Poster: Hierarchical Grid Location Management for Large Wireless Ad hoc Networks

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ABSTRACT

Recently, a new family of protocols has been introduced for large scale ad hoc networks that make use of the approximate location of nodes in the network for geographic routing. Location management plays an important role in such protocols, and in this paper, we propose a deterministic hierarchical scheme for managing the location information of nodes, and analyze the cost of such a scheme via probabilistic means and simulations. We find that the cost of hierarchical location management has an asymptotic overhead cost of $O(vN\ \log_2 N)$ for location registration, which is asymptotically lower than the location management overhead in protocols described in literature, and thus scales well with the increase in the number of nodes in the network.

Categories and Subject Descriptors

C.2 [**Computer Communication Networks**]: Wireless communication

General Terms

Algorithms Performance

Keywords

Ad hoc networks, Location Management

1. INTRODUCTION

While many solutions have been proposed for routing in mobile ad hoc networks, few have considered the issue of scalability of such protocols in networks having node membership in the order of thousands, and spread over a large geographic area. A unique characteristic of ad hoc networks is that the limited bandwidth of the wireless channel is shared by signalling traffic as well as data, and the former is given a higher priority than data. This works fairly well for current routing protocols in small networks with low node mobility, since the volume of signalling traffic is low enough to carry out the route discovery and maintenance phases efficiently. However, increased node mobility and node membership can lead to excessively high signalling traffic, leading to congestion and poor network performance. Intuitively, any routing protocol that tries to maintain state (e.g. a pre-computed source route, network topology) for routing purposes, appears non-scalable for ad hoc networks, since maintenance of the state requires additional signalling over the entire network.

Geographic forwarding, where each node is aware of its location (via a GPS receiver or other localization techniques), lends itself as a potential candidate for scalable routing in large ad hoc networks, since the amount of state information that each node needs to maintain is minimal. In dense networks, where the number of nodes per unit area is sufficiently large, geographic routing is especially attractive. However, geographic forwarding requires location management, in which nodes periodically update location servers of their current location which can then be queried by source nodes in an on demand fashion in order to locate destination nodes.

In this work, we propose a novel yet simple location management scheme for dense ad hoc networks, by extending SLALoM[1]. While the concept of hierarchical location/ mobility management is not entirely new, the contribution of this work lies mainly in specifying a distributed scheme suitable for ad hoc networks and analyzing the upper bound on the average signalling overhead incurred by the location management primitives in such networks. The basic idea of the scheme is to divide the topography into logical grids, and establish a *multi-level* hierarchy by designating leadership to nodes that are located within specific locales in the topography (see fig 1).

Hierarchical leader nodes serve as location servers, and are updated by other nodes on crossing grid boundaries, via location update packets. A lower order leader notifies its leader only if the location update requires it to update its leader. Thus, while the leaders in the highest level of the hierarchy know the approximate locations of all the nodes in the network, location information in servers becomes more accurate as one traverses down the hierarchy. Such a hierarchy ensures that localized movements result in location updates that are confined within the locale in which the movement took place. Location servers can now be queried by source nodes who wish to know the location of the destination, in an on demand fashion. Location queries in our

MobiHoc'03, June 1–3, 2003, Annapolis, Maryland, USA.

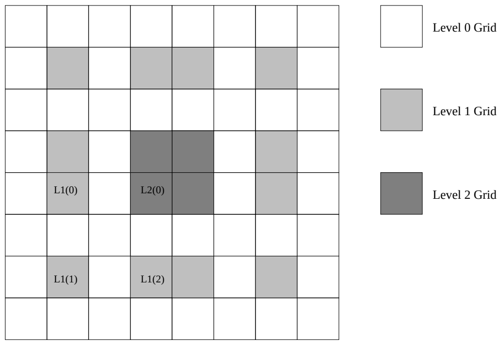

Figure 1: A three level hierarchy. A level 1 grid leader knows the exact location of all nodes located in the four level 0 grids under it. Level 2 leaders are constituted from level 1 leaders. A local broadcast protocol ensures that all the leaders in level 2 grids are aware of all the nodes in the network

scheme terminate deterministically, with queries intended for nearby destinations remaining local.

