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LANMAR Routing for Ad Hoc Networks by the Mobile Backbones

Asst. Prof. K. Pushpa Rani
CSE Department, MLRIT,
Hyderabad, Telangana, India

Asst. Prof B. Pavani
IT Department, MLRIT,
Hyderabad, Telangana, India

Asst. Prof M. Jhansi
CSE Department, MLRIT,
Hyderabad, Telangana, India

Abstract— A MANET is usually assumed to be homogeneous, where each mobile node shares the same radio capacity. However, a recent research has demonstrated its performance bottleneck through both theoretical analysis and simulation experiments and testbed measurements. This is further exacerbated by heavy routing overhead of ad hoc routing protocols when the network size is large. In this paper, we present a design methodology to build a hierarchical large-scale ad hoc network using different types of radio capabilities at different layers. In such a structure, nodes are first dynamically grouped into multi-hop clusters. Each group elects a cluster-head to be a backbone node (BN). Then higher-level links are established to connect the BNs into a backbone network. Following this method recursively, a multilevel hierarchical network can be established. Three critical issues are addressed in this paper. We first analyze the optimal number of BNs for a layer in theory. Then, we propose a stable and light overhead clustering scheme to deploy the BNs. Finally LANMAR routing is extended to operate the physical hierarchy efficiently. Simulation results using GloMoSim confirm that our proposed schemes achieve good performance.

Keywords— ad-Hoc Network, Scalability, Mobile Backbone Network, LANMAR Routing

I. INTRODUCTION

MANET(Mobile Ad-hoc Network) is assumed to be homogeneous i.e., all mobile nodes in the network share the same random access wireless channel with a single omnidirectional radio. However, a flat ad hoc network has poor scalability [1, 2, 3]. In [3], theoretical analysis implies that even under optimal network layout conditions, the throughput for each node declines rapidly toward zero while the number of nodes is increased. The measured per node throughput declines much faster in the real testbed than in theory. These results reflect that a "flat" ad hoc has an inherent scalability problem. Besides the capacity limitation, ad hoc routing protocols also pose a heavy burden to the network. Flooding is usually adopted by routing protocols to search a path or propagate routing information. In large-scale network with mobility, routing overhead will consume a major fraction of the available bandwidth. Thus further limits the scalability of "flat" ad hoc networks. As we will show, our mobile backbone routing scheme retains the simplicity of traditional ad hoc networks. In spite of the simple routing scheme, many of the typical backbone strategy benefits (such as short paths to remote nodes, small end-to-end delay, high quality link, enlarged network capacity, and QoS support etc.) can be successfully achieved. In our proposed hierarchical network architecture, only a portion of nodes with multiple radio capacities is required. These nodes are equipped with powerful radios in addition to general radios, which are supported by all the network nodes. The powerful radios will form higher-level backbone links, which can help reduce the "long hop" paths by adapting the hierarchical structure.

The paper is organized as follows. In section II, we review the scalability problem of ad hoc routing protocols. In Section III, we present our backbone election and deployment algorithm, and we evaluate it in section IV we report simulation results evaluating the performance of the proposed structure and compare it to other solutions.

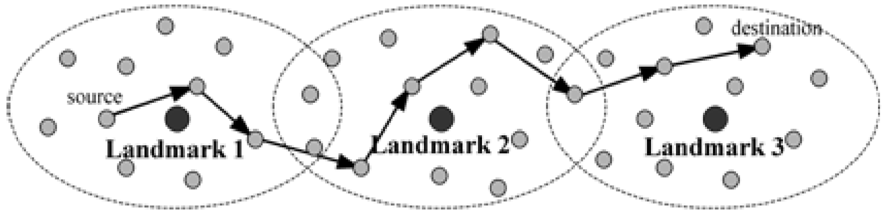
II. SCALABILITY PROBLEM OF ADHOC ROUTING PROTOCOLS

Larger ad hoc networks emerge in several application scenarios, such as in military or disaster recovery situations. Directly using the current "flat" ad hoc routing protocols in a large scale setting will cause performance degradation several reasons account for this performance degradation. The first reason is longer paths from sources to destinations, which naturally occur in a large scale network. In a typical case with existing radio power ranges and hundreds nodes spread over a large terrain, the average number of hops between source to destination can easily exceed ten. A breakage of any single link on the path will cause failure. Even without failure, the average end-to-end delay and delay variance may be too large to be acceptable by time-critical applications. The second reason is heavy line overhead generated by routing protocols. Proactive routing protocols, such as DSDV [7], Fisheye [5] and OLSR [6], relying on periodic exchanges of routing information, cannot scale well because they propagate routing information throughout the whole network periodically. With mobility present, more frequent updates are required to keep the information accurate, thus producing a large amount of control overhead. The "long hop" paths are more prone to break due to mobility and expiration of cached routes, which in turn, cause new flood-searches for new routes. In a mobile network example based on 100 nodes and 40 sources, the results in [4] illustrate that on demand routing protocols will generate so much routing overhead that they alone will consume most network capacity.

