USING MOBILE AGENTS FOR OFF-LINE COMMUNICATION AMONG MOBILE HOSTS IN A LARGE, HIGHLY-MOBILE DYNAMIC NETWORKS

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ABSTRACT

In dynamic networks such as packet radio and ad-hoc wireless network, each node acts as a mobile router, equipped with a wireless transmitter / receiver, which is free to move about arbitrarily. In this configuration, even if two nodes are outside the wireless transmission range of each other, they can still be able to communicate with each other in multiple hops, if other intermediate nodes in the network are willing to participate in this communication process. However, the dynamics of these networks as a consequence of mobility and disconnection of mobile hosts pose a number of problems in designing routing schemes for effective communication between any source and destination. Thus, even off-line communication between source and destination (e-mail, for example) would be inefficient, if not impossible, in a large dynamic network structure where hosts are highly mobile. This paper introduces a scheme using mobile agent to address this issue. Mobile agent in this context would act as a messenger that would migrate from a source and carry the message from a source to a destination. The scheme utilizes the location information (using the global positioning system, for example) and relies on the fact that the mobility of hosts in ad hoc networks are not totally random but follow a pattern of movement. A mobile agent can migrate off a source node with a message and navigate autonomously throughout the network to find out the destination in order to deliver this message. If the destination is disconnected from the network for some duration, the delivery of message will be deferred and the agent waits for its reconnection in an appropriate intermediate node. From the performance evaluation, it has been concluded that the proposed scheme consumes much less network resource compared to other routing schemes proposed in the context of highly dynamic large ad hoc network.

1. INTRODUCTION

A mobile agent is a program that can move through a network under its own control, capable of navigating through the underlying network and performing various tasks at each node independently [1]. Mobile agents are an effective paradigm for distributed applications, and are particularly attractive in a dynamic network environment involving partially connected computing elements [2]. In this paper, we propose to use mobile agents for off-line message transfer among mobile hosts in a large, highly-mobile dynamic networks

In dynamic networks such as packet radio and ad-hoc wireless network, each node acts as a mobile router, equipped with a wireless transmitter / receiver, which is free to move about arbitrarily. In this configuration, even if two nodes are outside the wireless transmission range of each other, they can still be able to communicate with each other in multiple hops, if other intermediate nodes in the network are willing to participate in this communication process. Thus, the notion of static base-stations and centralized control to manage host mobility is no longer a key requirement in this environment [3]. However, the dynamics of these networks as a consequence of mobility and disconnection of mobile hosts pose a number of problems in designing routing schemes for effective communication between any source and destination [5,6]. The conventional 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 route discovery procedure generates large volume of control traffic. In a highly mobile environment with a large number of nodes, even if a route is discovered, a route rediscovery needs to be initiated when an intermediate node, participating in a communication between two nodes, moves out of range suddenly or switches itself off in between message transfer [3]. An additional problem is the occurrence of disconnected component within a network, where a destination is not at all accessible by a source at some instance of time. This has been shown in the simulated environment in [3] that the occurrences of disconnected components increase the protocol overhead due to the generation of unproductive route request packets. Thus, even off-line communication between source and destination (e-mail or file transfer, for example) would be inefficient, if not impossible, in a large dynamic network structure where hosts are highly mobile. This paper introduces a scheme using mobile agent to address this issue.

Currently, there is a growing interest in using mobile agents as part of the solution to implement more flexible and decentralized network architecture [1]. Most research examples of the mobile agent paradigm as reported in the current literatures have two general goals: reduction of network traffic and asynchronous interaction. Magedanz et al. [7] has suggested that a smart message agent can serve as an asynchronous message carrier for its owner (e.g., retrieve e-mail asynchronously and forward to the current location of the owner), or as a broker that requests and sets up all requirements for services (e.g., establishes a real-time connection for media delivery). Recent interests in the application of mobile agent in mobile computing environment suggest that mobile agent can be an effective paradigm for distributed applications, where partially connected computers are involved [2]. However, the use of mobile agent in the context of multi-hop ad hoc wireless network has not been explored. In this paper, we attempt to show the effective use of mobile agent for off-line message communication in the context of highly dynamic, large ad hoc network.

Mobile agent in this context would act as a messenger that would migrate from a source and carry the message from a source to a destination. The scheme utilizes the location information (using the global positioning system, for example) and relies on the fact that the mobility of hosts in ad hoc networks are not totally random but follow a pattern of movement [4]. A mobile agent can migrate off a source node with a message and navigate autonomously throughout the network to find out the destination in order to deliver this message. The agent has an approximate knowledge about the location of destination and takes the advantage of host-mobility as a vehicle to physically migrate from one location to other. If the destination is disconnected from the network for some duration, the delivery of message will be deferred and the agent waits for its reconnection in an appropriate intermediate node.

