Poster Abstract: Sociological Orbit aware Location Approximation and Routing in MANET

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I. Introduction

In the real world, mobile users routinely move in between and spend a considerable amount of time at a few specific places of social interest. For example, a regular day in the life of a professor may involve *routine* visits to his/her office, a classroom or a conference room, while spending considerable amount of time in each of these venues. Thus, although it is hard to keep track of an user at all times, we can identify a list of possible places (e.g. office, conference room or classroom), that we refer to as "hub(s)", for locating the user.

In this paper, we study a "macro-level" sociological movement of mobile users and identify a partially deterministic "orbital" mobility pattern among these "hubs". The macro-level movement refers to the fact that our abstraction does not depend on the exact movement within a hub, or in between hubs. Rather, our abstraction only specifies a set of hubs where a node will repetitively visit and spend a significant amount of time. However, unlike molecules or planets that have deterministic and continuous orbital movement, mobile users do not have to follow any rigid schedules or routes. In other words, their orbital movement is partially deterministic.

We also propose an effective routing protocol for MANET called Sociological Orbit aware Location Approximation and Routing (SOLAR) to take advantage of the spatial and temporal locality of the mobile users (nodes) around these hubs. We show that the orbital movement pattern is not only general enough to be realistic, but is also specific enough to be useful. More specifically, it can be used to avoid a need for constant location tracking and flooding. Extensive numerical results are presented to establish the simplicity and superiority of SOLAR over other conventional protocols, such as DSR [1] and LAR [2] in terms of higher data throughput, lower control overhead, and lower end-to-end delay.

Note that our orbital movement pattern differs from existing mobility patterns studied in literature, in that it neither models the motion of the users at a micro-level (i.e., on small time scales or within small distances) [3], [4], nor simply predicts user locations via historical/statistical tracking information ([5], [6]). It also differs from the deterministic (orbital) mobility patterns assumed within Delay Tolerant Networks (DTN) [7], and the probabilistic (but non-orbital) mobility patterns assumed in intermittently connected networks [8], [9]. To the best of our knowledge, no prior work has explored the implication of such partially deterministic sociological orbits based mobility pattern at the macro-level and its application to routing in MANET, despite its practicality.

II. An Example Random Orbit Model

To illustrate the concept of the sociological orbital movement, we first construct a simple yet practical orbital model called the Random Orbit. The Random Orbit model allows for the creation of a certain number of hubs within the simulation terrain for all the nodes, as specified by the parameter *Total Hubs*. These hubs are located at random places within the terrain (and thus may overlap with each other). Each node can visit a subset of randomly chosen hubs, thereby creating a *Random Orbit*. The list of hubs a node visits is bounded by its *Hub List Size*, and the time it spends in each hub is specified by *Hub Stay Time*. Together, these two parameters define an Inter-hub Orbit (IHO). We also allow for an occasional change in the specific list of hubs assigned to a node in its IHO by defining an *IHO Timeout*, upon which a node is assigned a fresh list of hubs to visit.

The mobility model of individual nodes consists of two parts: movement inside a hub, and movement in between hubs. For convenience, the movement inside each hub (henceforth referred to as the Intra-hub Movement (IHM)) was chosen to follow a modified Random Waypoint mobility model, with a speed range denoted by *Intra-hub Speed* and a pause time denoted by *Intra-hub Pause*. For inter-hub movement, we define a Point-to-Point Linear (P2P Linear) model. With such an inter-hub movement, a node randomly selects a point within the destination hub and moves towards it linearly from its current position with a velocity defined by the range *Inter-hub Speed* (please refer to the middle of Table I for a summary of these parameters). ***While these two models are chosen for simplicity, the point to be noted here is that for each of the two parts, any known practical mobility models may be chosen***. In addition, this example Random Orbit model does not simply integrate two common mobility models (Random Waypoint, and P2P Linear), but most importantly, also introduces the practical orbital movement amongst hubs.

Figure 1 illustrates the Random Orbit model. Such a model is suitable for modeling wireless devices carried by users working in an office building, attending a convention, or around a university or corporate campus. As users move around, devices may either automatically, or with the user's permission or assistance, record the hubs visited most often, and share the hub-based orbital mobility profile with trusted "acquaintances". Such mobility profile can then help improve routing as described next.

