Using Foreign Agent For Home Agent Fault Tolerance in Mobile IP

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***Abstract*— In this paper, we are addressing the problem of Home Agent failure in Mobile IP Networks. In a single HA system, a challenge of a single point of failure occurs. i.e. if the HA is failed due to power failure or other reasons and the MN moves to another network, no information of its current location is being kept, and therefore no further packets can be destined to it. We are proposing to make use of Foreign Agents as redundant (Backup) for Home Agents, i.e. copying the needed data to a foreign agent to act as a Backup of the Home Agent at the point of failure. Any CN that wants to communicate with a MN should connect to a third party for the address of the failure-free agent that has the current location of that MN. In this way, the whole home network can be backed up. Also, our approach relies on Dynamic Backup rather than static (fixed) Backup, since the Backup foreign agent dynamically created on different foreign networks.**

***Keywords*— Agent, Foreign Agent, Mobile IP, Third Party, Fault Tolerance.**

I. INTRODUCTION

The development of wireless technology spreads out the wireless personal information products that are equipped with wireless communication interface. However, it has problems with the current TCP/IP protocol since the TCP/IP was built under the assumption that the end points are stationary. When a Mobile Node (MN) moves to another network without changing its IP address, it will not receive the packets destined to it. These packets still route to the origin Home Agent but not the current point of attachment. As a solution to this problem, the Internet Engineering Task Force (IETF) has defined Mobile IP to enable wireless users to maintain ongoing data sessions without interruption while changing locations, by using two IP Addresses for every MN: A static home address by which the MN and its network connections are identified. And a care-of-address (CoA) that changes as the MN's point of attachment to the network changes [6]. A MN is registered to its HA (Home Agent) and when moving to another network, it registers to a FA (Foreign Agent) and obtains a Care Of Address which is sent to its HA to keep up to date location of the MN. In Mobile IP protocol, the HA is the only mobile Agent that carries and maintains the current locations of its MNs. Moreover, if this HA fails, no further packets can be destined to those MNs. This paper presents a fault tolerant approach based on using a FA as a Backup for the faulty HA to takeover its job. The algorithms of Failure Detection, Take Over Process, and Recovery are fully described to produce a full fault tolerant solution.

The rest of the paper is arranged as follows: Section 2 describes briefly the state of the art and related work. Section 3 reviews some of Mobile IP functionalities. Section 4 defines the problem and describes the proposed solution. The last Section 5 summarizes the simulation results and discusses the performance metrics.

II. RELATED WORK

Many fault tolerant approaches have been proposed to address the problem of Home Agent Failure in Mobile IP. In [1], the concept of redundant home agents is used to handle the failure, so when one HA crashes, another HA takes over the job. When a MN sends a request to a FA, the FA forwards it to HA1 which process the request and forward it to HA2 which sends an Acknowledgement to HA1,and finally, HA1 sends back a reply message to the FA which forwards it to the MN. In their approach, a synchronization protocol is needed to synchronize all the HAs. This, of course, leads to high traffic signaling through the network. To reduce the load of synchronization, a stable storage approach was proposed in [2]. If the HA fails, one among other home agents on the network, can recover the bindings of all the mobile nodes registering with the HA by restoring the logged registration request messages from the stable storage and replying them. Moreover, each home agent should periodically save the bindings of all the mobile nodes registering with it on the stable storage and remove all the logged messages beyond the previous check point from the stable storage. Although this approach seems simple to implement and maintain, it costs time for fetching the binding table from the stable storage which represents another single point of failure. In [3], multiple failure-free mobility agents are selected to form a backup set for the faulty mobility agent. The work loads of the faulty mobility agent are redirected to the failure- free mobility agents in the backup set. The mobility bindings of the faulty HA can be restored by searching all the FAs' visitor lists. The restored mobility bindings are then distributed to the backup members. Collecting the entries from the FAs to reconstruct the mobility binding table is a highly time consuming process. The authors in [4] proposed a fault tolerant multi agent based schema stating that each mobile agent keeps a mobile agent table and a binding update table to manage the binding. Obviously, with too many tables that should be maintained on each mobile agent, performance degradation appears. In [5], a HA fault tolerant approach is also proposed where only two mobility bindings are maintained in the system. A synchronization process is needed to maintain the two mobility bindings among the HA and its Backup by forwarding the registration message and replying backward. Also, each mobile agent maintains two tables: HA table recording the HA backup location and Backup table which records the HA that will be taken over. This approach may lead to less registration latency than previous approaches but the synchronization process still has its latency. Also, too many tables are being maintained at each mobile agent. For all those approaches, none of them has considered the case of Home Network failure, i.e. the case when the whole network loses the connection to the world. In the previous approaches, if this happens, the HA and also its Backup(s) are down, thus no further connection to any belonging nodes can be done.