The performance of this scheme is evaluated in a simulated environment. It has been concluded that in a highly mobile , large ad-hoc wireless network, this scheme consumes much less network resource compared to other routing schemes proposed in the context of ad hoc network.

2. SYSTEM DESCRIPTION

The network is modeled as a graph G = (N,L) where N is a finite set of nodes and L is a finite set of links. Each node $n \in N$ is having a unique node identifier. We define the ***neighbors*** of n, $N_n \in N$, to be the set of nodes within the transmission range of n. It is assumed that when node n transmit a packet, it is broadcast to all of its ***neighbors*** in the set N_n.

Each node is assumed to have a **home location**. Generally speaking, home location is the most preferred location of a node where it normally resides. It means that even if a node is mobile, it eventually comes back to its home location.

It is assumed that each node knows its position using Global Positioning System (GPS) [8]. The use of GPS in the context of routing in ad hoc network has been proposed earlier in [8]. In this paper, it is also assumed that a node keeps track of the positions of its neighbors.

It has been observed earlier [4] that a node does not have a communication relationship with all the other nodes in the network; a node usually communicates with a limited number of nodes (*patron* host in [4]) in the network. Thus, it is assumed that a source node knows the home locations of its intended destination. If it does not know, a route request is generated [3] and the route reply carries the home location information. This would be useful for the source node in subsequent communications with the same destination.

3. A MECHANISM FOR AGENT CREATION AND NAVIGATION

3.1 The Structure of a Node

In order to facilitate agent's navigation for message communication, each node is assumed to have the following structure:

Node Id (n)
Home Location (x_n^{home}, y_n^{home})
Transmission Range (R)
Current Location (x_n, y_n)
Information about Neighbors (p) : (for all p : p, x_n^p, y_n^p)
Home Locations of Potential Destinations (d): (for all d : x_d^{home}, y_d^{home})

Each node is assumed to know its id, home location, transmission range and current location (through GPS). Each node transmits a periodic message to its neighbors to inform its id, current location. The receiving node appends this information (for all p : p, x_n^p, y_n^p).

Home locations of potential destinations may not be known initially. As indicated earlier, a request is initiated to search the destination (as is done in case of route discovery [[3]) to know the home location of the destination.

3.2 Agent Creation at the Initiator (source) Node

Whenever a node wants to send a message to another node which is not its neighbor, an agent is created as message carrier. The structure of the agent is :

Sender's Id and Home Location
Receiver's Id and Home Location
Navigation Procedure
The Body of the Message from Sender

3.3 Basic Navigation Procedure

The objective of the navigation procedure is to minimize the distance between the agent's current location (current location of the node where the agent is residing) and the home location of the destination. This criterion would enable an agent to select a neighbor of its current location and migrate there. If there is no neighbor available at that instant of time satisfying the above-mentioned criterion, the agent waits for a pre-specified amount of time and tries again. Because of high degree of node-mobility, the topology will change, and, it is assumed that the agent will eventually succeed to migrate.

For example, If the current location of an agent is (15,25), locations of three of its physical neighbors are (10,15), (30, 35) and (20, 30), and, home location of the destination is (65, 75), the agent would migrate to the node whose location is (30,35), since this migration would reduce the distance between the current location of the agent and the home location of the destination node. However, if the current location has two physical neighbors with locations (10,15) and (5,20), the agent would wait (since its current location is preferable to match the criterion) and retry after some time.

Most of the time the agent would not find the destination node at its home location. In that case, the agent has to wait in some node near the home location of the destination. However, because of the node-mobility, that node near the home location of the destination might move away. In that case, the agent would migrate to some other node following the same criterion of minimizing the distance with the home location of the destination. This *migrate-wait* loop would continue until the destination node reaches its home location and the message is delivered.

On successful delivery of the message at the destination node, an agent would terminate itself. If the agent can not deliver the message within a pre-specified amount of time, the agent would try to go back to the source node reporting a delivery failure and then terminate itself. However, it may so happen that the agent can not deliver this 'delivery failure' message also to its source node because of the mobility pattern of the source node. In that case, the agent would terminate itself after a pre-specified amount of time in order to reduce network load.

4. PERFORMANCE EVALUATION

The performance of the proposed scheme is evaluated on a simulated environment. In the simulation, the environment is assumed to be a closed area of 1000 x 1000 unit in which mobile nodes are distributed randomly. In order to study the delay and other time-related parameters, every simulated action is associated with a simulated clock of one second. Each node has been assumed to move at the rate of 30 units/sec. or 10 units/sec. in the specified area. We have deliberately chosen a high mobility pattern in order to study the effectiveness of the scheme. The neighborhood relationship is updated every second and accordingly the migration pattern of an agent is decided.

