DYNAMIC GROUP MOBILITY MODEL
FOR HYBRID NETWORKS

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ABSTRACT
This paper presents a dynamic group mobility (DGM) model for hybrid networks. In this model, the ad hoc network is placed in the cellular system. In ad hoc network, mobile nodes (MNs) can dynamically re-configure themselves triggering group partition and mergence. Therefore, MNs sometimes merge and move together and sometimes split and move individually. In cellular system, when group MNs roam from one local area to another, the group leader ensures the location update for the whole group. Since it is too expensive for each MN within the group to communicate all the time with the base station (BS), we designate the group leader to ensure the location update and the administrative tasks for the whole group. This allows to reduce the power consumption, and to limit the wireless bandwidth used.

Keywords: Mobility, Hybrid networks, Group leader, Group partition, Group merging, Simulation.

1 INTRODUCTION
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 many real life applications, 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 MNs can dynamically re-configure themselves triggering group partition and mergence. A good realistic mobility model must capture all these mobility dynamics in order to yield realistic performance evaluation results [2]. In this paper, in section 3, we present a group of three individuals of which one Worker, one Seller, and one Businessman; belonging to a single home. Depending on time of the day, individuals move either from home to workstations or from workstations to home. On the way to the workstations or back from the workstations, they move sometimes together and sometimes separately. Alternatively, they merge and split at some reference points placed on the way of workstations. On the other hand, the existing group mobility models assume that nodes in the same group stay in a homogeneous network throughout the whole simulation process. In DGM model presented in this paper, movement MNs in the scope of the group happens in ad hoc network while group movement from one local area to another happens in cellular system. In cellular system, when group MNs roam from one local area to another, the group leader ensures the location update and the administrative tasks for the whole group. This allows the reducing of the power consumption, as well as the limitation of the wireless bandwidth used. The paper is organized as follows. Section 2 presents the structure of DGM model. The model is an integration of ad hoc network and cellular system. Section 3 presents intra-group movement i.e. movement MNs in the scope of the group. In Section 4, we present inter-group movement i.e. when group MNs roam from one local area to another. Section 5 analyses the power consumption during inter-group communication i.e. communication between MNs and the base station. Section 6 analyses the performance of the model in ad hoc network through simulation results.
Conclusions and references appear in sections 7 and 8, respectively.

2 STRUCTURE OF DGM MODEL

Figure 1 illustrates the structure of DGM model. The model realizes an integration of ad hoc and cellular networks, i.e., ad hoc network for intra-group movement and cellular system for inter-group movement. It eliminates the need for each MN within the group to communicate with the base station. The group leader does this job for whole the MNs within the group. Group MNs is indicated by the yellow circles. The group moves from local area LA1 to local area LA2, separated by the line “LA border”. Group movement from LA1 to LA2 is indicated by the dashed arrow [8].

3 INTRA-GROUP MOVEMENT

Intra-group movement happens in ad hoc network when MNs move in the scope of the group. Ad hoc network is the infrastructureless mobile network which has no fixed gateways (routers). All nodes are capable of movement and can be connected dynamically in an arbitrary manner. Nodes of these networks function as routers which discover and maintain routes to other nodes in the network. Example applications of ad hoc networks are emergency search-and-rescue operations, meetings or conventions in which folks wish to quickly share information, and data acquisition operations in inhospitable terrain [1]. This section provides the movement of three individuals of which one Worker, one Seller, and one Businessman.

3.1 Trip Chain

The trip chain is a sequence of actions to be executed; execution of an action requires person to change location (for example, shopping requires going to shops, lunch requires going to restaurants, etc…). After finishing current activity, the next activity is chosen and new movement is initiated [6].

Figure 2 illustrates the weekday’s trip chain of individuals. In this example, 4 switch stations are placed in the trip chain. At the switch stations either the group partitions into individuals or individuals merge into group. Such group dynamics happen under the control of configured partition and merge probabilities. Each group member is defined with a member stability threshold value. At the switch stations, each individual in the group will check whether its stability value is beyond its group stability threshold value. If it is true, this individual will choose a different path. A group partition happens. When several individuals arrive at the same station and select the same path for the next movement, naturally, they will merge into one group [2].
from their respective workstations. After lunch, individuals move together toward the reference point switch station 2. Here, the group partitions and everyone moves toward his own predefined destination. At the end of daily’s activities, individuals merge into group at the reference point switch station 3 and together return back at home as centroid.