III. MOBILE IP OVERVIEW

In Mobile IP Wireless Networks, Mobility Agents are routers maintaining the binding between the two addresses in a transparent manner, which are classified as: Home Agent (HA), located in the home network and maintains the mobility bindings of the mobile hosts using a table called the Mobility Binding Table, fig.1 depicts the format of the MBT. And Foreign Agent (FA): located in the foreign network that the MN visits and maintains a visitors List. The basic functions of the Mobile IP protocol are as follows: Agent Discovery for obtaining CoA, Registration of the obtained CoA, Tunneling to the CoA, and Deregistration of the CoA.

Home Address	Care-of Address	Lifetime (in sec)
131.193.171.4	128.172.23.78	200
131.193.171.2	119.123.56.78	150

Fig.1 Mobility Binding Table

The agent discovery can be carried out in two ways: The Mobility Agents advertise their presence by broadcasting advertisement messages periodically. Or the MN can transmit agent solicitation messages that are acknowledged by the mobility agents. For the registration process, first, the MN finds out if it is in its home network by listening to advertisements from its HA. If it is, then it continues to operate without any requirement for mobile services. If the MN is in a foreign network, it registers with the FA by sending a Registration Request message, which includes the permanent IP address of the MH, the IP address of its HA and the CoA information. The FA performs the registration process on behalf of the mobile host by relaying this request to the HA. Upon receiving the request, the HA updates its routing table, approves the request, and sends a Registration Reply back to the FA. The FA then updates its visitor list and relays the reply to the MN, fig.2 and fig.3 depict the format of the registration message request and reply, respectively. When a CN wishes to communicate with an MN, it uses the original address of the MN, so the packet goes to HA. From the mobility binding, the HA encapsulates the packet (IP-in-IP or GRE) and sends it to the CoA. The FA de-capsulate the packet and extracts the original packet that was sent by the CN. The FA then sends this packet to the MN using the Home address destination. The reverse route from MN to CN may or may not follow this path. The deregistration process is involved in discarding the CoA when the MN moves from one location to another, so, it acquires a new CoA and the old CoA is discarded. The MN sends a Registration Request to the HA with a lifetime set to zero and the HA updates its mobility binding table. The MN need not deregister at the FA, as the service offered by the agent will expire after the lifetime of its entry. The FA then drops the entry for the MN from its visitor list.

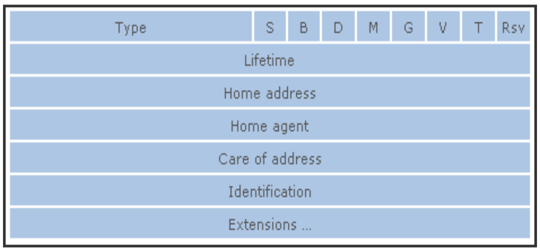

Fig.2 Mobile IP registration request message structure

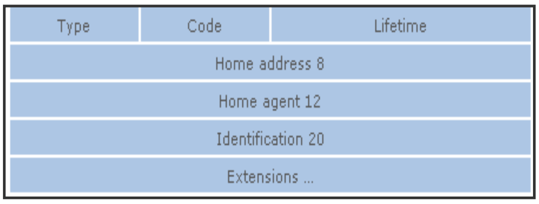

Fig.3 Mobile IP registration reply message structure

IV. PROBLEM STATEMENT AND PROPOSED SOLUTION

A. *Problem Statement*

Mobile IP is solving the issues of mobility successfully, but it suffers from a major drawback. Every packet destined to the MN has to go through the HA. So home agent failure is a serious problem. HA is needed for: initial connection setup between the CN and the MN, deregistration and registration when the MN moves. Thus, when the MN is visiting a foreign network, and the HA fails for some reason, then MN will be completely disconnected from the entire world. In short words, HA becomes a single point of failure, as all the responsibility is entrusted with it. To solve this single point of failure and make the Mobile IP system more fault-tolerant, a new protocol is required. This protocol must be simple and easy to use in the existing infrastructure without much modification to other entities in the system such as FA and MN.

B. Proposed Solution

1) *Objective and Advantages:* The solution scheme is based on the concept of making use of foreign networks, i.e. Use a Foreign Agent as a Backup for the Home Agent. Reaching this objective can lead to many Advantages: 1. Make use of Protocol Messages, thus, reducing overhead needed for a new connection to transfer a copy of the Mobility Binding Table to the Backup. 2. Creating a Dynamic Backup rather than Static, the last accessed FA is the selected Backup. 3. Not just HA Backup, but Home Network Backup, if the whole network is down, the outside belonging MNs can still be communicated.