We ran simulations for networks of sizes 20, 40 and 60 mobile hosts with range of transmission varying from 50 to 150 unit in each case. Each node starts from its home location, selects a random location as its destination and moves with a uniform, predetermined velocity towards the destination. Once it reaches the destination, it waits there for a pre-specified amount of time, selects randomly another location and moves towards that. After a few movements in this fashion, the node selects its home location and comes back to its home location. After all the nodes reach back to their home locations in this fashion, a session is said to be complete. During a session, several source-destination pairs are selected randomly for message communication. The pattern and speed of movements are different for different settings with a mobility rate of individual node ranging from 10 to 30 units per second.

First, we have selected arbitrary source-destination pairs and studied the time taken by an agent, initiated by a source, to reach within the transmission range of the home location of the destination node. As discussed earlier, the success of the scheme depends on two factors : i) the agent, initiated by a source, should reach within the transmission range of the home location of the destination node quickly; and, ii) it should continue to stay within the transmission range of the home location, waiting for the destination node to reach its home location. Figure 1 shows the behavioral pattern of an agent for an arbitrary source-destination pair for different transmission range (R) and different number of nodes (N) in each case. . The initial distance between source and the home location of the destination was 660, when an agent was initiated. For R=50, it takes much longer time for an agent to come within the home location of the destination compared to R=100 or R=150. For R=50 and N=20, it is even uncertain to predict whether the agent would remain within the transmission range of the home location of the destination. The reason is, for low R and low N, there are situations when the agent is not finding any proper intermediate node to migrate in order to reach near the home location of the destination. Even at R=50, the situation is better when N is high (N=60, for example).

Situation is much better when R=150. At all node density (N=20,40,60), the convergence time is low; at the same time, it is evident from figure 1 that the agent will always remain within the transmission range of the home location of the destination, waiting for the destination to deliver the message.

Next, we have studied the average number of hops an agent would require to deliver a message to a destination node. A set of source-destinatin pairs are selected and each source initiates an agent at T=0. Three cases have been studied where each destination has been forced to reach its home location approximately at i) T=50, ii) T=100, and iii)T=200.