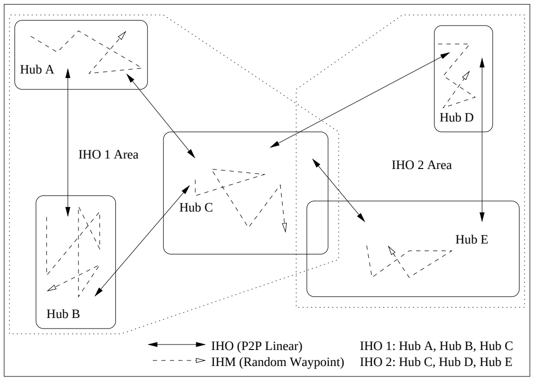


Fig. 1. The Random ORBIT Model

III. Sociological Orbit aware Location Approximation and Routing (SOLAR)

We now briefly describe our Sociological Orbit aware Location Approximation and Routing (SOLAR) protocol. SOLAR uses a concept of "acquaintance" similar to that in the Acquaintance Based Soft Location Management (ABSoLoM) protocol [10]. However, SOLAR differs from ABSoLoM mainly in that the latter may require a node to frequently update its acquaintances with its exact coordinates but the former does not.

In SOLAR, two mobile nodes get *acquainted* with each other by sharing each other's hub lists when they are within radio range. When a source node needs to send data to a destination, it first checks its cache to see if the destination node's hub list is known. If so, data packets are *geographically forwarded* [11] to the hubs on the list. If not, the source node sends a *query* packet to its acquaintances asking if any of them knows the hub list of the destination. An acquaintance sends a *response* packet containing the hub list of the destination back if it knows, or ask its own acquaintances for further help otherwise. The query is forwarded up to a maximum number of logical hops (a logical hop corresponds to a transmission between a node and its acquaintance), after which it is dropped. If the source does not receive a positive response packet within a timeout, it floods the first data packet. When a destination receives the data packet, it can send a response containing its current hub (and hub list) back to the source.

IV. Performance Analysis

We present a subset of our simulation results comparing the performance of the SOLAR protocol with that of DSR and LAR scheme 1 (LAR1), using GloMoSim [12]. In our implementation of SOLAR, we use 2 as the maximum number of *logical hops* any *query* packet may take before it is dropped. For comparison, we borrow the DSR and LAR1 implementations already available in the GloMoSim distribution. Table I lists the parameters used in the simulations.

We chose three metrics to evaluate the performance of each protocol as described below:

Data Throughput: this metric is defined as the ratio of the total number of data packets received correctly by all destinations, to the total number of data packets generated by all sources.

Relative Control Overhead: this metric is defined as the amount of control information (or additional data as is the case of flooding a data packet) measured in bytes that each node sends for each successfully received data packet in the network.

Approximation Factor for End-to-End Delay: this metric is defined as the ratio of the end-to-end delay of a packet to the delay observed for a packet in an ideal situation.

Below, we present only the results on how the total number of hubs (given a fixed terrain) affect the performance of the protocols. The number of hubs in the terrain affects protocol performance due to its direct impact on the expected node density within hubs, and the hub list sizes of each node. The effects of other parameters such as the number of nodes, radio range and hub size and inter-hub speed have also been evaluated, and the results have indicated similar relative performance of the three protocols.

