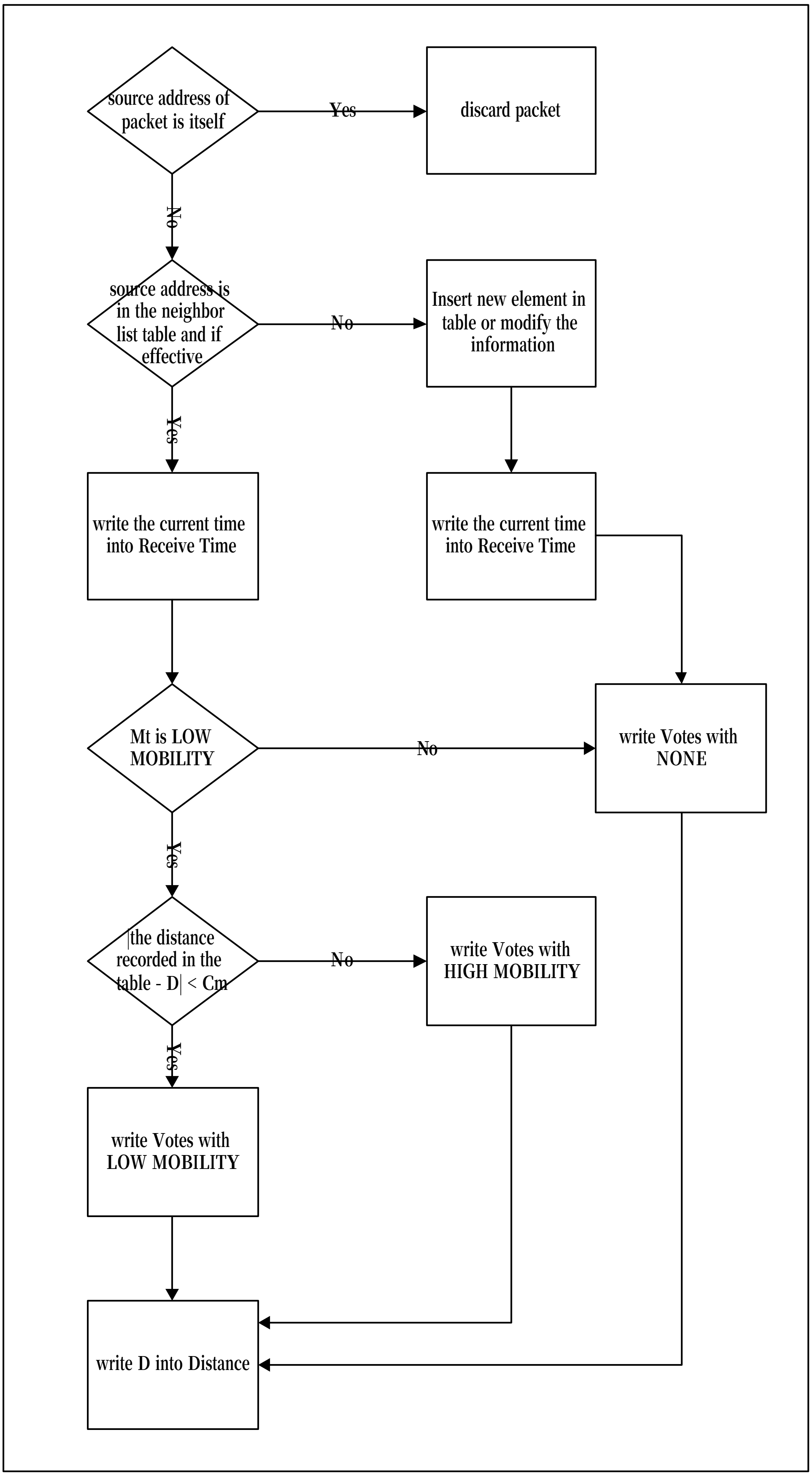

Figure.1 Work flow of receiving hello message

In Figure 1, when the node receives a hello message from the neighbor node, it will look up the neighbor list table to check whether this node has recently received the hello message sent from the same neighboring nodes. If this hello message is not the latest of the successive messages, the node will write the related information into the neighbor list table and write NONE in the column of Vote. If this hello message represents the latest of the successive messages from the underlying neighboring node and also this neighboring node belongs to the low mobility type currently, the node will compare the distance derived from this hello message and the previous hello message. If the distance difference is larger than the mobility threshold C_m, the node will set own mobility type to be high, otherwise it will assume that its mobility type is low.

