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Optimal Load Balancing of Hierarchically Structured Multiple Home Agents

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Abstract— Mobile IP has become increasingly important to provide continuous network connectivity to the Internet regardless of the physical location of the mobile nodes. In this paper, we focus on Multiple Home Agents (HA) for Mobile IP to achieve improved performance concerning data transfer, system throughput and overhead for message passing. We introduce the concept of Bulletin Board (BB) as a repository to store the current status information of all HAs. Our primary goal is to discover an optimal HA efficiently to transfer the load considering hierarchy level and percentage of load. Besides this, our research considers how system load can be distributed uniformly using threshold based approach in a hierarchically organized multiple HA network. We have done a comprehensive simulation study by NS-2 to compare how the entire system load is distributed between multiple HAs and Single HA.

Index Terms— Bulletin Board, Bit Vector, Home Agent, Load Balancing, Threshold.

1 INTRODUCTION

MOBILE IP [1], the well known Internet Protocol extension, is the fundamental technology to support various mobile applications. Mobile IP allows users to keep fixed IP addresses which are essential for consistent and uninterrupted connections while roaming between networks.

In mobile IP networks, each Mobile Node (MN) has a permanent IP, known as home address belonging to the home network. The home network is unique to a given mobile node, with its prefix matching the home address of the MN. While roaming away, the MNs keep receiving packets destined to their home address as those packets get forwarded to their current location by a Home Agent (HA) which a fixed node is residing in the home network. According to [2], a home agent is defined as a router on a mobile node's home network, which tunnels IP datagrams for delivery to the mobile node when it is away from home and keeps current location information updated for the mobile node.

In the basic Mobile IP protocol, HA can be a single point of failure. The collapse of a single HA may then result in the loss of connectivity for abundant MNs located throughout the Internet. To alleviate this problem, this paper introduces the concept of hierarchically organized Multiple Home Agents, where the entry load is distributed among multiple home agents. To enhance the system's consistency and performance, a modified threshold based load balancing policy is proposed. An electronic message board, named bulletin board is also proposed in this paper to depict the status of HAs continuously. The status of a HA refers to whether it is in a normal state to have more loads or in an overloaded or underloaded state etc. It also covers proposed concept and structure of the Bulletin Board that provides most recent information about the current status of the hierarchically structured HAs and this reduces lots of overhead during message passing.

This paper is organized as follows: Section 2 provides the literature review. The proposed solution is presented in section 3. Section 4 represents the results of the simulation study. Conclusion and future work are depicted in section 5.

2 BACKGROUND STUDY

In order to avoid single home agent problem, an architectural model for multiple HA is designed and implemented in [3]. The key task of a home agent is to receive IP datagrams intended for the roaming mobile hosts currently registered, and tunnel the encapsulated packets to their present spot. When the number of serviced mobile hosts increases significantly, it may happen that the HA agent saturates and the packets queue up, causing extensive delays. Jue & Ghosal [4] proposed a protocol extension that enables several nodes in the home network to become home agents, sharing the workload and improving the overall performance. The concept of multiple HAs was proposed in [5]. In

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that structure, each HA is assigned a specific topological level in its domain, where the level information is a hop-distance from the exit router. The hop-distance is calculated by counting the number of hops to reach the exit router. So, if the HA is closer to the exit router of the home domain, with respect to hop-distance, the level is higher. The exit router is defined as the router from which Internet traffic leaves the home domain. Each HA then computes its own level metric and advertises it to all the other HAs. The mobile node is notified about such hierarchy and chooses the closest HA.

Authors in [6] have proposed a dynamic double threshold load balancing policy, in order to distribute the system load and to improve the system performance. Using a double-threshold approach, they have defined upper and lower thresholds to be used by HAs where an HA is said to be "vacant", if its queue length falls below the lower threshold, and "full", if it exceeds the upper threshold. When the queue length exceeds the threshold, an HA attempts to transfer one MN to another under loaded HA. The authors in [7] have suggested a new load balancing procedure where each HA regularly advertises the number of available MN that it is able to accept. They have also proposed to implement this procedure in the IPv6 router advertisement message sent by the HA.

3 Proposed Solution

In this research, we use double threshold load balancing policy proposed by the authors of [6]. We have enhanced their policy by introducing additional two states to provide optimal load balancing, minimize context switching and message passing. Instead of each HA maintaining the list and priorities of all HAs based on the threshold based approach, a number of Bulletin Boards (BB) containing the states of HAs are maintained. Each HA only sends the status update information to the BB. Thus, the message transferring overhead is reduced and searching an optimal HA becomes easier.

