Evaluating the Performance of Mobile Agent-Based Message Communication among Mobile Hosts in Large Ad Hoc Wireless Network

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Abstract

In 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. 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 ad hoc network structure. 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. 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. 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 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. 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 [4,5]. 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 [6,7]. For example, the 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[8]) 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. 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 unidirectional links. Each node $n \in N$ is having a unique node identifier. Since in a wireless environment, transmission between two nodes does not necessarily work equally well in both direction [3], we assume unidirectional links. Thus, two nodes n and m are connected by two unidirectional links $l_{nm} \in L$ and $l_{mn} \in L$ such that n can send message to m via l_{nm} and m can send message to n via l_{mn}. In a wireless environment, each node n has a wireless transmitter range. We define the ***physical 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 ***physical neighbors*** in the set N_n.

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

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. However, a node may decide to change its home location dynamically.

We define the ***logical neighbors*** of node n, $M_n \in N$, to be the set of nodes whose home locations are within the transmission range of the home location of n. It is assumed that when node n changes its home location, it is communicated to all of its ***logical neighbors*** in the set M_n. Each node knows the home locations of its logical neighbors.

It has been observed earlier 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 the network. Thus, it is assumed that a source node knows the home location 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

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 physical neighbors to inform its id, current location and home location . The receiving node appends this information and checks whether the home location of the transmitting node is within the transmission range of the home location of the receiving node. If yes, it appends the id and home location of the transmitting node as Logical Neighbor. 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 and Basic Navigation Procedure

Whenever a node wants to send a message to another node which is not its physical neighbor, an agent with *Agent type=0* is created as message carrier. The objective of the basic 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 physical neighbor which is closer to the home location of the destination node and migrate there. If there is no physical 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). However, if the current location has two physical neighbors with locations (10,15) and (5,20), the agent would wait and retry after some time.

3.3 Behavior of an agent near the home location of the destination node

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.

3.4 Redirecting an agent by the logical neighbor of the destination node

A node might decide not to come back to its home location in near future and like to specify a new home location where all the messages for that node needs to be redirected. A node needs to inform all its logical neighbors about its new home location. Since the node knows only the home locations of its logical neighbors, it initiates an agent with *agent type =1*, one for each of its logical neighbor, which would carry this message regarding this change. On receiving this message, the logical neighbor updates the relevant field, recording the new home location of the node under consideration.

When a destination node changes its home location, a source node does not know it. Hence, the agent which is created to carry the message to the destination would reach eventually the original home location area of the destination node, waiting for the destination node to arrive at that point. In this situation, a logical neighbor of the destination node can redirect the agent towards the new home location of the destination node.

While the agent is waiting for the destination node at its home location area, the agent would encounter with the logical neighbors (whose home location area is the same as that of the destination node). If the agent finds the information regarding the new home location of the destination node in any of its logical neighbor, the agent would redirect itself towards that location using the same navigation procedure.

A destination node that has set a new temporary home location may decide after some time to reset that to its original home location or to another temporary home location. However, before this messages reaches all of its logical neighbors, an agent might encounter a logical neighbor of that destination node and redirect itself towards the old temporary home location of the destination node. In this situation, the agent is said to be misguided. The agent needs to come back after some time to the original home location of the destination node in order to re-track the destination node.

4. Performance Evaluation

4.1 The Setting

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. 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 (N) with range of transmission range (R) 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.

4.2 Evaluating the validity of the Scheme

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 number of nodes at 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.

4.3 Evaluating the Effectiveness of Agent-based Message Communication

Next, we ran the simulator for 1000 sec. The timings were adjusted to ensure that each node reaches its home location twice at random interval during this session and stays there for 10 seconds. 30 message communications were initiated, each at an interval of five seconds. The source and destination for each message communications were chosen randomly. A certain percentage of nodes (10%) have changed their home locations during the session and agents with type 1 were generated to incorporate the redirection mechanism as discussed.