2) *Fault Tolerant System Model Creating a Backup:* when a MN moves to a foreign network, it sends a registration request to the Foreign Agent. The FA then communicates with MN's HA and asks to grant registration process. The HA updates its MBT and replies with a Registration Reply Message, At this point, the Mobility Binding Table is added to this message to be sent to the FA (Note that only the Mobile Nodes Mobility Binding information is considered here due to the fact that MNs are much more sensitive to the HA failure than stationary nodes). Recall to the message reply format, an extension field can be used to carry this information and officiate the purpose.

The FA receives the message, retrieves the MBT and stores it and then relays the message (excluding the MBT) to the MN and finishes the registration process. Now, the FA has the up to date Binding Table and can be a useful Backup. An important issue occurs here which is, every time a MN moves to a foreign network, a new Backup with a different copy of the MBT is created. To keep up with the up to date Backup, a third party is used to store the address of the last accessed FA (up to date Backup). So, each time a Backup is created, its address should be stored at this third party. This can be done easily by the HA which communicates the third party and stores the address of its newest Backup. Fig.4 summarizes the Backup Creation process.

HA Failure Detection: When a CN wants to communicate with a MN, it connects directly to the third party - instead of the HA- and, asks to redirect it to an active Agent which has the current location of that MN. The third party checks the availability of the HA from its local records, since the third party is always aware of the status of the Mobility Agents of the system. If the HA is active, the connection is redirected to it and the ordinary process proceeds. On the other hand, if it is inactive (Down), the connection is redirected to the stored address corresponding to the faulty HA.

Takeover Process: At the point of HA failure, the CN is provided, redirected and connected to the HA Backup, which is the FA that hosts one or more of the faulty HA MNs. Now, this Backup will takeover the job and relay the packets destined to a MN by fetching the stored Mobility Binding Table to get the current location of that MN.

Recovery: At HA Recovery, it communicates with the third party and asks for the address of the last created Backup just before failing. The third party then provides the HA with the address of its last Backup. The HA communicates the Backup directly, retrieves the Binding Table and get back to work.

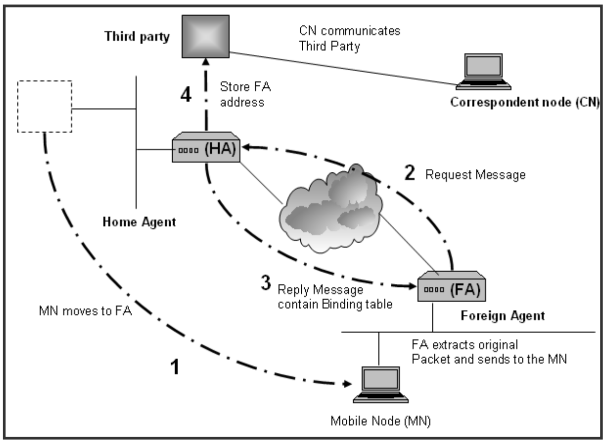

Fig.4 Backup Creation Process

Now, almost a complete fault tolerant solution is described, and below is a list of the benefits and advantages over other approaches:

- Dynamic Creation of Backup, i.e. no fixed backup is predefined. The last accessed FA is the Backup of the HA.
- Make Use of existing messages, i.e. the usage of the registration reply protocol message to carry a copy of the up to date MBT, thus no need for a separate connection to share or synchronize the MBT.
- No too many Table Maintenance is at HA, thus reducing the load at the HA.
- Can tolerate the Failure of the whole Home network, if the Home Network looses connection to the world, the Backup is still active (outside the network), and thus the outside MNs that belong to the faulty Home Network can still be communicated through that Backup.
- No need for Failure detection Algorithm to be implemented at FAs, the detection of HA failure is carried out directly by the third party.
- Also, the Recovery algorithm needs not to be implemented at FAs.
- No modification is needed at MNs and thus no infrastructure changes are done.

V. PERFORMANCE EVALUATION

Registration Cost: In MIPv4, the MN sends the registration message via the FA that is topologically close to the MN. The FA must process the registration and forward it to the HA. The HA must process the registration message, update its table with the new IP address, modify the tunnels and send an acknowledgment to the MN via the FA. If the MN moves back to it's HA subnet, then the MN can send registration packet directly to the HA which processes the packet, and returns the acknowledgment directly to the MN [7].

