A Distributed Mechanism for Topology Discovery in Ad Hoc Wireless Networks Using Mobile Agents

Romit RoyChoudhury
Dept. of Computer Science
Haldia Institute of Technology
West Bengal
INDIA

S. Bandyopadhyay*
PricewaterhouseCoopers Ltd.
Sector V, Saltlake
Calcutta 700 091
INDIA

Krishna Paul
Cognizant Technology Solutions
Sector V, Saltlake
Calcutta 700091
INDIA

* e-mail : somprakash.bandyopadhyay@in.pwcglobal.com

ABSTRACT

The dynamics of wireless ad hoc networks as a consequence of mobility and disconnection of mobile hosts pose a number of problems in designing proper routing schemes for effective communication between any source and destination [1]. The conventional proactive routing protocols that require to know the topology of the entire network is not suitable in such a highly dynamic environment, since the topology update information needs to be propagated frequently throughout the network. On the other hand, a demand-based, reactive route discovery procedure generates large volume of control traffic and the actual data transmission is delayed until the route is determined. Because of this long delay and excessive control traffic, pure reactive routing protocols may not be applicable to real-time communication. At the same time, pure proactive schemes are likewise not appropriate for the ad hoc network environment, as they continuously use a large portion of the network capacity to keep the routing information current.

In this paper, we have discussed a mobile multi-agent-based framework to address the aspect of topology discovery in ad hoc wireless network environment. In other words, we have designed a multi-agent based protocol to make the nodes in the network **topology aware**. Our primary aim is to collect all topology-related information from each node in the network and distribute them periodically (as updates) to other nodes through mobile agents. The notion of *stigmergic communication* [2] has been used through the implementation of a shared information cache in each node. Moreover, we have used a concept of *link stability* [3] and *information aging* based on which a predictive algorithm running on each node can predict the current network topology based on the current network information stored at that node. We have demonstrated through performance evaluation of a simulated system that the use of mobile multi-agent framework would be able to make each node in the network *topology aware* without consuming large portion of network capacity. This would eventually help us to implement a proactive routing protocol without much overhead. Moreover, as a direct outcome of infiltrating topology information into the nodes, the foundations for designing distributed network management and implementing communication awareness [3] get automatically laid.

The basic idea of using agents for topology discovery has been explored in MIT Media Lab [4] earlier with certain limitations : first, node mobility and its effect on system performance has not been quantified. Second, the information convergence (convergence of the difference between actual topology information and the topology information as perceived by a node at any point of time) and its relationship with number of agents and agent migration frequency has not been clearly defined. Third, the navigation strategies used do not ensure a balanced distribution of recent topology information among all the nodes. We have tried to overcome these difficulties. Moreover, we have defined a concept of link stability and information aging based on which a predictive algorithm running on each node can predict the current network topology based on the current network information stored at that node.

Mobile agents or messengers that hop around in the network [5] are a novel solution to the problem of topology discovery. The agents hop from node to node, collect information from these nodes, meet other agents in their journey, interact with both to collect updates of parts of the network that they have not visited or have visited a long time back**,** and gift these collected data sets to newly visited nodes and agents. It is to be noted that by controlling migration time-interval (time-to-migrate or TtM) of an agent, it is possible to control the agent traffic in the network. Moreover, the agent would always migrate from a node to only one of its neighbor after pre-specified time-tick. So, the network would never get flooded with propagation of agents.

A major aspect underlying the infiltration of topology information into mobile nodes is that the information carried must be recognized with a degree of correctness. Since the agent navigation is asynchronous and there is an obvious time gap between the procurement of information by an agent from one node and its delivery by the same agent to another node, it becomes imperative to introduce a concept of recency of information. For example, let us assume two agents A_1 and A_2 arrive at node n, both of them carrying information about node m which is multi-hop away from node n. In order to update the topology information at node n about node m, there has to be a mechanism to find out who carries the most

recent information about node m : agent A_1 or agent A_2 ? To implement that, every node in the network has a counter that is initialized to 0. When an agent leaves a node after completing all its tasks at the node, it increments that counter by one. We term this counter as *recency token.* At any point of time, the magnitude of the recency token of any node represents the number of times that node was visited by agents since the commencement of the network. This also implies that if two agents have a set of data concerning the same node, say node A, then the agent carrying the higher recency token value of node A has more current information about it.

We have defined a concept of *information aging* on link-affinity based on which a predictive algorithm running on each node can predict the current network topology based on the current network information stored at that node. *Link-Affinity* , associated with a link between two nodes n and m, is a prediction about the span of life of that link in a particular context [3]. We apply this notion to predict the topology by each node and thus be cautious before data transfer is initiated.

We have developed two metrics: *average connectivity convergence* and *average link-affinity convergence* to quantify the deviation of actual network topology with the network topology perceived by individual nodes at any instant of time. We have experimented with different mobility, transmission range and TtM on a 30-node ad hoc network. We have done a set of experiments to derive that the optimum agent population should be *half the number of nodes* in the system. From the results, it is clear that the average connectivity convergence improves with decrease in mobility. With TtM=100 msec., the connectivity convergence goes below 80 % for a high mobility of 30 m/s. However, the time to migrate (TtM) could be lowered to produce better results even at high mobility. But this has the obvious effect of congestion in the system as the system sees more agent traffic in the medium per unit time. However, our predictive mechanism in the context of TtM=100 msec. could yield satisfactory results with the convergence values over 98 % (Fig. 1). Thus we see that resorting to the predictive mechanisms can improve performance significantly.

References

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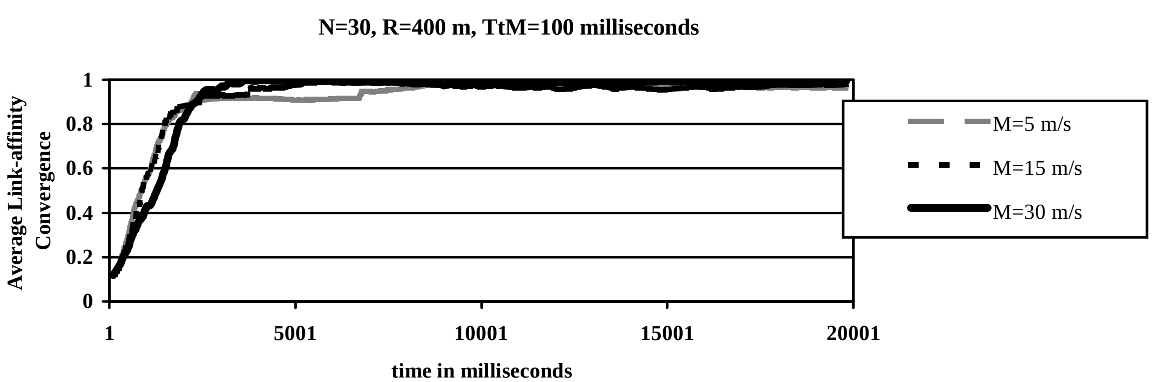

Fig. 1 Variation of Average Link-Affinity Convergence with time using Predictive Mechanism