Phase II: The majority rule and the sending process

A network node periodcially broadcasts the hello message with its own (calculated) mobility type incorporated. Since a network node may find many neighboring nodes, thus receiving more than one pair of useful distance data, it will apply a majority rule to estimate and determine its own mobility type before the transmission of the hello message as follows. Take node (A) again for illustration. If Node (A) has received n distance information from n neighbor nodes and only k of them are low mobility ones, Node (A) will obtain k effective distance information. Among these k pairs of effective distance information, assume that i of them is calculated to be greater than the mobility threshold. Let C_v represents the majority threshold parameter, where $0 < C_v < 1$. The majority rule is then carried out as follows.

- if $(i / k) >= C_v$, Node (A) will declare itself the low mobility type
- if $(i / k) < C_v$, Node (A) will declare itself the high mobility type

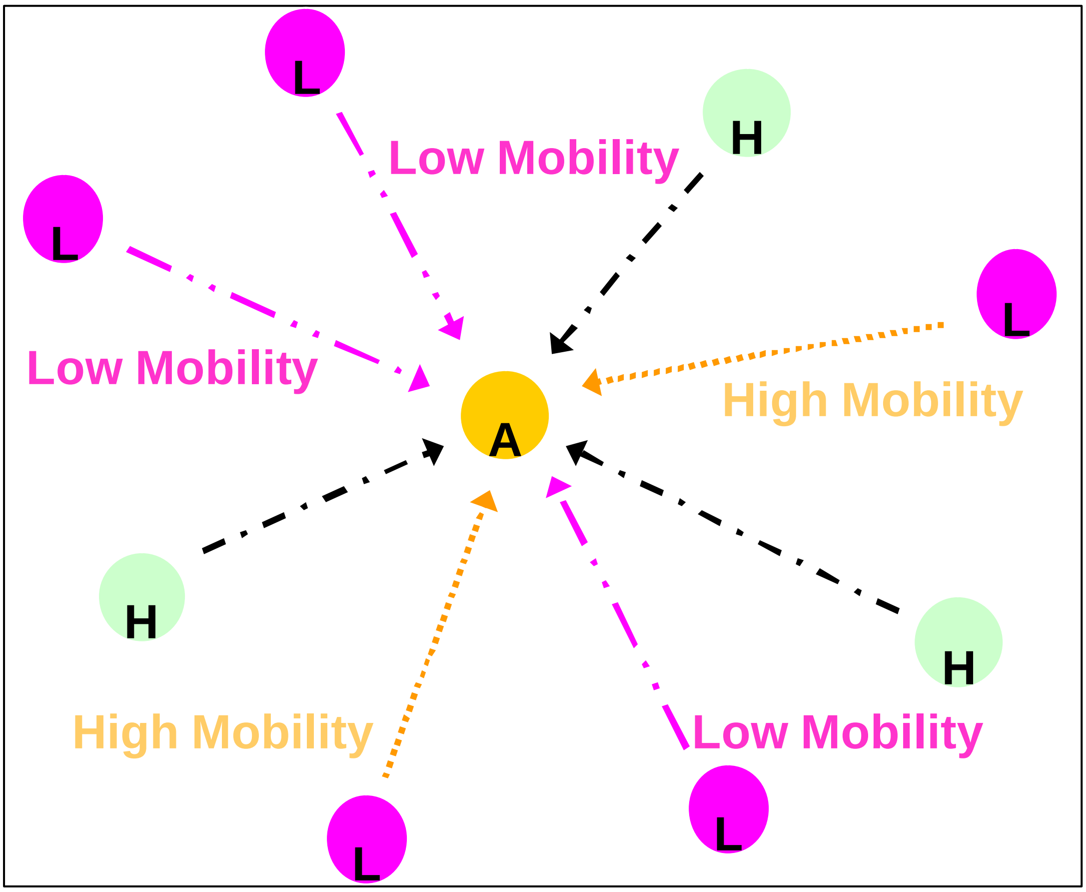

Figure.2 Example of majority rule

In the illustrative example of Figure 2, there are 8 neighboring nodes of Node (A), and 3 of them are high mobility, 5 of them are low mobility. Thus k=5. From these 5 low mobility neighbors, Node (A) acquires 2 High Mobility distance information as well as 3 Low Mobility distance information. Thus i =3. If C_v=0.75, (i / k) = 0.6 < C_v = 0.75, which means there are not enough number of relative Low Mobility information from its low mobility neighboring nodes. Then Node S will claim its mobility type is high mobility. However if C_v=0.5, (i / k) = 0.6 > C_v = 0.5, which means there are enough number of Low Mobility information from low mobility neighbor nodes. Then Node S will claim its mobility type is low mobility. Therefore, the majority threshold parameter, C_v, represents an important system parameter for our mobile awareness mechanism.

The detailed work flow of sending the hello message is in Figure 3.