3.2.1 Aggregated Activities Sequence

Person’s behavior can vary in different days in the week. In such a case aggregation of activities is used. Figure 3 illustrates aggregated activities sequence of individuals. Probability of switching to particular activity between states, which is 100%, is omitted. The switching probabilistic values from the current location to the next indicate the probabilistic frequency to visit the next location.

**Figure 3:** Aggregated activities sequence of person 1, person 2, and person 3:

We observe that the probabilistic frequency for person 3 to switch from home to business is higher than 71, 4% (85, 7%). This because we assume that he can go from home to business even the weekend. Similarly, the probabilistic frequency to return back at home just after entertainment is higher than 71, 4% because he can go from home to entertainment and return back at home just after entertainment the weekend.

3.2.2 Aggregated Activity matrices

For aggregated activity matrices, the next activity is chosen from a set of alternatives with a certain probability.

3.2.2.1 Activity Transition Matrix

Activity transition matrix stores transitions between activities for each person depending on time of the day. At different time of day unlike changes between activities are possible. For example, after work, at 12:00 a person is likely to go to lunch, but at 17:00 he is more likely to go home [6]. According to
the activities sequence in figure 2, the model utilizes a probability matrix to determine the location of a particular individual in the next time. Therefore, the probability matrices indicate the probability for an individual to switch from the current location to the next depending on time of the day. The probability matrices used are:

### Legend:
P1, P2, P3 = Probability matrices for persons 1, 2, and 3; respectively.
H, S, W, M, B, Sa, E = Home, Switch station, Work, Meal, Business, Sale, and Entertainment; respectively.

#### 3.2.2.2 Activity Duration Matrix

Activity duration matrix stores the information about duration of person’s activities at certain time period. At various time periods, the same activity can last for different amount of time. For example, a lunch in a restaurant at 12:00 can take 30 minutes, but after 19:00 it might take 3 hours [6]. According to the activities sequence in figure 2, the model utilizes a probability matrix to determine the amount of time spends by a particular individual at visited location. The probability matrices used are:

**Location**

<table>
<thead>
<tr>
<th>Time (H)</th>
<th>10-12</th>
<th>3:00-3:30</th>
<th>5-8</th>
<th>0:30-1:00</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>P1 = S</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>W</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>M</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

**Time (H)**

- **Legend:** P1, P2, P3 = Probability matrices for persons 1, 2, and 3; respectively.

From probability matrices, we observe that individuals spend the same amount of time at home (10-12H), at switch stations (3-3:30), and at restaurant (0:30-1:00). Indeed, individuals usually merge simultaneously at these reference locations and split simultaneously from those.

#### 3.2.3 Algorithm of activities’ sequence

The activity or a certain mobility behavior that a person will demonstrate is determined by his current intention; for instance a person who is hungry would intend to move toward the restaurant. The act of being hungry is his current mental state. That is, intention is again governed by mental states. The mental state of a person is a function of various factors. For example, how often a person gets hungry is regulated by habits and characteristics such as age, health, appetite, the time since last eating and the amount of food taken at that time [9].

The intention algorithm illustrated below determines what mobility act a person will take part in:

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if (person==worker) then
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...
if (mental state==need work) then go to work station, work
else if (mental state==hungry) then go to restaurant, eat
else if (mental state==tired) then stop work, go home
else work

else if (person==businessman) then
if (mental state==need business) then go to town, do business
else if (mental state==hungry) then go to restaurant, eat
else if (! entertainment) then go to a playground, play
else if (mental state==tired) then stop entertainment, go home
else do business

else if (person==seller) then
if (mental state==need sell) then go to a market, sell
else if (mental state==hungry) then go to restaurant, eat
else if (mental state==tired) then stop sell, go home
else sell