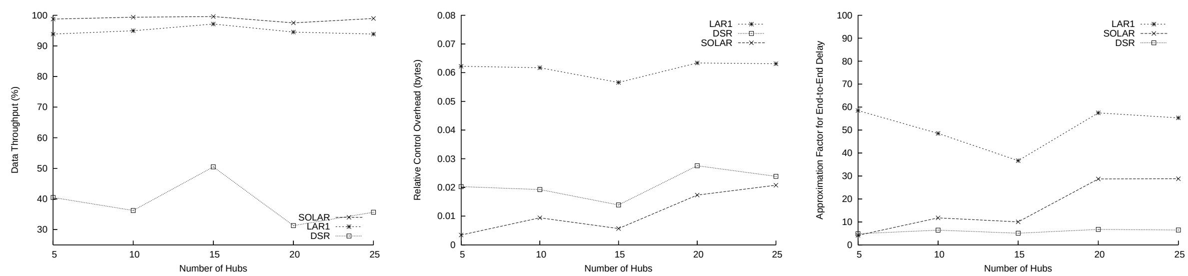
Data Throughput: The number of hubs seems to have little impact on the throughput performance of SOLAR and LAR1 but has an interesting impact on DSR, as seen in Figure 2(a). With a very few hubs, the number of nodes that happen to stay within each hub at any given time can be very large. This exacerbates the *broadcast storm* problem (increased MAC layer contention) in DSR, leading to unsuccessful route discovery and poor throughput. The performance of DSR improves with the number of hubs, but after a point, it deteriorates once again due to higher mobility of nodes and route failures. LAR1 employs the caching of velocity and location information that helps in limiting the amount of flooding required, thereby resulting in much better performance. In SOLAR, since there is inter-hub movement and the hub list information is shared amongst nodes, there is sufficient means to locate nodes and route packets to them, irrespective of the number of hubs.

Relative Control Overhead: From Figure 2(b), we note that the majority of the overhead in flooding based protocols such as LAR1 and DSR is due to the route discovery process. Specifically, in LAR1, the iterative route discovery by defining expected regions lead to excessive flooding of discovery packets when nodes move long distances due to their IHO or when mobility is high. On the other hand, DSR adopts a less aggressive flooding scheme and is shown to have a lower overhead than LAR1. In SOLAR, hub lists stay valid for a longer time (than node locations or routes), minimizing the number of query/response packets. Thus, the number of location update packets are kept minimal, leading to a much reduced control overhead than either DSR or LAR1.

Approximation Factor for End-to-End Delay: The above reasons also explain the approximation factor for delay of all the protocols as seen in Figure 2(c). LAR1 has the highest delay due to its iterative estimation of node location,

TABLE I
SIMULATION PARAMETERS

GENERAL PARAMETERS			
Simulation Duration (each run)	1000s	Terrain Size	1000m x 1000m
Number of Nodes (*Users*)	*Vary*, (Default= 100)	Radio Range	*Vary*, (Default= 250m)
MAC Protocol	IEEE 802.11	Mobility Model	Random Orbit (RW + P2P)
ORBIT PARAMETERS			
Total hubs	*Vary*, (Default= 15)	hub Size	*Vary*, (Default= 200m-300m)
hub Stay Time	50s-100s	IHO Timeout	250s - 500s
hub List Size	2 to Total hubs	Inter-hub Speed	*Vary*, (Default= 10m/s-30m/s)
Intra-hub Pause	1s	Intra-hub Speed	1m/s-10m/s
TRAFFIC PARAMETERS			
CBR connections	200 (5 packets each) Random	Data Payload	512 bytes per packet



(a) Data Throughput (%) (b) Relative Control Overhead (c) Approximation Factor for E2E Delay

Fig. 2. Protocol Performance vs. Total number of Hubs

and increased control overhead. In SOLAR, as the hub list size grows with the number of hubs, it may take a longer time to get the hub list of a destination, thereby incurring marginal increase in delay with increasing number of hubs. DSR performs the best, but a point to note is that this delay in DSR is only averaged over the data packets it successfully received, which is far less than any other protocol. Overall, all protocols seem to perform the best with a moderate number of hubs for the default simulation terrain.

V. CONCLUSION

In this work, we have exploited a higher level of mobility information abstraction. Specifically, we have observed the social influence on the macro-mobility of each MANET user and suggested an orbital movement pattern for each user based on a list of places or hubs that they frequently visit. We have used this simple yet practical mobility information to improve routing performance. In particular, we have proposed a Sociological Orbit aware Location Approximation and Routing (SOLAR) protocol for MANET and established the advantages of SOLAR over conventional MANET routing protocols like LAR and DSR in terms of higher data throughput, lower control overhead, and lower end-to-end delay. As a future work, we will explore alternate protocols for inter-hub as well as intra-hub routing in-order to further enhance SOLAR performance.

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