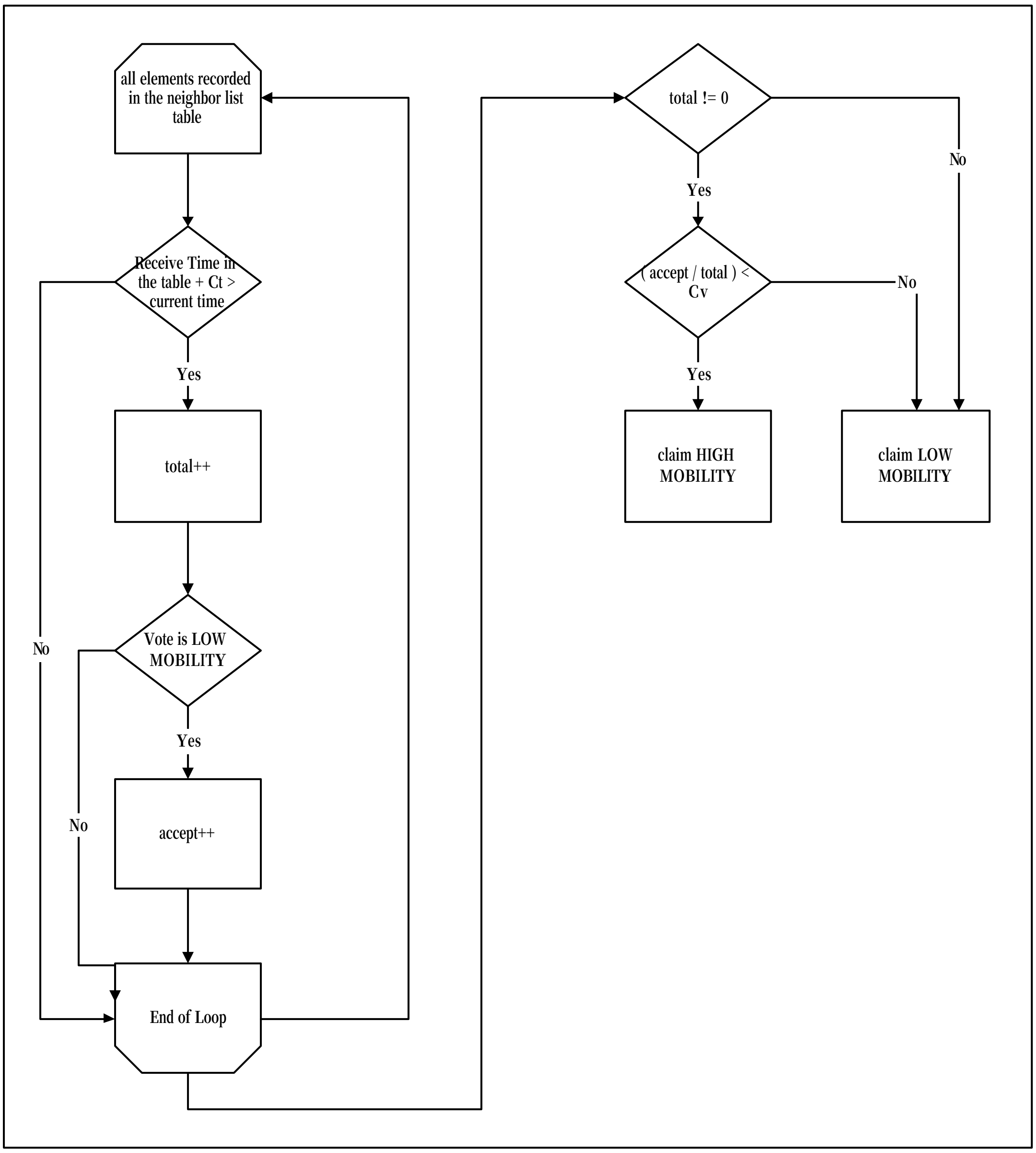

Figure.3 Work flow of sending hello message

As revealed in Figure 3, before a network node sends its hello message, it must estimate its mobility type first and then include this information into the hello message. It first check its neighbor list table and pick up the effective records. In these records, there are three kinds of values written in the neighbor list table, NONE, LOW

MOBLITY, HIGH MOBILITY. We will not consider any records whose value is NONE. In the work flow, The total number of LOW MOBILITY and HIGH MOBILITY is “total” and the number of LOW MOBILITY is “accept”. Compared to Figure 2, the value of “total” is k and the value of “accept” is i. Thus the majority rule calculation constitute the major process for sending the hello message.

Section III: Simulation Environment and Node Movement Model

In this section, we will evaluate the performance of mobile awareness algorithm in the wireless ad hoc networks. In the simulation, we select Waypoint mobility model as the basic node mobility model. In the Waypoint mobility model, when the node choose its destination position, the moving speed and the pause time as the current movement parameters, it uses the same moving speed toward the destination position and pauses for a certain period of time after arriving at the destination. However, we find such movement model may cause some undesired results for our simulation environments. Suppose the moving area is large enough and the node chooses a destination far from the starting position. If the moving speed is very slow, then the node will maintain such a low speed for a long time even during the simulation time. On the contrary, the high speed nodes will move in a short time relatively. Thus the topology changing is not drastic. The simulation result of Waypoint mobility model is shown in figure 4.

