Efficient Management of Domain Foreign Agents in Mobile Computing Environment Using Load Balance

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Abstract. Mobile IP is a protocol standard designed to be used in a mobile computing environment. However, Mobile IP has a drawback to incur a lot of handoff delays and waste network resources, since CoA registration packets need to go through a HA first whenever a mobile node moves. To solve such problem, this paper proposes a new scheme that, for intra-domain movement, efficiently performs local handoff without notifying the HA. Specifically, based on the notion of load balance, the proposed scheme allows every FA in a domain to become the root FA(a.k.a. Domain FA) dynamically, thus distributing the registration task into many other foreign agents. Our simulation results show that the proposed method proves to reduce registration packets by approximately 7–15% more than existing methods.

1 Introduction

Mobile IP is a standard designed to transparently provide the mobility for the wireless devices on the Internet. One of the drawbacks of Mobile IP is that whenever a mobile node moves to a foreign network, it should register its new CoA(Care-of Address) with its home agent [4]. During frequent movement of the mobile node, if the home network is far away from the foreign network, this address registration can incur a few problems such as exorbitant handoff delays, packet loss, etc. To alleviate these long-standing problems involved in CoA registration process [2,6], this paper proposes a new scheme that, for intra-domain movement, efficiently performs local handoff without notifying the home agent. Specifically, based on the notion of load balance, the proposed scheme allows every foreign agent in a domain to become the domain root dynamically, thus distributing the registration task into many other foreign agents. The dynamic root assignment through load balancing ultimately leads to fast network response due to less frequent transmission of registration packets.

This paper is organized as follows. Section 2 briefly describes Mobile IP and some approaches to solve CoA registration problems. Section 3 gives a detailed description of a new scheme proposed in this paper. Extensive experimental results and analyses are presented in Section 4. Lastly, Section 5 summarizes this paper.

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2 Relevant Researches

2.1 Mobile IP

Mobile IP is designed for a mobile node to have two IP addresses: home address and care-of address(CoA). The home address is an IP address to uniquely identify the mobile node, while the care-of address is an IP address used to forward packets delivered with home address to the mobile node when the node is not attached to its home network[1]. Mobile IP requires two agents for a mobile node: home agent(HA) and foreign agent(FA) [4, 5, 6]. The home agent is responsible for the management of the home address and the CoA of the mobile node. The foreign agent is a mobility agent on the foreign network to which the mobile node is currently attached, and offers its IP address to the mobile node as the CoA. The home agent can receive all the packets destined to the mobile node and if needed, can redirect them to the foreign agent, which then forwards the received packets to the final mobile node.

One shortcoming in Mobile IP, also known as *triangle routing*, is that the packets destined to the mobile node must be routed through the home agent, even when the mobile node and the correspondent node are physically near to each other. The triangle routing problem brings about a lot of communication delays [3,4]. To avoid this triangle routing, a mechanism called *route optimization* was suggested. However, the route optimization scheme still has some problems with micro mobility, smooth handoff, and security.

2.2 Hierarchical Mobility Management

There are a lot of overheads (e.g., protocol latency) involved in registering a new CoA after the detection of a mobile node' movement. In particular, if the foreign network is far away from the home network or if the handoff is repeatedly performed due to small many movements, the overheads will be enormously significant. In this context, *hierarchical mobility management* was devised to reduce such overheads by registering the new CoA with a specific local agent on the foreign network, not with the home agent on the home network.

The hierarchical mobility management scheme is based on the hierarchy of foreign agents in a domain(Figure 1)[1,3,4,7]. The root of the tree, which is called root FA or DFA(Domain Foreign Agent), is responsible for all foreign mobile hosts within the domain. The first time when a mobile node moves into a foreign domain, a new CoA of the mobile node is registered with the home agent. Hereafter, for every intra-domain movement, the corresponding CoA is registered with the DFA, not the home agent. In this way, the hierarchical scheme hides the mobility within the foreign domain from the home agent, and thereby leads to the dramatic reduction of CoA registration–related time and messages. However, it has serious drawbacks that the DFA is only a single node to be responsible for the address registration of all mobile nodes in the domain, and therefore, the DFA is easily overloaded with the heavy traffic from the correspondent nodes.

3 New Scheme for Management of Domain Foreign Agents

Figure 1(a) illustrates a scenario in which a mobile node performs a handoff from one foreign agent labeled FA8 to another foreign agent labeled FA9, using a conventional mobility management mechanism. The request message for address registration is generated by FA8 and passes up through FA4, FA2, and FA1 to the home agent, HA. In response to the request, the home agent sends an acknowledgement, which will come down through FA1, FA2, and FA4 to the destination agent, FA9. The conventional method forces all messages to pass through the root FA, FA1, which will soon be a bottleneck for message traffic. Additionally, the above scenario requires as many as 8 message transmissions, though the FAs participated in the handoff are adjacent to each other.