2. LOCATION UPDATE OVERHEAD

To find the upper bound for the average location update overhead for a uniformly distributed network with density γ per unit grid and k levels of hierarchy, we compute P_i, the probability that a L_i^{th} server was updated, and $\bar{d_i}$, the average distance traversed by an update packet on an L_i^{th} boundary crossing. If d is the side of an L_0 grid, we have

$$P_i \quad = \quad \frac{1}{2 \times [1 - 2^{-k}] \times 2^{i-1}} \qquad (1 \leq i \leq k) \quad (1)$$

and

$$\bar{d_i} \quad \leq \quad 2^{i-1} \times d(\frac{2 + \sqrt{(2)}}{4}) \qquad (1 \leq i \leq k) \quad (2)$$

Hence, the average distance traversed by an update packet

$$\begin{aligned} D \quad & \leq \quad 2 \times \sum_{i=1}^{k} P_i \bar{d_i} \\ & = \quad O(k) \text{ for large } k. \end{aligned} \quad (3)$$

If v is the average velocity of a node, and z is the average distance that a packet traverses ($z \leq r_t$, where r_t is the radio range) during a single transmission, the average location update cost per node for the hierarchical grid location management is

$$\begin{aligned} c_u \quad & = \quad \frac{v}{d} \, (\frac{D}{z} + \bar{b}) \\ & = \quad O(v \, \log_2 N) \text{ packets/sec/node} \end{aligned} \quad (4)$$

where $\bar{b}$ is the broadcast cost for the location update process. The total location update cost for the entire network is then

$$C_u \quad = \quad O(vN \, \log_2 N) \text{ packets/sec} \quad (5)$$

Thus, the location update cost is proportional to the average velocity and increases only logarithmically with the number of nodes for our scheme. This value of location update cost is lower than that of [1]($O(vN^{\frac{4}{3}})$) and [2]($O(vN^{\frac{3}{2}})$).

3. SIMULATION ANALYSIS

To verify the practical aspects of our location management scheme, we implemented both the hierarchical location management scheme and SLURP[2], a well known location management scheme described in literature, in *Glomosim*[3]. The simulation results are obtained by assuming $r_t = 350$ m, $d = 250$ m, $\gamma = 5$, $k = 4$, and Random Waypoint ($v_{max} = 25$ m/sec, $v_{min} = 0$ m/sec, pause = 0 sec) as the mobility model. Figure 2 shows how each scheme scales in terms of location update overhead. As the number of nodes increases, hierarchical location management outperforms SLURP. This can attributed to the fact that, while location updates are localized in our scheme, a location update in SLURP traverses a longer path to reach the location server. Other simulation results indicate that the lower sig-

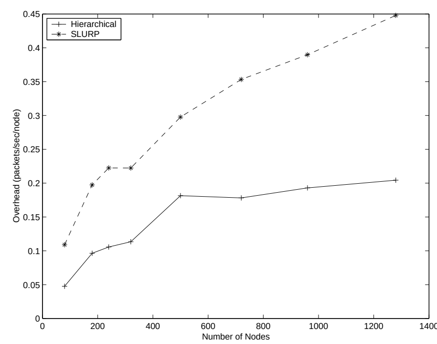

Figure 2: Location Update Overhead as a function of number of nodes

nalling traffic leads to better data throughput and delay for the hierarchical scheme, indicating that our scheme leads to better utilization of network resources.

4. CONCLUSION

In summary, we proposed a new location management scheme which uses a simple multi-level hierarchy for location server set-up and location information management. We analyzed the scheme for asymptotic performance of location management for uniform node movement, and found that the location registration cost increases only logarithmically with the number of nodes. Simulations results verified our analysis and showed that hierarchical location management performs much better, and thus, is a promising contender for location management in a wireless ad hoc network architecture.

5. REFERENCES

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