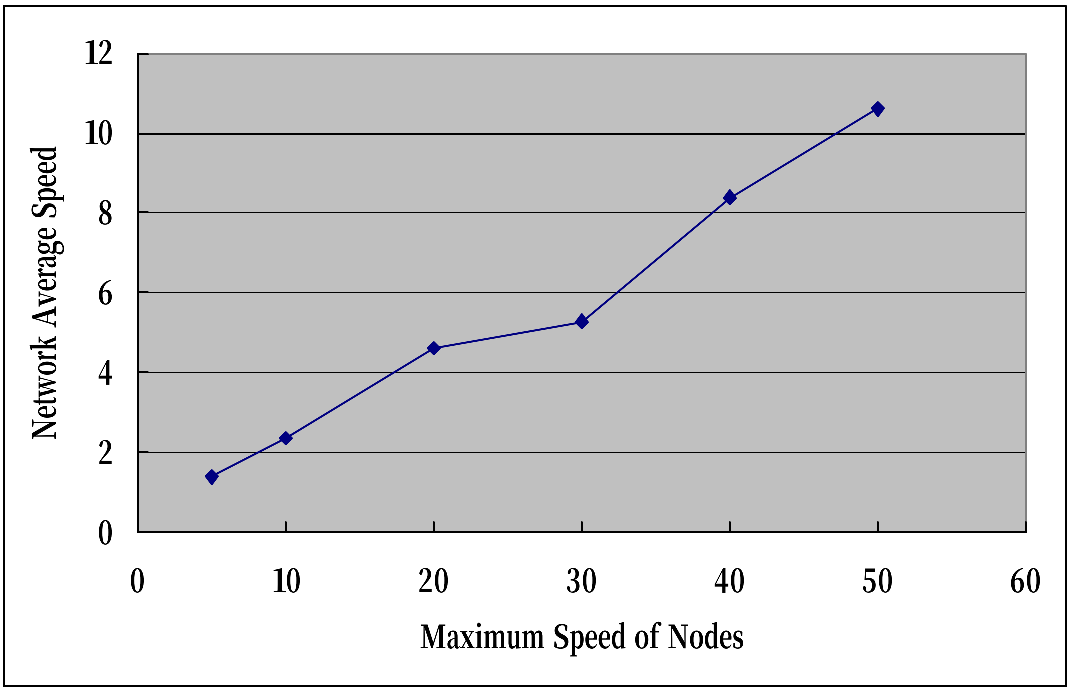

Figure.4 Waypoint mobility model

In the simulation, there are 16 nodes moving freely in 1000m x 1000m area, the moving speed is uniformly distributed. In Figure 4, x axis represents the maximum speed of the uniform distribution and y axis denotes the network average speed. As we can see, if the moving speed is uniformly distributed between 0m/s to 20m/s, the network average speed is below 5m/s. If we set maximum speed to 40m/s, the network average speed is around 8m/s. We still cannot obtain a sufficiently high changing topology even we choose the maximum spped to 50m/s where we only have the network average speed reaching 10m/s. It is noted that 50m/s already represents the very high moving speed of 180km/hr. We thus design a modified movement model, named Modified Waypoint mobility model, to incorporate a highly changing topology for our simulation study. The mechanism we designed is Lower Speed Shorter Distance. If a slow moving node with speed lower than a speed constant S_L, the maximum distance the node can move is limited to a range constant D_u. Thus we can create a more dynamically changing network topology to evaluate our Mobile Awareness algorithm. The result of Modified Waypoint mobility model is shown in Figure 5.