In this section, the modifications that are accomplished over the basic single HA Mobile IP Communications to enhance the system consistency and performance by providing a modified threshold based load balancing policy is articulated. It also covers proposed concept and structure of the Bulletin Board.

3.1 Developing the Concept of Bulletin Board

In this research, we utilize the concept of Bulletin Board (BB) for maintaining a repository of the current information about the HA's such as HA's hierarchy level and load balancing status etc. All HAs forms a multicast group titled Home Agent Multicast Group (HAMG). The members of the HAMG must listen to the advertised address of the active BB. According to the authors of [6], when a HA changes its status, it multicasts the most recent updated status information in the HAMG multicast group. In our proposed solution, such information is only send to well-known address of the active BB. The active BB receives the information and replaces the old entry for that particular HA by the most recent one. A receiver HA copies the message from the channel instead of removing it when it makes a receiver request on the channel. Thus a multicast message remains available to other HAs as if it has been posted on the bulletin board. In this research, the concept of BB is used to reduce the message transferring overhead and establish an efficient way of searching an optimal HA.

In order to keep the information up to date and to preserve the concurrency of the messages, real time information is included with each message to find out the most recent state and level of the HAs. The messages stored in the BB are sorted according to the value of the time field. The clocks of all HAs must be either synchronized or they have to use a same global clock.

In our proposal, the BB maintains a table structure called HA Status Information Table as shown in Fig.1. The size of the table must be equal to the maximum number of HAs supported by the system. Each table entry stores a HA-ID

HA-ID	STATUS	HA-LEVEL	TIME

Fig. 1. Structure of the HA Status Information Table

field – IP address of the HA that uniquely identify the HA, HA-LEVEL - represents the position of the HA in hierarchical structure, STATUS - the current status of the HA for load balancing, TIME - represents the real time when the data is entered in the Bulletin board.

3.2 Distributed Approach of the BB

A mobile IP multiple HA system with a single BB demonstrates a centralized scenario which creates a bottleneck for the home network. If the BB discontinues functioning, then overall system will be affected, causing inconsistency all over the network. A small number of HAs are designed so that they maintain replicas of BBs, where only one is in active state and the others are in stand-by states. Every BB contains a HA Status Information table, which consists of several columns representing such as HA-ID, Status, HA-level etc.

Contents of the HA Status Information tables are replicated in all BBs. When the active one starts to malfunction, because of some hardware or software problem, then the stand-by BB takes over the job of the failed BB. All BBs of a home network form a multicast group called *Bulletin Broad Multicast Group (BBMG)*. All the group members of a BBMG communicate periodically via live messages with each other. When a stand-by BB does not receive any reply of live message from the active BB, it assumes that the active HA's functionality is aborted.

To maintain the consistency of information preserved in BB, we use replicated, non-migrating block (RNMB) [8]. BB itself is a non migrating replicated block in the memory