To overcome the above limitations, several techniques have been proposed to make ad hoc routing protocols more scalable. For example, Fisheye [5] propagates link state packets with different frequencies to nodes inside vs outside its Fisheye scope respectively. The control overhead of on-demand routing protocols can also be reduced by repairing a broken route locally at the node, which experiences the link breakage as is done in WAR [8, 9]. All of these schemes provide scalability improvements in the routing protocols themselves. However, the performance problems intrinsic of the “flat” ad hoc network structure (eg, paths with many hops, etc) still remain.

III. LANMAR WITH MOBILE BACKBONE

LANMAR is an efficient routing protocol designed for ad hoc networks that exhibit group mobility. Namely, one can identify logical subnets in which the members have a commonality of interests and are likely to move as a "group". The logical grouping is reflected in the address used within the ad hoc network, namely the two field address <Group ID, Host ID>. One may notice a similarity between the group address and the IP address. In the group address the “network” address is replaced by the “group” address. The Internet uses network IDs to drive the packet to its final destination. In the Internet, the networks have a temporal and geographical permanency. In a mobile ad hoc system, there are no permanent, geographically meaningful subnetworks. There are, instead, groups of nodes moving together. It is thus natural to exploit these temporally persistent groups to support the type of hierarchical routing used in the Internet. The Internet uses Link State or Distance Vector routing schemes. Instead, LANMAR uses the notion of landmarks to keep track of such logical groups. Each logical group has one node serving as a "landmark". The landmark node is dynamically elected. The routes to landmarks are propagated throughout the network using a distance vector mechanism (in this study, we assume DSDV). In addition to landmark distance vector propagation, LANMAR relies also on a local, myopic routing algorithm (in this paper, we use Fisheye State Routing (FSR) [5], with limited scope.



LANMAR Routing in an Ad Hoc Network without Backbones

Fig1:

The backbone node election is completely distributed and dynamic. It must result in a backbone node distribution that reflects the distribution of ordinary nodes. A Distributed Clustering algorithm is the most common approach to this problem.

IV. EVALUATION

In this section, we present simulation results to compare the LANMAR in the MBN with the original LANMAR routing in a “flat” ad hoc network. The purpose of these experiments Same network scenario as in previous experiments is used and channel bandwidths of the “short range” and “long range” radios are set to 2Mbps and 4Mbps (e.g. W2/W1 = 2) respectively. The scope of backbone election is fixed to be 2, as under which number of elected BNs is approximate to the optimal value. Results are given from Fig. 2 & Fig. 3.

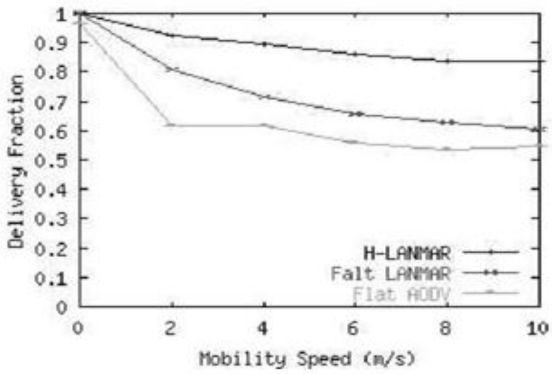


Fig. 2: Comparison of delivery fraction vs. mobility

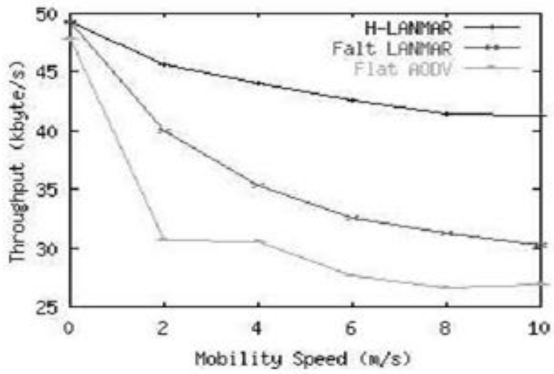


Fig. 3: Comparison of throughput vs. Mobility

V. CONCLUSIONS

In this paper, we presented schemes to establish and operate a “physical” multi-level hierarchical ad hoc network with mobile backbones (MBN). The optimal numbers of backbone nodes at each layer are derived through theoretical analysis. A stable multihop clustering scheme is also proposed to elect required backbone nodes and organize the hierarchical network. For efficient routing in such a hierarchical structure, we proposed to use an extension of the

LANMAR routing scheme. The LANMAR routing solution is key to the feasibility and efficiency of the hierarchical structure. It is robust to mobility and yet reaps the benefits of the hierarchy. For example, backbone links are automatically selected by the routing scheme if they can reduce hop distance to remote destinations. Fault tolerance and system reliability of the proposed scheme have also been discussed. In essence, the proposed scheme combines
the benefits of "flat" LANMAR routing and those of a physical network hierarchy. Simulation results using the Parsec/GloMoSim platform show that the proposed scheme significantly improves the performance of non-hierarchical schemes and that it is robust to failures.

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