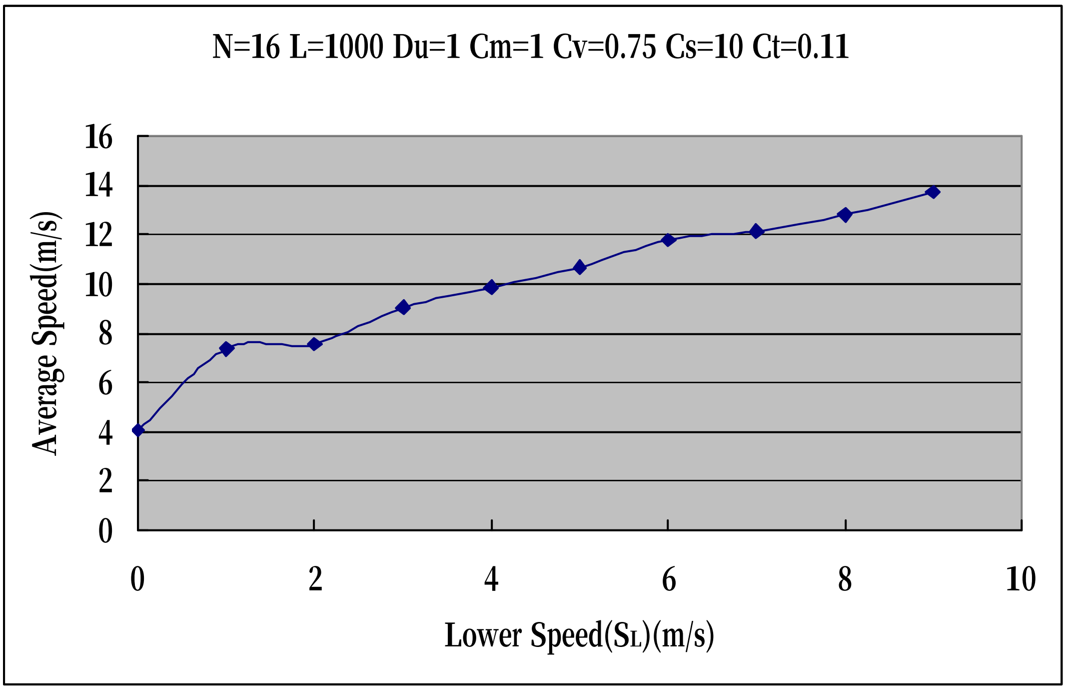

Figure.5 Modified waypoint mobility model

In Figure 5, the speed uniform distribution is from 0m/s to 20m/s and we can change the network average speed by changing the threshold of Lower Speed(S_L). In our simulation, we adopt Modified Waypoint mobility model as the node movement model.

The table 1 describes the parameters and their associated notations used in the simulation environment.

N	number of total nodes
L	length of the square moving area in meters
D_u	range constant in modified waypoint mobility model
S_L	speed constant in modified waypoint mobility model
C_m	mobility threshold

C_v	majority threshold
C_s	boundary speed of mobility type
C_t	period of hello message

Table.1 Simulation parameters and notations

Section IV: Performance Evaluation

In this section, we evaluate the performance of our proposed mobility awareness mechanism via simulations. We are mainly concerned with the correct probability of mobility type estimation. We show the simulation results in Figure 6 and Figure 7.