Form Table 1 and 2, it is interesting to note that the average number of hops taken by an agent to deliver a message is not significantly high. Moreover, it does not depend much on the number of nodes for a particular transmission range. Since an agent always migrate to one "appropriate neighbor", the number of hops does not depend much on number of nodes in the system. However, with more number of nodes, more number of options will be available to an agent for migration, increasing the hop-counts. Even then, the increase in traffic with increase in number of node is not significantly high. This is in contrast with the existing routing algorithms in the context of ad hoc network, where the control traffic generated grows up drastically with increase in node density [9].

As expected, the number of hops decreases with increase in transmission range. When transmission range is high, an agent would be able to take a "longer" hop, reaching the destination faster. This is also in contrast with the existing routing algorithms, where the control traffic generated grows up drastically with increase in transmission range [9].

The maximum number of hops taken by an agent to deliver a message is high in few cases (Table 1 & 2). This is because of the fact that there is a change in home location of destination node and the agent was redirected towards the new home location of the destination.

5. CONCLUSION

If the nodes in the network are less mobile and the size of the network is small, existing routing protocols designed in the context of ad hoc multi-hop network 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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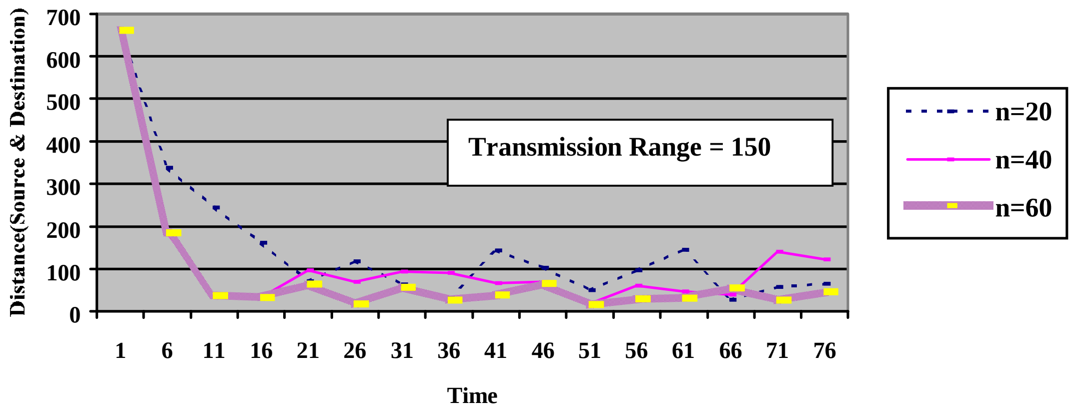

Figure 1. Time taken to reach within the transmission range of the home location of a destination from an arbitrary source at mobility rate 30 units / sec.

Transmission Range	Number of Nodes	Number of Messages Initiated	Number of Messages Delivered	Total No. of Hops Taken to Deliver all messages	Max. no. of Hops taken by an Agent to Deliver a Message	Average No. of Hops taken by an Agent to Deliver a Message
150	60	30	30	140	24	4.7
	40	30	30	127	19	4.2
	20	30	30	102	13	3.4
100	60	30	30	266	36	8.9
	40	30	30	263	27	8.8
	20	30	30	210	23	7.0
50	60	30	30	323	35	10.8
	40	30	30	306	33	10.2
	20	30	28	252	16	9.0

Table 1 : Agent-based message communication with node velocity 10 units / sec

Transmission Range	Number of Nodes	Number of Messages Initiated	Number of Messages Delivered	Total No. of Hops Taken to Deliver all messages	Max. no. of Hops taken by an Agent to Deliver a Message	Average No. of Hops taken by an Agent to Deliver a Message
150	60	30	30	152	18	5.7
	40	30	30	124	14	4.1
	20	30	30	122	14	4.1
100	60	30	30	219	32	7.3
	40	30	30	197	26	6.6
	20	30	30	248	25	8.3
50	60	30	30	341	43	11.4
	40	30	30	228	17	7.6
	20	30	30	292	22	9.7

Table 2 : Agent-based message communication with node velocity 30 units / sec