For the purpose of the new scheme presented in this paper, assume that all foreign agents are structured in a form of binary tree, and that each node in the tree is labeled in the order as in Figure 1. Then, the basic idea of the new scheme is that based on the notion of load balance, it allows every FA in a domain to become the DFA dynamically, thus distributing the CoA registration task into many other foreign agents in a domain.

Consider Figure 1(b) that depicts how the proposed scheme works when the same scenario as in Figure 1(a) is applied. The proposed scheme first figures out the common ancestor FA, FA4, between FA8 and FA9, then designates the ancestor FA as a new DFA, and next lets the new DFA forward the registration message to the home agent. The registration message will include all information specific to this handoff, such as source FA, destination FA, new DFA, etc. In return for the registration request, the home agent will communicate with new DFA (i.e., FA4) for the delivery of an acknowledgement. Subsequently, the new DFA forwards the received acknowledgement to the destination FA, FA9.

Note some benefits from using the proposed method. The proposed method can enable the traffic having passed through one bottlenecked DFA to be now distributed into each and every FA in a domain, as well as can alleviate some stubborn problems in mobile environment such as packet loss and delay, thanks to fewer number of message transmission and faster response time.

One core part of the proposed scheme is the algorithm to select a new DFA. Basically, the algorithm finds the greatest common FA for the given two input FAs. The detailed steps and the pseudo code for implementing the steps are described below.

– Assume two input nodes are FA_p and FA_f, where FA_p represents the FA at which a mobile node is now present, and FA_f represents the FA to which the mobile node is going to move.
– Make FA_p and FA_f be positioned at the same tree level by moving only the higher level FA up to the lower level along the tree branches (recall that the level of the root is lowest). The modified new FAs are then denoted again as FA_p^* and FA_f^*.
– Find out the nearest parent, FA_{root}, of two modified FAs (i.e., FA_p^* and FA_f^*).
– Choose FA_{root} as a new DFA.

```
Find-Nearest-Parent-Node( ){
  divide i, j by 2 until i = j;
```

```
    set node i or j as as a parent;
  }
  ...
  if(Level(i) = Level(j))
    Find-Nearest-Parent-Node( );
  else if(Level(i) < Level(j)) {
    do j = ⌈j/2⌉ until (Level(i) = Level(j));
    Find-Nearest-Parent-Node( );
  } else {
    do i = ⌈i/2⌉ until (Level(i) = Level(j));
    Find-Nearest-Parent-Node( );
  }
```

Consider Figure 1(b) again to see how the DFA selection algorithm works when a mobile node moves from FA4 to FA15. According to the previous notation, the algorithm starts with FA_p = FA4 and FA_f = FA15, then finds out FA_p^* = FA4 and FA_f^* = FA7 as two modified FAs at the same tree level. At the last step, the algorithm yields FA_{root} = FA1 as the closest parent of FA_p^* and FA_f^*, and declare that FA_{root} = FA1 now becomes a new DFA.

The above scenario (switching FAs from FA4 to FA15) gives a kind of worst-case examples. However, in the real world mobile computing environment, it is believed that the circumstances like this scenario rarely happen because the mobile node mostly roams around adjacent foreign agents.

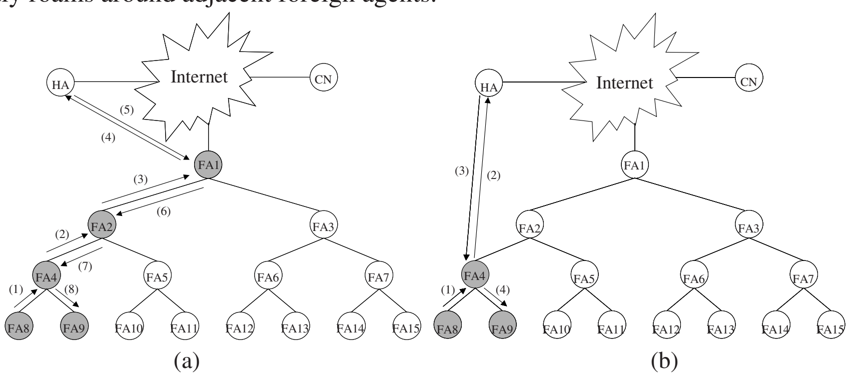

Fig. 1. (a) A scenario for registering CoA in a tree-structured domain by existing methods. (b) An exemplar scenario for registering CoA in a tree-structured domain by the new method

4 Simulation Results

This section presents some experimental results comparing the proposed method and existing methods. Figure 2 provides the result for the best scenario in which the handoff occurs between an FA and its child FA. Regarding existing methods, as the tree level of handoff-related FA nodes gets deeper and deeper, the number of messages transmitted increases linearly because the messages must climb up the branches of the tree to the root node. On the contrary, the proposed method produces a constant number of messages because the DFA is not fixed to the root node, but can become any node in the tree according to the DFA selection algorithm presented in this paper. Theoretically, the above scenario is plausible, but in most practical cases, the message count of the proposed method is expected to come between the two lines in Figure 2.

