Active Home Agent Load Balancing for Next Generation IP Mobility based Distributed Networks

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Abstract. Mobile IPv6 is the widely acknowledged technology that supports mobility in networks. A single home agent in the network suffers from the issue of single point of failure and consequently focuses on the deployment of multiple home agents in the network. The load sharing mechanism in most of the exiting methods is passive and centralized in approach. Moreover, the failure detection and recovery mechanism uses the concept of periodic messaging updates which results in signaling overhead. Hence, a new method of active load sharing that is distributed in nature is proposed in this paper. The proposed method contributes a load balancing mechanism at the registration time itself using the concept of preferred home agent. The paper investigates the existing methods and presents the comparative analysis with the proposed method. The advantages of our proposed load sharing are active and distributed approach, less signaling overhead and better throughput.

Keywords: IPv6 mobility · Distributed load balancing · Failure recovery Optimized routing

1 Introduction

The fundamental communication protocol is the Internet Protocol (IP) that delivers the datagram across the network using the concept of IP address in the packet header. A unique address is assigned to every device that is connected to the internet and it is used in the identification of the devices while sending or receiving data packets [1, 2]. Mobile IPv4 has many limitations such as: optimized routing issue, Home Agent (HA) single point of failure, multiple HAs support and IP security. Mobile IPv6 (MIPv6) provides solution to these problems and came as an acknowledged technology [3]. A specific IP home addressing is associated to the home network to which Mobile Node (MN) connects [4]. A temporary care-of-address is attained by the MN when it moves away from the home network to the foreign network as shown in the Fig. 1.

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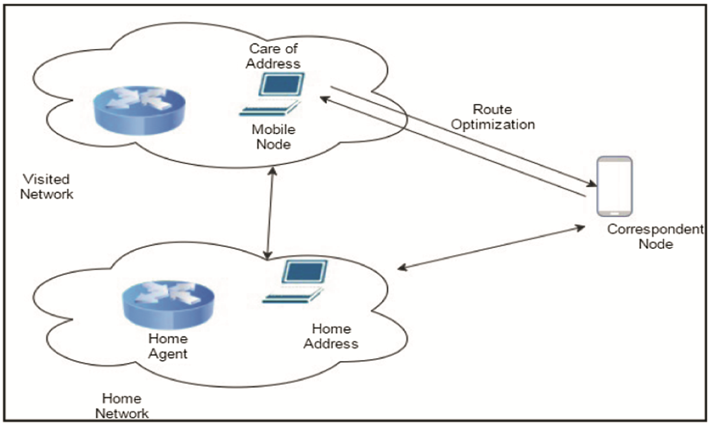

Fig. 1. Mobile IPv6 operation

A registration request is sent by the MN to its home address agent that updates the HA regarding the MN's current location. HA processes the request and provides acknowledgement to the MN. One HA is managing MN registration, cache maintenance and tunnelling of data packets to MN's current location result into the improper load on the HA and produces bad performance report [5].

There are two common approaches: the centralized approach and the distributed approach for HA load balancing. A single HA act as a key entity in the centralized approach. It collects the load sharing information from all of the neighbouring HAs to take decision for the fairly distribution of load among the HAs. The HA act as an administrator for the load sharing but suffer from the problem of single point of failure. This issue is resolved in the distributed approach, where each and every node shares the load information with one another and updates the detail accordingly [6]. The load balancing mechanism mostly uses the concept of "heart beat messages" in order to keep the HAs updated. These messages are basically the router advertisements that every router multicasts at a constant rate. With the reduction in the router advertisement interval, signaling and synchronization overhead occurs [7–11].

This paper focuses on the need of an efficient active load sharing mechanism. The proposed model uses the HA list table and MN list table to keep track of the load measure of each and every node in the network. The information at every node is updated using *Information_Updated* message. If the HA is not in the overloaded state or has at least one HA as the *pref_HA*, then it can address the registration request by the new MN. Failure detection request helps to determine any HA failure in the network and subsequently perform failure recovery. From the comparative results, it is identified that the proposed work outperforms the other existing mechanisms.

The rest of the paper is organized as follows. Section 2 discusses the previous works related to this domain. Section 3 gives the detailed description of the proposed method. The comparative analysis is presented in Sect. 4. Finally Sect. 5 concludes the paper.