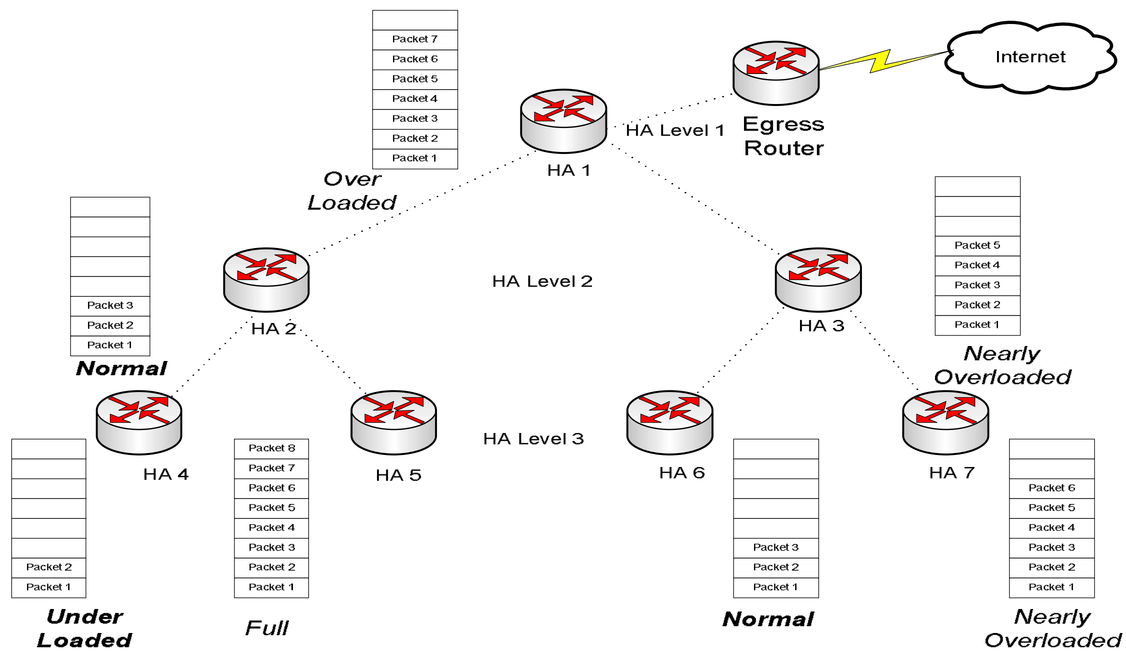

Fig. 2. Selection of Optimal HA.

where location of block is fixed and multiple nodes contain replica of block.

All replicas of BB blocks maintain consistency. When the HA changes its state, it sends an update message revealing the modification to the active BB. The active BB searches Home Agent Status Information table by requesting HAID and replace the corresponding table entry by the current status and sends an ACK to the corresponding HA. After that, the active BB multicasts the most recent modification to the BBMG. Then all stand-by BBs send ACK for this message. In this way, all BBs maintain concurrent information available for the system.

3.3 Modified Threshold Based Load Balancing Policy

Optimal HA can be defined from two perspectives: From the hierarchical point of view, an optimal HA refers to a router, which has the minimum hop distance from the exit router (egress router) if the MN is away from the home network. From load balancing perspective, an optimal HA is the one, which has minimum load at a certain point of time. In this definition, load refers to the number of packets currently stored in the HA queue. According to Fig. 2, HA2 is the optimal choice since it is in Normal state and minimum hop distance with respect to egress router.

To ensure satisfactory system performance for a hierarchically organized home network, we proposed the threshold based Load Balancing (LB) policy using the idea of the double threshold policy as a starting point. To improve the threshold based approach, we have planned the following modifications. There are three pointers LT, MT and UT, which represents lower threshold, midpoint threshold and upper threshold of the HA queue respectively, where

$$MT = (LT + UT) / 2$$

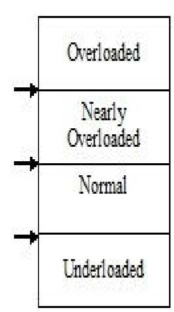

Fig. 3. HA Queue Status

3.4 Defining HA Queue Status

We have divided the queue which holds the incoming packets into several slices which represents four queue statuses shown in Fig. 3.

The proposed states of the HAs are represented by 2-bit vector in our research which is illustrated in the following Table 1.

Our modified LB policy easily solves the problem because, according to modification, initially HA2 shows its status as-- nearly overloaded and HA3 shows its status as --Normal as illustrate in the Fig. 2. So in the beginning, HA3 is selected as optimal HA for load transfer and load is transferred until the overloaded HA reaches to almost the nearly-underloaded state.

TABLE 1
STATES OF THE HAS ARE REPRESENTED BY 2-BIT VECTOR

Status	*Usage (%)*	*Bit Vector*
Under loaded	0-25	00
Normal	26-50	01
Nearly Overloaded	51-75	10
Overloaded	76-100	11

TABLE 2
SIMULATION PARAMETERS

Simulation Parameter	Description
N	The number of HAs in the system
st_{ss}	Start Simulation Time
st_{sf}	Finish Simulation Time
δ_{sp}	simulation period
D	no. of packets dropped by each HA during δ_{sp}
A	The number of packets arrived
h_l	Hierarchy level
S	The number of packets served
LB	Current Load of HA
T	System Throughput

4 SIMULATION

The goal of our research is to enhance both the system performance and consistency by accumulating multiple HAs as opposed to single HA system in the context of using modified optimal load balancing policy. We use NS-2 as our simulation plastform. NS-2 [9], [10] is an event-driven simulator and is widely used for networking research. The parameters used to produce the simulation suite for this research are presented in Table 2.

4.1 Dropped Packets

In Fig. 4 and Fig. 5, we plot the number of data packets dropped within 200s time against the number of HAs. This graph shows this comparison between the single HA and the multiple HA. The single dot represents the total number of data packets dropped by the single HA during the full simulation period.

The Scenario 1 and 2 shows how the single HA in a system become exhausted by servicing a large number of MNs since almost all communication usually take place via HA in Mobile IP, so its rate of packet loss increases with oppose to multiple HA where the burden of serving the MNs are distributed among multiple HAs.