To estimate this Registration process cost, assume the following parameters:

k: Number of hops on shortest path between FA and HA
Cp: Cost to process packet/message at a node.
Ct: Cost to transmit one message over one hop
z: binding table size / packet size
L: Number of hops on shortest path between FA and CN
S: Number of sessions between MN and all its CNs

Then the Registration Cost can be calculated as follows:

Registration without binding table transmission

$$Reg(k) = 2C_p + (k+1)C_t \quad (1)$$

Registration with binding table transmission

$$Reg_{ps}(k,z) = 2C_p + (k+1)C_t + z[C_p + (k+1)C_t] = (2+z)C_p + (k+1)(2+z)C_t \quad (2)$$

While, In [7], the Registration cost is calculated as follows:

$$Reg_4(k,S,L) = 2C_p + 2(k+1)C_t + S[C_p + 2(L+1)C_t] \quad (3)$$

And, In [5], the cost is given as follows:

$$Reg_6(k) = 2[2C_p + (k+1)C_t] = 4C_p + (2k+2)Ct \quad (4)$$

Fig. 5a shows the Number of hops on shortest path between FA and HA Vs. cost calculated by equation (2), and as can be seen, fixing the Binding table size, the more hops between HA and FA, the more cost is consumed.

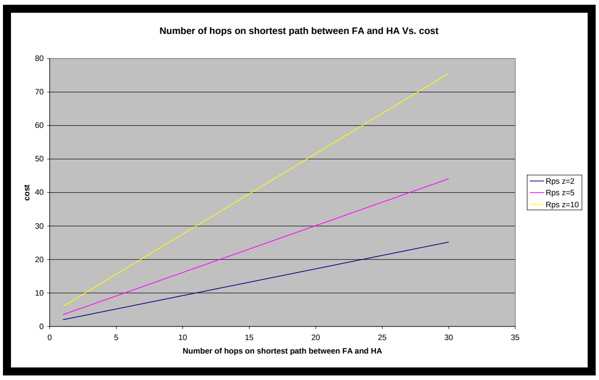

Fig.5a Number of hops on shortest path between FA and HA Vs. cost

Fig.5b shows cost vs. binding table size, varying the table size and fixing the number of hops between HA and FA. The relation is linearly increasing.

Fig.6 compares the registration cost of the three schemes; the costs are obtained by applying the equations (2), (3), (4). and as can be seen, our model relies in the middle, i.e. it's showing lower cost (delay) than in [7], while higher than in [5], this is can be explained as our scheme transfers the mobility binding table out of the network during the registration process, while in [5], this is done inside the Home network only. This degradation in performance can be connived as our model can backup the whole network rather than the only the HA. Moreover, a dynamic instead of static backup is established.

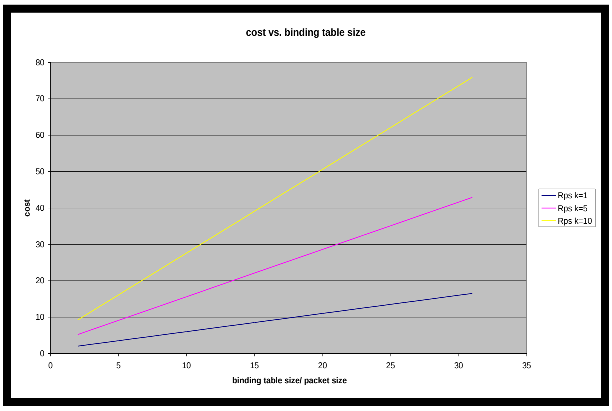

Fig.5b Size of Binding Table Vs. cost

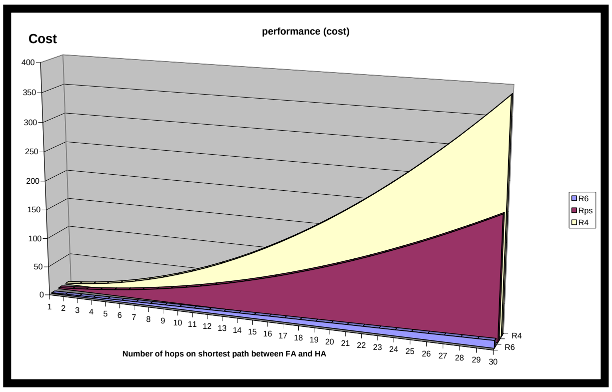

Fig.6 Cost Comparison between the three schemes

VI. Conclusion and Future Work

In mobile IP networks, a single point of failure which is the HA can cause disconnection of all MNs that belong to its network. A new fault tolerant approach is proposed in this paper based on using one of the FAs of the foreign networks as a backup for the HA.

As a future work, the mobility ratio of the MNs can be considered to control the selection of the MN that will trigger the transfer of the MBT rather than transferring it at each FA registration process. A good idea is to set a timer and at each registration process, this timer is checked and if it is below some threshold, no MBT transfer is done, while if this timer exceeds the threshold, the transfer process is triggered. Thus, reducing traffic and network recourses consumption.

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