3.2.4 Group Leader Selection

Several criteria have been proposed for leader selection in ad hoc networks, including: (i) highest degree, where nodes with the maximum number of neighbors are selected as group leader. This approach has low rate of group leader change, but suffers from low input since the throughput is shared among group members. (ii) extrema-id where the node with the smallest or greatest id is assigned as the group leader. The shortcoming of this approach is its bias, against nodes with extrema ids; (iii) node weight, which is an integrated metric for evaluating the suitability of a node as a group leader. It can depend on various factors such as the resource richness and the neighbor count. Above criteria are essentially based on group attributes. Therefore, it is natural to integrate them to evaluate a node’s suitability for acting as a leader, by tuning different weights on different metrics for different scenarios. In particular, in this paper, we consider the following two metrics, which are locally available on each node for election of group leader:

*Resource richness. Powerful nodes with richer resources are considered more suitable as group leaders. This is because group leader consumes more resources such as battery and computing than other group members. It also improves group performance, because weak group leaders tend to be the bottleneck, e.g., group leader is responsible for forwarding inter-group communication. In particular, we consider the following resource-related attributes: (a) CPU load; (b) memory; (c) battery and (d) bandwidth.

*Time until now since last time being a leader. This factor contributes to load balance among peers. The overall weight can be calculated as follows, with relative importance (e.g., $w_1$, $w_{11}$) specially defined for different applications (e.g., by group initializer). Weight = Resource*$w_1$ + Elapsed_time*$w_2$  \[ w_1 + w_2 = 1 \]

Resource*$w_1$ = CPU_Load*$w_{11}$ + memory*$w_{12}$ + battery*$w_{13}$ + bandwidth*$w_{14}$ \[ w_1 = w_{11} + w_{12} + w_{13} + w_{14} \]

Note that it can be easily extended to cover other metrics, and metrics need normalization since they are in different units and are not comparable. In case of tie of overall weights, the leader is selected randomly. Leader rotation is started if some node has an overall weight higher than the current leader. This may result from multiple reasons: the current leader’s weight keeps falling with longer time of being leader or a member’s resources get richer (e.g., gets power plugged-in). Change of leader requires the transfer between the old and new leaders, the information that is only kept in the leader (e.g., the leaders of other neighbor groups). And the new leader needs to inform the whole group the changes of leader, along with the group information including group member list. As stated, group management over MANET requires managing mobility-induced changes in group membership in a manner that is transparent to applications. Since a new node is detected by the network layer an event-based mechanism can be installed on the leader to invite the new comer to join the group, on the condition that the group is able to accommodate more members. The leaving of a node can be similarly handled by the leader’s sending an event-invoked group-wide announcement of updated member list [7].

4 INTER-GROUP MOVEMENT

Inter-group movement happens in cellular network when group MNs roam from one local area to another. The cellular network is an infrastructure network with wireless last hop from fixed and wired gateways (See figure 4). The gateways for these networks are known as base stations. A mobile terminal within these networks connects to, and communicates with, the nearest base station that is within its communication radius. As a mobile travels out of range of one base station and enters into the range of another, a handoff occurs from the old base station to the new so that the mobile is able to continue communication seamlessly throughout the network. Typical applications of this type of network include cellular systems, which allow Telecommunication accesses over wide areas [1].
4.1 Location Registration

In order to correctly deliver calls, the public land mobile networks (PLMN) must keep track of the location of each mobile terminal (MT). Location information is stored in two types of database, VLR (Visitor Location Register) and HLR (Home Location Register). As the MTs move around the network coverage area, the data stored in these databases may no longer be accurate. To ensure that calls can be delivered successfully, the databases are periodically updated through the process called location registration. Location registration is initiated by an MT when it reports its current location to the network. We call this reporting process location update. Current systems adopt an approach such that the MT performs a location update whenever it enters a new LA. Recall that each LA consists of a number of cells and, in general, all BTs belonging to the same LA are connected to the same MSC (Mobile Switching Center).