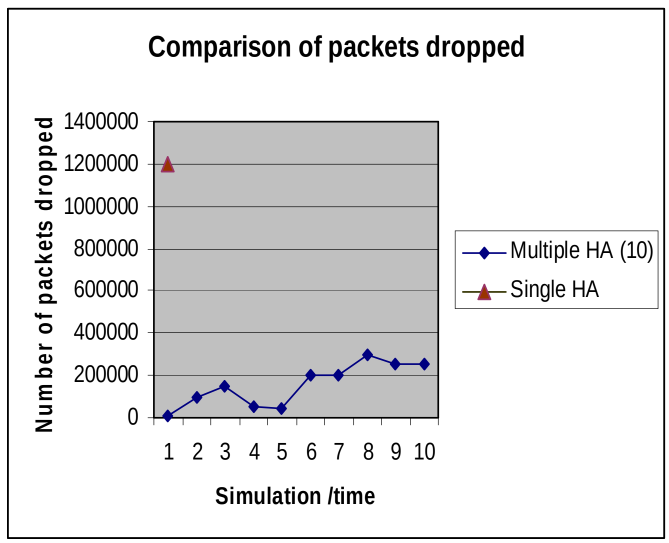

Fig. 4. Number of data packets dropped by single HA and multiple HA where N =10, MN = 30 and ts = 200s.

Each dot on the Load Balancing curve represents the percentage of load for each HA. Similarly, each dot in the Hierarchy Level curve represents the hierarchy level for each HA.

4.2 Utilized Load (%)

Load refers to the number of packets currently stored in the HA queue. Fig. 6 and Fig. 7 shows the comparative simulation result for the percentage of load of each HA within

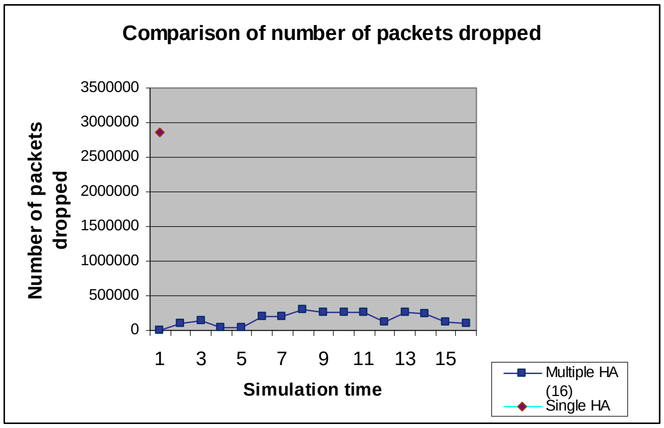

Fig. 5. Number of data packets dropped by single HA and multiple HA where N =16, MN = 45 and ts = 200s

200s for single HA and multiple HA where there are N =6, 10 and N= 6, 10, 16 respectively and the number of MN is

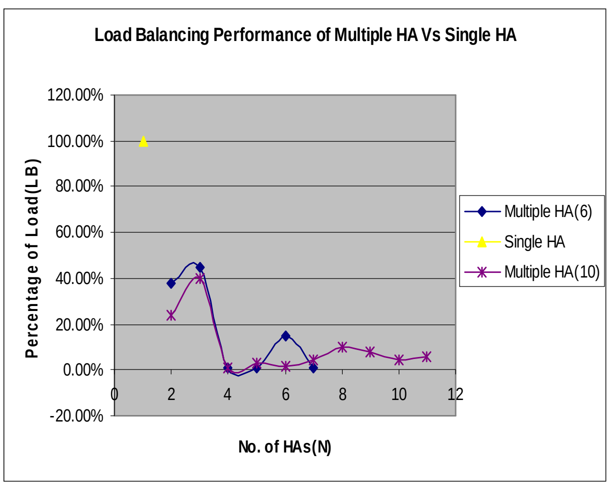

Fig. 6. Comparison result for the (%) of load of each HA within 200s for single HA and multiple HA (N =6, 10 &MN = 30).