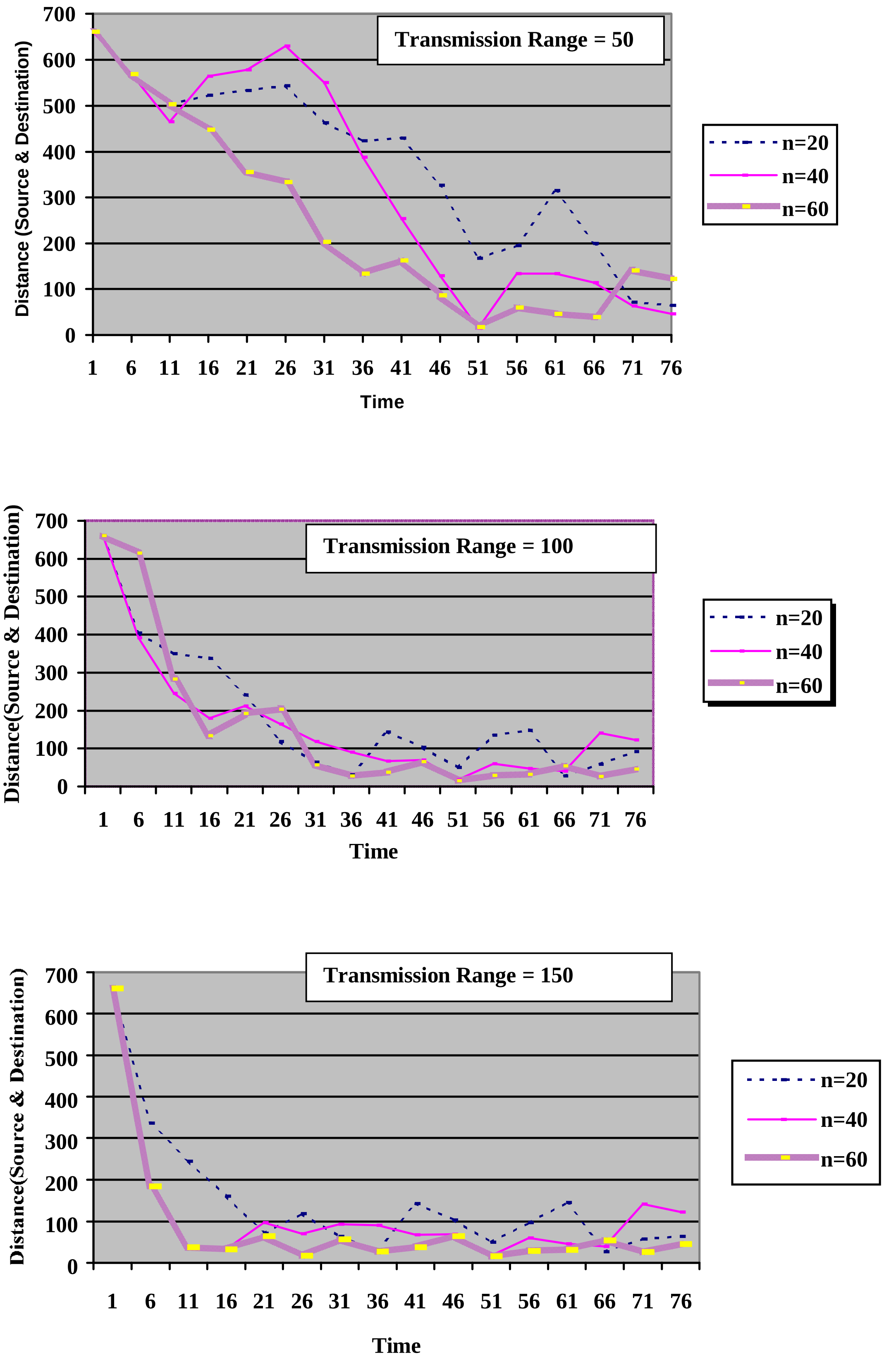

Figure 1. Time taken to reach within the transmission range of the home location of a destination from an arbitrary source at mobility rate 30 units / sec.

In each case, the transmission range is 150 unit; however, the number of nodes and mobility are different (Figure 2). This is an important study to see the amount of traffic generated within the network during this agent-based communication.

Form Figure 2, it is interesting to note that the number of hops does not depend on the number of nodes. Since an agent always migrate to one "appropriate neighbor", the number of hops does not depends on number of nodes in the system. This is in contrast with the existing routing algorithms, where the control traffic generated grows up drastically with increase in node density.

A second interesting observation is that the incremental number of hops with increase in T is approx. 10 hops per 100 seconds i.e. 1 hop per 10 seconds. Thus, even if the destination reaches its home location after a long time, the overhead in terms of communication resource utilization by an agent, waiting to deliver a message, is not significant.

When mobility is low, number of hops are less compared to the situations where mobility is high. This is expected, because, more dynamic is the network, more number of intermediate hops would be required by an agent to converge.

5. CONCLUSION

If the nodes in the network are less mobile or the size of the network is small, existing routing protocols designed in the context of ad hoc multi-hop networks work well. However, as discussed earlier, for a large, highly dynamic ad hoc network where each node has a pre-defined home location, agent-based scheme for message delivery is much more efficient and effective, exploiting the basic theme of mobile agent paradigm: reduction of network traffic and ease of asynchronous interaction.

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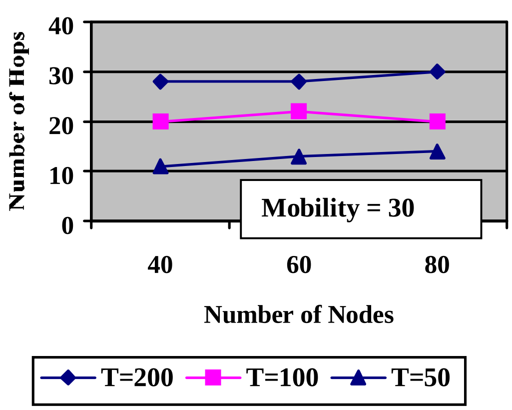

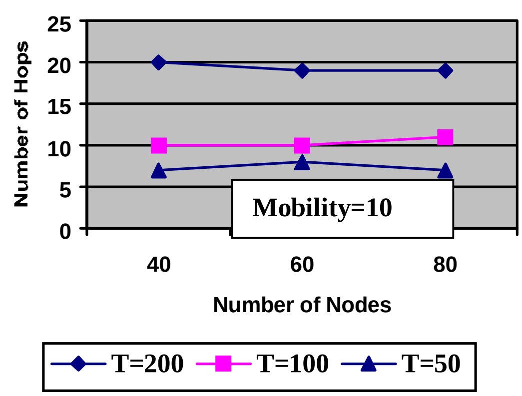

Figure 2. Average number of hops required by an agent to reach a destination node from a source node where T is average time taken by the destination to reach its home location