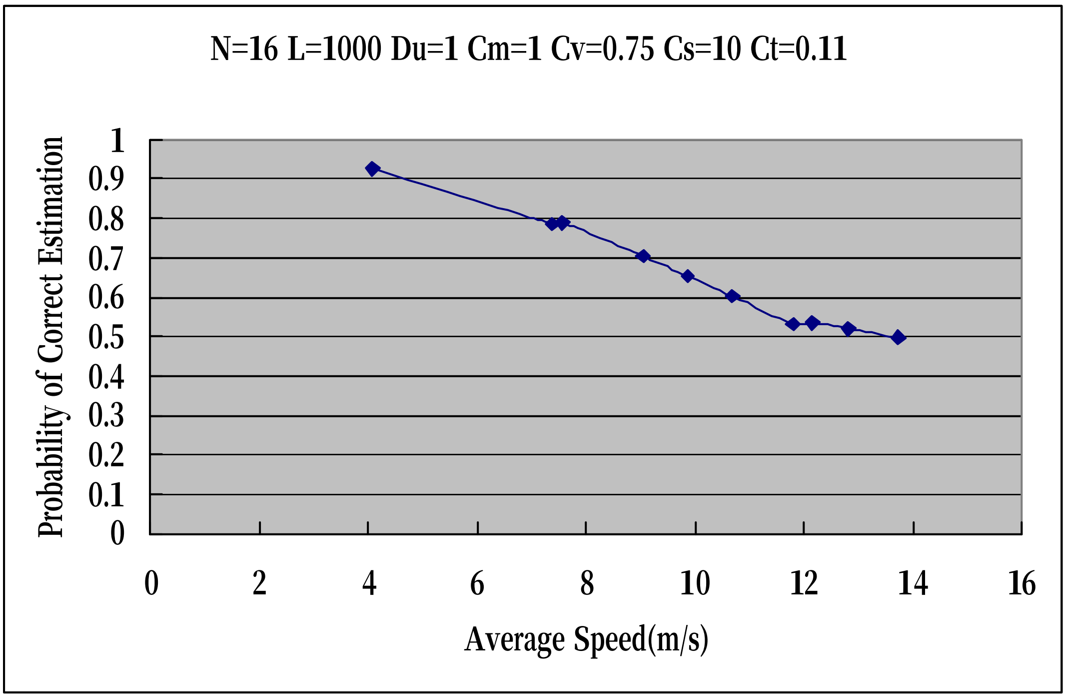

Figure 6

Probability of correct estimation under different network average speed

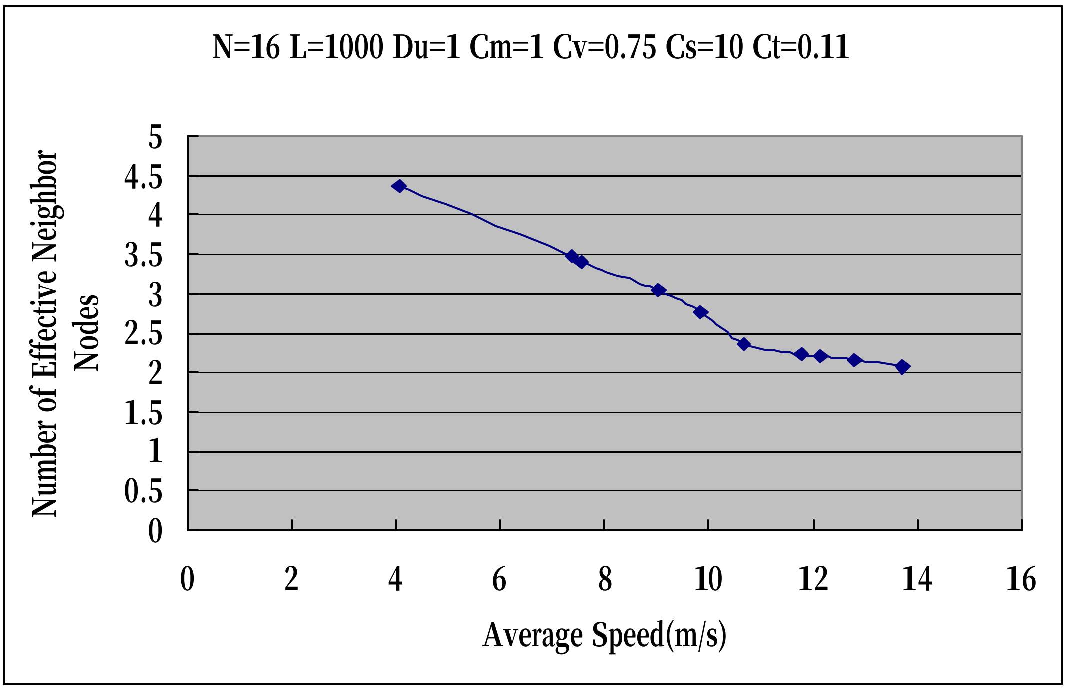

Figure 7

Number of effective low mobility neighboring nodes under different network average speeds

As the average network speed increases, the probability of correct estimation and the number of effective neighbor nodes decline. Since the number of the high mobility nodes increases, the number of effective low mobility neighboring nodes decreases and the requirement of the node estimating its mobility type as low mobility is strict when the network averge speed arises. After all, the probability of correct estimation is above 50% even when the network average speed reaches 14m/s while the maximum speed of the node is 20m/s.

Then we evaluate the moving area corresponding to the total number of nodes. The network environment are set to 1000m x 1000m and 2000m x 2000m, and the total numbers of nodes are 16, 50, and 64. We show the simulation results in figure 9.