When an MT enters an LA, if the new LA belongs to the same VLR as the old LA, the record at the VLR is updated to record the ID of the new LA. Otherwise, if the new LA belongs to a different VLR, a number of extra steps are required to i) register the MT at the new serving VLR, ii) Update the HLR to record the ID of the new serving VLR and iii) deregister the MT at the old serving VLR. Figure 5 shows the location registration procedure when an MT moves to a new LA. The following is the ordered list of tasks that are performed during location registration:

1. The MT enters a new LA and transmits a location update message to the new base station.
2. The base station forwards the location update message to the MSC which launches a registration query to its associated VLR.
3. The VLR updates its record on the location of the MT. If the new LA belongs to a different VLR, the new VLR determines the address of the HLR of the MT from its Mobile Identification Number (MIN). This is achieved by a table lookup procedure called Global Title Translation. The new VLR then sends a location registration message to the HLR. Otherwise, location registration is complete.
4. The HLR performs the required procedures to authenticate the MT and records the ID of the new serving VLR of the MT. The HLR then sends a registration acknowledgement message to the new VLR.
5. The HLR sends a registration cancellation message to the old VLR.
6. The old VLR removes the record of the MT and returns a cancellation acknowledgement message to the HLR [3].

4.2 Paging

Typically, fixed hosts connected to the Internet remain online for extended periods of time, even though most of the time they do not communicate hence such hosts are excluded from routing cache. When a correspondent node transmits packets for a host, which is excluded from routing cache, gateway router broadcast in their domain to find a host. This action incurs large overhead. Therefore Cellular IP uses a paging technique [10]. A Paging Area (PA) is identified by its Controlling Foreign Agent (CFA) and Paging Foreign Agent (PFA) IP addresses. A Paging Area Identification (PAI) is constructed by appending its PFA IP address to its CFA IP addresses. As a network prefix distinguishes a network, a PAI is used for identifying a PA in a particular Regional Area (RA). In this way, each PA is uniquely identified by using a small amount of bandwidth. PAI extension is shown in figure 6.
PAIs are distributed by Agent Advertisements with a PAI extension. Therefore, MNs detect their PA by receiving Agent Advertisements.

a) When a CFA receives packets from the Home Agent (HA) sent to an idle MN, it sends Paging Requests to all PFAs in its RA.

b) All PFAs will not relay Paging Requests to all MNs in their PAs. Before relaying Paging Requests to their MNs, PFAs search their visitor lists to find out the MN in idle mode. Only the PFA which has the MN’s home address in its visitor lists will send Paging Requests to its PA.

c) When a MN finds its home address in the Paging Request, the MN sends the Paging Reply to its PFA. The MN changes its mode to active and starts its active timer.

d) When the PFA receives the paging reply, it sends a Regional Registration Request to its CFA.

e) The CFA sends back a regional registration reply to the PFA.

f) The PFA sends a paging reply to its CFA.

Paging procedure is shown in figure 7 [11].

4.3 Handoff Management

Handoff management plays an important role in the integration of heterogeneous wireless networks. Horizontal handoff (intra-system handoff) occurs when a mobile terminal is moving out of the coverage area of a base station into the coverage area of another BS within the same system. Vertical handoff (inter-system handoff) is defined as handoff between BSs that are using different wireless network technologies. It usually occurs in wireless overlay networks where the coverage areas of different tiers of networks are overlapping to each other [5]. Handoff (or Handover) management enables the network to maintain a user’s connection as the MT continues to move and change its access point to the network. Handoff management includes two conditions: intracell handoff and intercell handoff. Intracell handoff occurs when the user moves within a service area (or cell) and experiences signal strength deterioration below a certain threshold that results in the transfer of the user’s calls to new radio channels of appropriate strength at the same BS. Intercell handoff occurs when the user moves into an adjacent cell and all of the terminal’s connections must be transferred to a new BS. While performing handoff, the terminal may connect to multiple BS’s simultaneously and use some form of signaling diversity to combine the multiple signals. This is called soft handoff. On the other hand, if the terminal stays connected to only one BS at a time, clearing the connection with the former BS immediately before or after establishing a connection with the target BS, then the process is referred to as hard handoff. Handoff management research concerns issues such as efficient and expedient packet processing; minimizing the signaling load on the network, optimizing the route for each connection; efficient bandwidth reassignment; evaluating existing methods for standardization; and refining quality of service for wireless connections. Figure 8 lists the handoff management operations [4].