2 Related Work

The distributed approach is used in Dynamic Home Agent Address Discovery (DHAAD) protocol follows the concept of distributed approach. This is used by most of the load balancing mechanism for the HA registration in which each HA maintains the list of all the HAs in the network. MN sends an address discovery to the anycast address of a HA and waits for the response. In case of no acknowledgement from the HA, MN resends the registration request. Inter Home Agent (HAHA) protocol also comes under the distributed approach and uses the concept of DHAAD. In this method, whenever HA is in failed state or overloaded state, it sends the HA switch message to the affected MNs. The MN disconnects its current binding and sends the registration request to the preferred HA mentioned in the switch message. If the preferred HA is not specified, it uses DHAAD request message for the HA registration process [12–14].

Home Agent Handoff (HAH) scheme maintains a list of HAs and uses the main features of DHAAD and HAHA methods. Each and every HA shares the information with one another which helps in taking decision of HA re-assignment during HA failure or overloading state. HA sends the HAH switch message to the affected MNs. After receiving the HAH message, the MN follows the same HA registration steps as taken in HAHA method.

The hybrid load balance mechanism comprises of multiple MIPv6 based HAs and MNs. A traffic load table is maintained by each HA which is sorted in descending order of the traffic load field. A timer is associated to each entry of the binding update table and HA reassignment occurs if the timer goes out.

In, Virtual Home Agent Reliability Protocol (VHARP) architecture, one home link contains multiple HAs having different link local IP addresses and one global IP address taken as global HA address [15]. All the communication between the correspondent node and any HA in a home link takes place through this global HA address, representing a single virtual view. There are three states for a HA in this method: active HA, backup HA and inactive HA. The failure detection and recovery mechanism uses the periodic "*Heart Beat Messages*" and does not suffer from any service latency because it is transparent to the MN. Virtual Home Link (VHOL) follows the same architecture and working as VHARP described in [16]. The failure detection mechanism follows the message exchange technique and is transparent to MNs. This method utilizes all the secondary links in addition to the primary link and results in better resource utilization [17].

The addition of more hardware resources and improvement in web server services is suggested in the web services load balancing techniques [18–20]. Distributed and loosely coupled web servers can be deployed to get better solution. This approach is not cost effective. Multiple HA deployment scheme (MHADS) presents dynamic load balancing mechanism and improves the overall performance. The edge router in the home link acts as a Balancer as well as a monitor (BM). It selects the best HA during the registration process and provides active load sharing. Each HA sends update to the BM in regular interval of time. The absence of this update signals the HA failure to the BM, therefore it sends failure detection request to confirm the failure. The ring backup chain is reconstructed for the failure recovery mechanism. The Virtual Private Network based Home Agent Reliability Protocol (VHAHA) contains multiple HAs in a home link that can take any state out of these three states: active HA, backup HA and inactive HA. Global HA address is assigned to the Virtual Private Network (VPN) and each HA shares the status using "*heart beat messages*". When a packet reaches the global HA address, the least loaded HA that is nearest to the MN receives the packet. The "Home Agent Group" (HA Group) method has a main HA that manages all the mobility related tasks and a stand-by HA to take over the responsibility when the main HA fails. It uses the messaging concept in order to identify the HA failure [21–23] which is followed by the destruction of the tunnel with the failed HA and reconstruction of a new tunnel with another HA.

3 Proposed Model

3.1 Notations

Table 1 show the notations used in the proposed scheme.

Table 1. Notations used in the proposed scheme

Symbols	Descriptions
Thres_val	Maximum number of MNs that a HA can provide services
Load_val	Number of the MNs attached to the HA
Pref_HA	Preferred HA for the MN for the registration

3.2 Detailed Descriptions of the Proposed Scheme

In the proposed scheme, each HA maintains a table that keeps tracks of the load measures of the rest of the HAs in the network as shown in Table 2. The HA is assumed to be in overloaded state when the *load_val* of the HA equals the *thres_val*. If it is overloaded then it cannot serve the new registration request and cannot serve as the *pref_HA* as well.

Table 2. HA list table

HA	Load	Thres_val
HA_i	$Load\_val_i$	$Thres\_val_i$

Each MN records the current CoA in addition to the *pref_HA* address in MN data table as represented in Table 3. *pref_HA* helps in the reduction of the re-registration of the MN during the HA failure. Consequently, reduces the failure recovery time. The proposed method also provides optimized routing because HA registration request by a MN is always acknowledged by the nearest HA. If the nearest HA is in overloaded state, it examines it's HA list table in order to determine the next preferred HA for the registration and update the same to the MN.