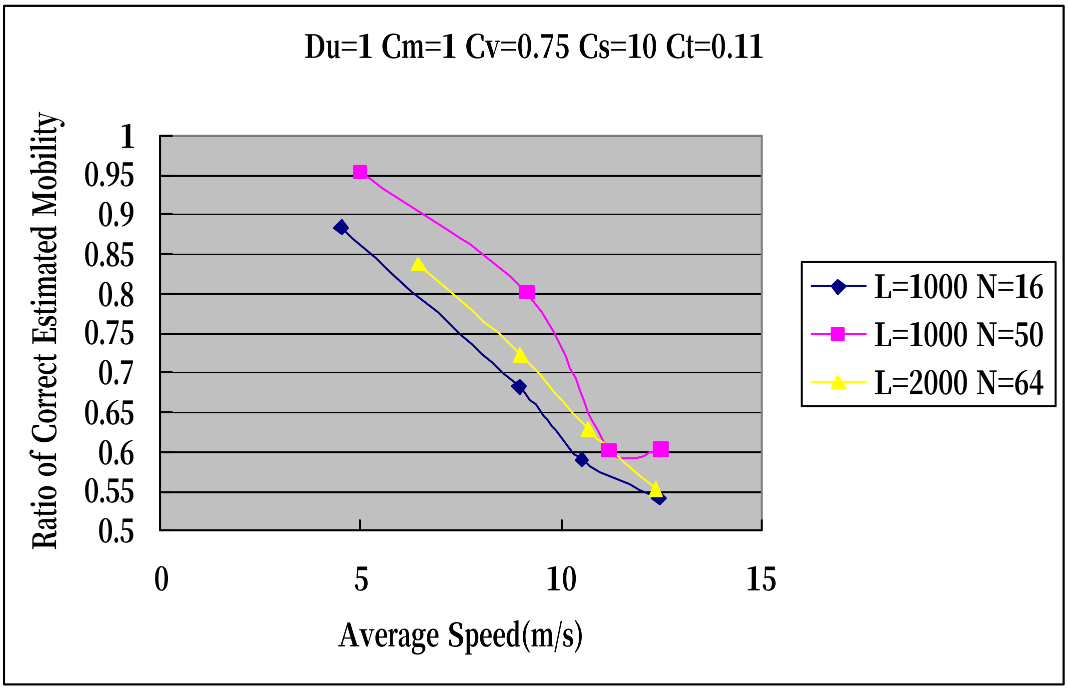

Figure. 8 Different dense of nodes

In Figure 8, we first compare the simulation results of N=16 and N=50 in the same moving area of L=1000m. Simulation results show that the more total number of nodes, the more accurate of the estimation. This is reasonable because more nodes means more effective neighbor nodes and the estimation will be more accurate. But we take a look to the simulations of N=16 with L=1000 and N=64 with L=2000. The nodal density of two networks is the same because of 16/(1000*1000) = 64/(2000*2000). Although the correct estimation probability of 64 nodes is larger than that of 16nodes, the ratio of correct estimated mobility is not exceeding 5% to the N=16 with L=1000. Then we compare N=16, N=50 and N=100 with the same L, L=1000. The simulation result is shown in Figure 9.

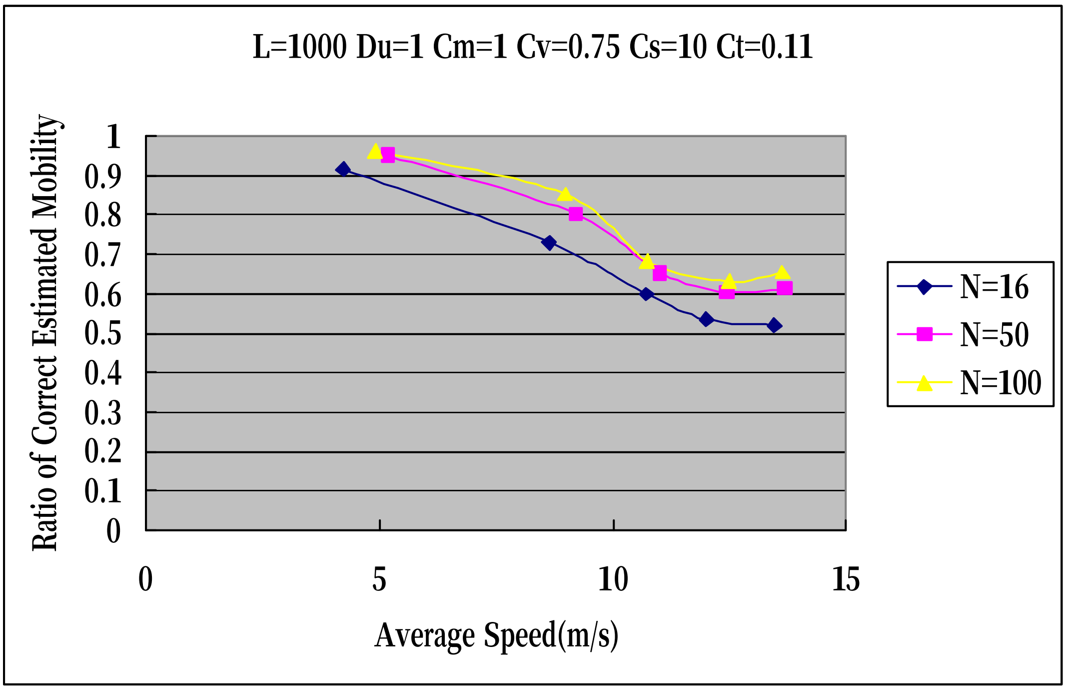

Figure. 9 Different dense of nodes

From Figure 9, with the same value of L, larger N indicates higher ratio of correct estimated mobility.

The reason why the node fails to estimate it mobility type correctly can be classified into two apsects. One is overall and another is because of the speed of the node.

Overall, our Mobile Awareness algorithm is to estimate the absolute speed of each node. However, when the node estimates the distance difference of two nodes, it can only obtain the relative speed. For example, if two nodes are moving with the speed of 10m/s toward the opposite direction, the relative speed is 20m/s. As for the incorrect mobility type estimation due to the aspect of the speed of the node, two cases can be observed. One is that the slow moving node incorrectly estimates its mobility type to a high mobility type and the other is the fast moving node incorrectly estimates its own mobility type to a low mobility type. The reasons why the slow moving node incorrectly estimates its own mobility type to be high is as following.