5 POWER CONSUMPTION ANALYSIS

Let E be the average power consumption of an MN communicating with the base station and e be the average power consumption between MNs in group. It has been shown that the power that an MN uses to transmit a message is on proportion to the square of the distance to the destination. From figure 1, it is obvious that the communication distance in the scope of the group is much shorter than to the base station. This implies that E >> e. In traditional location update scheme, when a group of (n) MNs crosses one location area to another, every MN sends a location update message to the base station.
Therefore, the total energy consumption is \( nE \). While in DGM scheme, every time that the group crosses the border LA, only the group leader is charged to report location update. Therefore, the whole system uses only \( E \) for each crossing. Even we add the cost for member joining, quitting, leader selection, leader rotation, the power consumptions are still saved for the whole system [8].

6 SIMULATION

6.1 Simulation Description

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 DSDV routing protocol under the DGM model. For our simulation purpose, the performance metrics collected include the flow of data packets and the drop packets. Our evaluations are based on the simulation using Network Simulator environment (NS-2); we extract the useful data from trace file. The graphs are generated using Matlab. Simulation environment consists of 3 wireless nodes forming an ad hoc network, moving over a 500 X 500 flat space, DSDV routing protocol for 30 seconds of simulation time; the Time To Live (TTL) is 32 seconds. The traffic consists of tcp type with 3 connections; packet size is 1060 bytes.

6.2 Simulation Results

Figures 9, 10, and 11 show sending packets from node 1 to node 2, from node 0 to node 2, and from node 2 to node 1; respectively. The router message for these figures is RTR (Router Trace). According to figures 9, 10, and 11, when \( t < 4 \) Seconds, nodes move together hence there is no sending packets. For \( 4 < t < 22 \), we note on the figures sending packets from one node to another. Sending packets increases almost linearly with the time. For \( t > 22 \) Seconds; nodes are merging hence sending packets ceases. Figure 12 shows the drop packets from node 1 to node 2. For \( t < 6.1 \), nodes are close each other thus we don’t observe drop packets. For \( 6.1 < t < 7.2 \), the amount of drop packets increases linearly with the time. That is, when the distance between nodes increases, the probability of drop packets increases, too. For \( t > 7.2 \) nodes are merging, no drop packets. Figure 13 shows the drop packets from node 2 to node 1. Similarly as figure 12, there is no drop packets when nodes are close each other. Otherwise, the amount of drop packets increases linearly with the time. The router message for figures 12 and 13 is mac.
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7 CONCLUSIONS
The mobility models proposed so far in the literature assume some kind of permanent group affiliation. In this paper, we presented in section 3 the movement of three individuals in the scope of the group. In this example, the group affiliation is not permanent. Individuals sometimes merge and move together and sometimes split and move individually. On the other hand, the existing group mobility models assume that nodes in the same group stay in a homogeneous network throughout the whole simulation process. However, the DGM model presented in section 2, realizes an integration of ad hoc and cellular networks. Indeed, in DGM model, intra-group and inter-group movements happen in different wireless networks. In section 4, we presented the group movement in cellular system. In cellular system, when group MNs roam from one local area to another, the group leader ensures the location update for the whole group. This allows the reducing of the location update signaling in the database side significantly as well as the consumption of wireless bandwidth for location update message. Analysis presented in section 5, shows that the DGM scheme greatly saves energy for MNs during inter-group communication. In section 6, we have evaluated the performance of DSDV routing protocol under ad hoc network. Simulation results are highly dependent on the movement behaviors of mobile node, the routing protocols under investigation and simulation environment. We implemented mobility model in NS-2 environment and converted the useful trace file to graphs using Matlab. Obtained results agree with expected results based on the theoretical analysis.

8 REFERENCES


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