Table 3. MN data table

CoA	HA	Pref_HA

3.2.1 HA Registration and Active Load Balancing

Step 1: When MN is in the Home network, it works as it is in a fixed network.
Step 2: MN enters foreign network and broadcasts HA registration using DHAAD

Step 2.1: Nearest HA sends the acknowledgement along with the *pref_HA* for the future registration process and updates the HA list table.
Step 2.2: If the nearest HA is overloaded

Step 2.2.1: It sends the *pref_HA* to the MN
Step 2.2.2: MN sends the registration request to the *pref_HA*
Step 2.2.3: *pref_HA* sends the acknowledgement to the MN plus the new *pref_HA* after examining its HA list table

Step 3: HA broadcasts the new registration update to the rest of the HAs in the network

Step 3.1: HAs update their HA list table and send *Information_Updated* acknowledgement to the HA (Fig. 2).

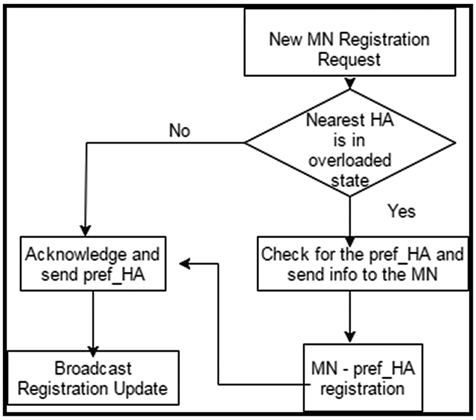

Fig. 2. Flowchart for active load sharing mechanism

3.2.2 HA Failure Detection

Step 1: HA1 broadcasts the MN registration update to the rest of the HAs in the network
Step 2: HAs reply back with the *Information_Updated* acknowledgement to the HA1
Step 3: If the HA1 receives *no-reply* from any HA in the network named HA2

Step 3.1: HA1 sends failure detection request to the *no-reply* HA2
Step 3.2: Again the *no-reply* from the HA2 is taken as the failure of the HA2 (Fig. 3)

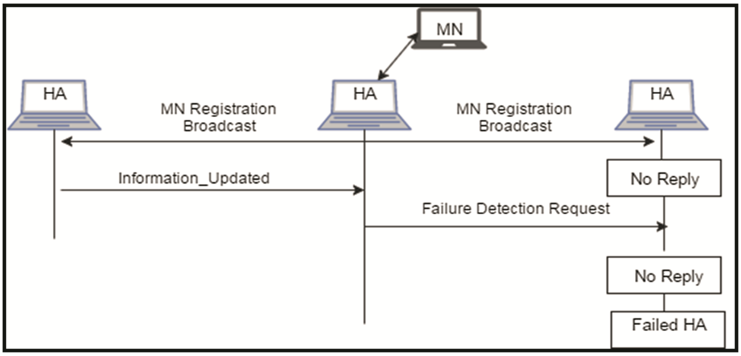

Fig. 3. Failure detection mechanism

3.2.3 HA Failure Recovery

Step 1: The failure of the HA2 is detected using the 3.2.2 Failure Detection

Step 2: HA1 deletes the entry of the HA2 from its HA list table

- **Step 2.1:** HA1 broadcasts this information to the rest of the HAs in the network
- **Step 2.2:** HAs update their HA list table accordingly and reply with the *Information_Updated* acknowledgement to the HA1

Step 3: Affected MNs of the failed HA2 sends binding update to the *pref_HA*

- **Step 3.1:** If *pref_HA* is not overloaded
  - **Step 3.1.1:** It sends the binding acknowledgement to the MN along with the *pref_HA*
  - **Step 3.1.2:** *pref_HA* updates its HA list table and broadcasts it to the other HAs
- **Step 3.2:** If *pref_HA* is overloaded
  - **Step 3.2.1:** It examines its HA list table and return the *pref_HA* to the MN for the registration.

Step 4: MNs establishes the connection and correspondingly update their MN data table

4 Comparison and Analysis

In this section, the performance of the proposed method is compared with the existing methods for load sharing and failure detection mechanism. The most predominantly used mechanism in load sharing is passive in nature, it takes place only after the registration of the MN to the HA. The edge router BM provides active load sharing in MHADS method by selecting the best HA at the time of registration process itself. The load sharing overhead is high in redundant HA method because it is not transparent to the MN and adds to the OTA signaling.