1. The number of effective neighbor nodes is not enough. Effective neighbor nodes are the neighbor nodes which claimed its mobility type low mobility. If C_v is large and the number of effective neighbor nodes is not enough, the low mobility nodes will be hard to estimate their mobility type as low mobility. For example: in figure 7, when the network average speed is above 10m/s, the number of effective neighbor nodes is 2. We have set C_v 0.75 in the simulation environment and because the number of effective neighbor nodes is 2, then the node only can get two effective distance information. Therefore the node must get two LOW MOBILITY records in theses 2 effective distance information to estimate its mobility type as low mobility. Besides, the probability of correct estimation of effective neighbor nodes is also another reason of wrong mobility estimation.

Now we consider the reason why the high mobility node incorrectly estimates its mobility type to a low mobility type:

1. If the number of effective neighbor nodes is zero, there exists no any reference node around the node. In the situation, the node will claim its mobility type as a low mobility type according to our Mobile Awareness algorithm.
2. The node with high moving speed may not cause relative distance difference larger. We show the example in Figure 10. In Figure 10, assume that node B claimed its mobility type as low mobility. Node A receives the hello message from Node B then moves the distance L3 to arrive at A'. Node A receives another hello message from node B again. The difference of distance is L1-L2 and if |L1-L2| is smaller than C_m, node A will record LOW MOBILITY for this distance difference information.

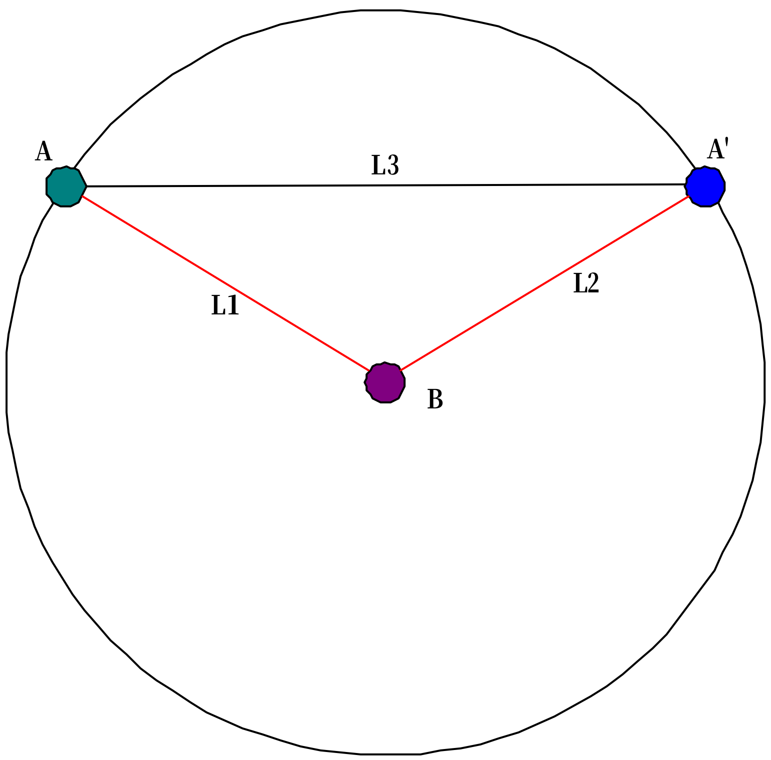

Figure.10 High speed node may not cause greater difference of distance

Section V: Conclusions

In this paper, we propose and develop a simple heuristic mechanism to characterize the instant mobility type of network nodes. We assume theat all network nodes can move arbitrarily, and none of them is equipped with any positioning device. The network nodes cooperate to calculate the instant mobility type. With distance information of neighboring nodes and a simple majority rule, the node can estimate its mobility type. Then the node will broadcast its mobility type to its neighboring nodes.

From the simulation result of section IV, Mobile Awareness Algorithm does provide the ability of mobility estimation to the nodes in wireless ad hoc networks. We have evaluated the performance of Mobile Awareness Algorithm and we found that the ratio of correct mobility estimation is related to the average network speed. The nodes will have 60% above to correct estimating its mobility type while the average network speed is around the boundary of the mobility type. In our simulation, even if the average network speed reaches 15m/s(the maximum speed of the nodes is 20m/s), the ratio of correct mobility estimation is still above 50%. The performance of Mobile Awareness Algorithm is well in the simulation. We also evaluate how the nodal density of networks is related to the correct mobility estimation.

We have mentioned some issues of wrong mobility estimation in section IV and we are working out the solution to these problems. Since mobile awareness algorithm acheives a certain degree of correct mobility estimation, we will survey the superioty of the low mobiltiy nodes over the high mobility ones and take advantage of the low mobility nodes. The research of path setup using low mobility is underway and we find the path composed of low mobility nodes having higher connection time from the preliminary results.

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