30. Here we observe that the system load is uniformly distributed among multiple HAs.

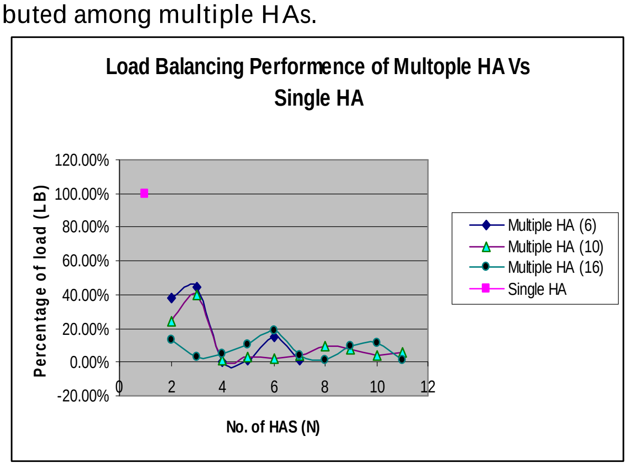

Fig.7. Comparison result for the (%) of load of each HA within 200s for single HA and multiple HA (N =6, 10, 16 &MN = 30).

4.3 System Throughput

In this research, system throughput (τ) implies the difference between the numbers of packets arrived and number of packets dropped per unit time. . The Fig. 8 depicts the comparative simulation result of system Throughput for multiple HA vs Single HA system for each 50s duration from 0s to 200s.

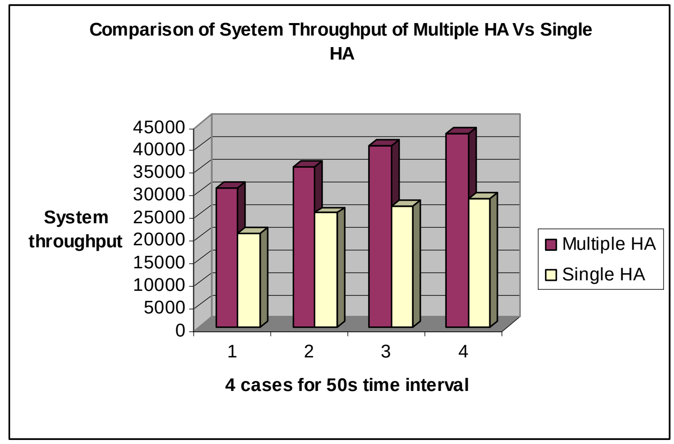

Fig. 8. Performance analysis of system Throughput for multiple HA vs Single HA system for each 50s duration from 0s to 200s.

5 Conclusion

In this paper, we focused on the Multiple HA Mobile IP Architecture to achieve improved system performance concerning data transfer, system throughput and overhead for message passing. In order to obtain above specifications, we introduce the concept of Bulletin Board (BB) as a repository to store the current states of all HAs residing in a Multiple HA Network. We propose optimal load balancing policy using threshold based approach and examine how the load balancing is performed with dynamically changing number of mobile nodes. We have done a comprehensive simulation study

References

[1] Ghosh, D. 'Mobile IP'. Available from: http://www.acm.org/crossroads/xrds7 2/mobileip.html, Access Date: 31 June 2010.

[2] Perkins, C. 'IP Mobility Support', IETF RFC 2002, IBM Corporation, 1996.

[3] Romdhani, I. and Munoz J., 'Hierarchical Home Agent Architecture for Mobile IP Communications', in the 11th IEEE Symposium on Computers and Communications, 26-29 June 2006.

[4] Jue J.P., and Ghosal D. 'Design and analysis of replicated servers to support IP-host mobility' in enterprise network, Communications, ICC 97 Montreal, 'Towards the Knowledge Millennium', vol. 3, pp. 8-12, 1997.

[5] Chambless, B., Binkley, J. 'HARP - Home Agent Redundancy Protocol' chamblessmobileip-harp-00.txt, IETF Draft, 1997..

[6] Vasilache, A., Li, J. and Kameda, H. 'Threshold-Based Load Balancing for Multiple Home Agents in Mobile IP Networks', Telecommunications Systems, vol. 22, issue 1-4, pp. 11-31, 2003.

[7] Deng H., Haley, B., Duan, X., Zhang, R. and Zhang K. 'Load Balance for Distributed Home Agents in Mobile IPv6', IETF Internet Draft, draft-deng-mip6-haloadbalance- 02.txt, 2004.

[8] Sinha, P.K. 'Distributed Operating Systems: Concepts and Design', Wiley-IEEE Press, 1996.

[9] "The NS Manual" - The VINT Project -A Collaboration between researchers at UC Berkeley, LBL, USC/ISI, and Xerox PARC., June 7, 2005.. Available from: http://www.isi.edu/nsnam/ns/doc/ns_doc.pdf, Access Date: 31 June 2010.

[10] NS-2, Available from: http://www.isi.edu/nsnam/ns/index.html. Access Date: 31 June 2010.

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