The complicated network architecture in VHARP and VHOL adds to the load sharing overhead. The hybrid method also suffers from the load sharing overhead due to the maintenance and advertisement of the traffic load table. As shown in Table 4, the MHADS has low load sharing overhead as compared to the above discussed method. It is centralised as it uses the edge router that acts as the balancer for the entire network. Every HA sends update messages in regular interval to the BM. The proposed method faces less overhead than MHADS because it is distributed in nature and does not put any overhead on a particular router or a HA.

Table 4. Comparison of load balancing mechanism of existing methods

Metrics	Load sharing mechanism (active/passive)	Load sharing signalling
Redundant HA	Passive	7
Hybrid	Passive	7
MHADS	Active but centralised	5
VHOL	Passive	9
VHARP	Passive	6
Proposed method	Active and distributed	3 or 5

4.1 Comparison of Signaling Overhead

Figure 4 shows that VHARP causes remarkable message exchange. It faces more signaling overhead in comparison to the VHOL because it has less time interval to advertise router messages. Redundant HA method also has significant signaling overhead due to the OTA signaling in addition to the periodic *"Heart Beat Messages"*. MHADS and HA Group also rely on the concept of *"Heart Beat Messages"*. Although VHAHA provides active load sharing, it has higher number of messages exchanged as

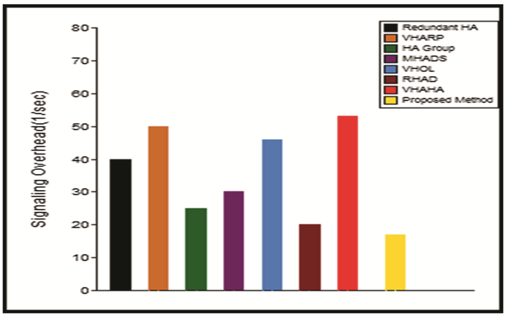

Fig. 4. Comparison of signaling overhead

compared to other methods. The proposed method experiences the least signaling overhead because it does not uses the concept of periodic *"Heart Beat Messages*". The message broadcasting takes place only when an event occurs.

4.2 Failure Recovery Time vs Number of MNs

HA group method takes notable time as compared to the rest of the methods due to the process of tunnel destruction and reconstruction. Figure 5 shows that VHAHA, VHARP and VHOL takes comparable amount of time in failure recovery. The exchange of service takeover request and answer messages followed by the reconstruction of the ring backup chain adds to the failure recovery time in MHADS. Every MN maintains a MN data table in the proposed method. This table keeps track of the *pref_HA* which helps in the reduction of the failure recovery time because each MN knows the next preferred HA.

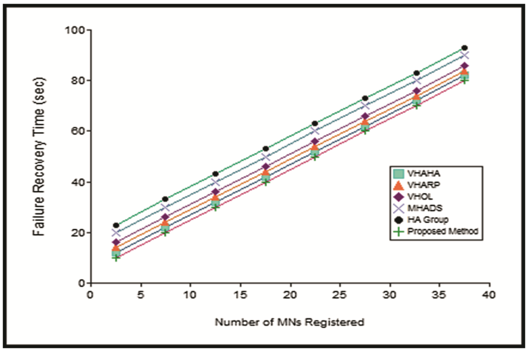

Fig. 5. Failure recovery time vs Number of MNs

4.3 Registration Time vs Number of MNs

It can be depicted from the Fig. 6 that as the number of the MN increases, the time taken for the HA registration for the MNs also increases. VHARP and VHOL have comparable time for the HA registration process. Although VHAHA follows the architecture of the VHARP, it has better registration time than VHARP method. In this, few HAs are taken to build VPN which is addressed using one global HA. In MHADS, the edge router receives the registration request and selects the least loaded HA during the registration process itself. The proposed method uses DHAAD mechanism, which provides less registration time for the MN-HA registration as compared to the other discussed methods.