Meanwhile, Figure 3 plots the performance comparison between the existing methods and the proposed method when the two FAs around which the mobile node will roam are selected at random. The horizontal axis represents the number of FA nodes included in a domain and the vertical axis represents the ratio of message volumes created by the new method to the message volumes created by the old method, with the rate of 1.0 fixed for the old method. For each group of FA nodes on the horizontal axis, we made a random selection of FA_p and FA_f nodes from the group 10000 times, and applied the proposed scheme to each selected pair of FA nodes. The sum of the message volumes generated by each pair is computed and then divided by 10000 to get an average message volume. The ratio of two average message volumes from old methods and the new method is finally computed and plotted into the graph. Simulation results tell us that the ratios on the vertical axis corresponding to the newly proposed method fast converge into equilibrium as the number of nodes increases. Specifically, when the node count goes beyond 32768, the ratio approaches to a constant, 0.93, which proves that the proposed method can reduce the total message traffic by at least 7%.

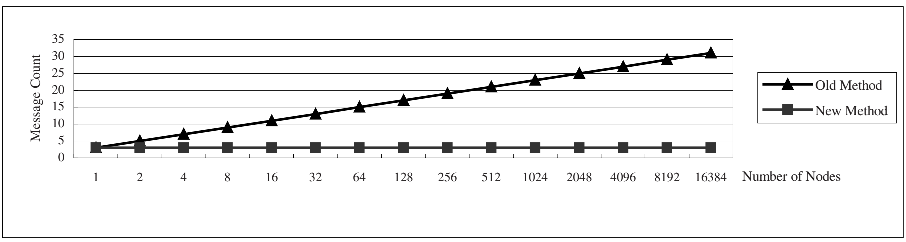

Fig. 2. Comparison of existing methods and the new method: the best scenario

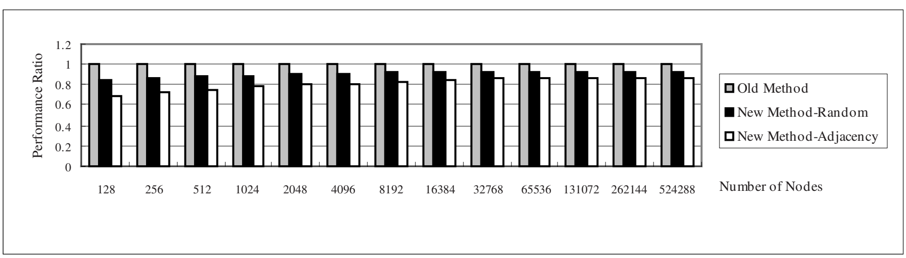

Fig. 3. Comparison of existing methods and the new method: foreign agents participated in the handoff are selected at random or adjacent to each other

The improvement of 7% is made when the handoff happens between two arbitrary FAs in a random fashion. However, it is easily observed in the real world that the handoff is often performed between adjacent FAs. Figure 3 also shows the performance comparison when the adjacent handoff is executed. We can infer similar interpretations as the previous random case. That is, when the node count is greater than 32768, the ratio fast converges to a constant, 0.85, which corresponds to approximately 15% reduction in total message traffic by the proposed method.

5 Conclusion

To meet the ever-increasing demand for mobile computing, Mobile IP was introduced and is now gaining popularity more and more. However, Mobile IP has some shortcomings related to the mobility management.

This paper proposes a new mobility management scheme that, for intra-domain movement, efficiently performs local handoff without notifying the home agent. Specifically, based on the notion of load balance, the proposed scheme allows every foreign agent in a domain to become the domain root dynamically, thus distributing the registration task into many other foreign agents.

Our simulation results exhibit that our proposed method proves to reduce the total message traffic by approximately 7-15% more than existing methods. The proposed method prevents the message traffic from swamping the root node in the tree. Rather, the traffic is now fairly distributed into each FA in a domain. Plus, the proposed method can alleviate some stubborn problems in mobile environment such as packet loss and delay, thanks to less number of message transmission.

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