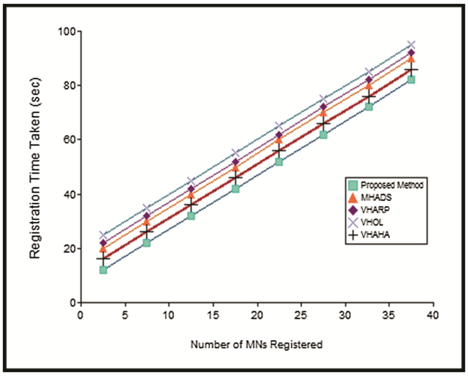

Fig. 6. Registration time vs Number of MNs

4.4 Load Sharing Signaling Overhead

The exchange of periodic *"Heart Beat Messages"* in VHARP and VHOL methods adds to the signaling overhead. Although VHOL solves the issue of the entire home link failure in case of VHARP, it faces more overhead due to the redundancy in the home links architecture. Figure 7 shows that hybrid model has less load sharing signaling overhead in comparison to the previously discussed methods. It uses the concept of traffic load table and each entry in the table has a timer coupled to it. When a HA overloads, re-assignment process get started in which HA does not wait for the ICMP request message and sends the ICMP reply message. Each HA sends update messages to the BM in MHADS method. BM acts as a balancer in load sharing mechanism and selects the least loaded HA for the registration process. The proposed method has the least load sharing signaling overhead because the broadcasting of the messages takes place only if any update or event occurs. It does not suffer from the periodic signaling overhead of *"Heart Beat Messages"* as present in the other methods.

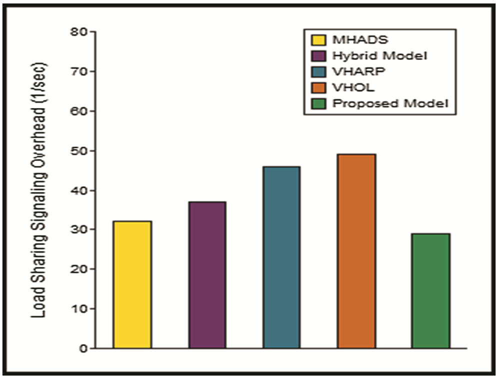

Fig. 7. Comparison of load sharing signaling overhead

4.5 Impact of Number of Registrations of MNs on the Throughput of the HAs

As shown in Fig. 8, the throughput increases with the increase in the number of registered MNs but it starts decreasing, if number of MNs becomes more. HA Group method faces the great fall in the throughput performance because of the tunnelling mechanism. VHOL utilizes all the primary home links as well as the secondary home links and has better throughput than VHARP method. The redundant HA has the least throughput in comparison to the other methods due to the OTA signaling overhead. The MHADS performs active load sharing and provide better throughput. Its performance is comparatively low than hybrid model due to the ring backup chain process in failed HA recovery mechanism. The proposed method has no overhead of ring backup chain process or periodic *"Heart Beat Messages"*. Moreover, the nearest HA sends the acknowledgment to the MN if it is not overloaded, else it updates the MN for the next preferred HA.

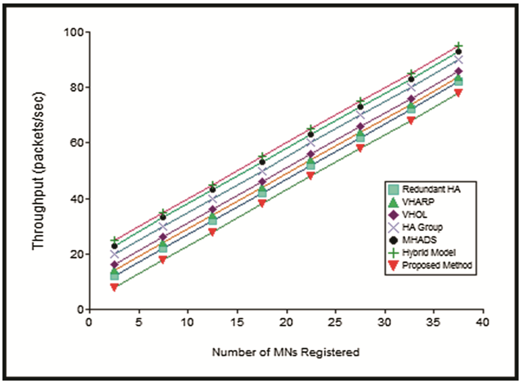

Fig. 8. Throughput Vs Number of MNs

5 Conclusion

In this paper, a new method is proposed for the distributed active load sharing mechanism in which load balancing is taken care during the HA registration process itself. It also describes how failure detection and recovery can be performed effectively under the proposed scheme. The centralized approach is predominantly used in most of the existing methods and faces the issue of single point of failure. The proposed method overcomes this limitation by incorporating distributed approach. Moreover, most of the methods use passive load sharing and concept of *"Heart Beat Messages"* for failure detection and recovery mechanisms. This results in signaling overhead, longer time for failure recovery and poor throughput performance. Although MHADS uses the concept of active load sharing, it is centralized in nature and the edge router acts as a sole point of failure. The comparative analysis of the proposed scheme with the existing methods show that it has better throughput, takes lesser time in failure recovery and has less signaling overhead. Future work can be extended in the field of proactive failure detection and recovery while maintaining less signaling overhead.

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