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Implementation of MHMIP and Comparing the Performance With MIP and DHMIP in Mobile Networks

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Abstract - Managing the mobility efficiently in wireless networks causes critical issue, in order to support mobile users. To support global mobility in IP networks The Mobile Internet Protocol (MIP) has been proposed. The Hierarchical MIP (HMIP) and Dynamic HMIP (DHMIP) strategies are also proposed for providing high signaling delay. Our proposal approach “Multicast HMIP strategy” limits the registration processes in the GFAs. For high-mobility MTs, MHMIP provides lowest mobility signaling delay compared to the HMIP and DHMIP approaches. However, it is resource consuming strategy unless for frequent MT mobility. Hence, we propose an analytic model to evaluate the mean signaling delay and the mean bandwidth per call according to the type of MT mobility. In our analysis, the MHMIP gives the best performance among the DHMIP and MIP strategies in almost all the studied cases. The main contribution of this paper is to implement the MHMIP and provide the analytic model that allows the comparison of MIP, DHMIP and MHMIP mobility management approaches.

Index terms – Mobility management, Mobile IP, Multicast HMIP, Bandwidth, Time delay.

I. INTRODUCTION

Mobile Computing is becoming increasingly important due to the rise in the number of portable computers and the desire to have continuous network connectivity to the Internet irrespective of the physical location of the node. The Internet infrastructure is built on top of a collection of protocols, called the TCP/IP protocol suite. **Transmission Control Protocol (TCP)** and **Internet Protocol (IP)** are the core protocols in this suite. IP requires the location of any host connected to the Internet to be uniquely identified by an assigned IP address. This raises one of the most important issues in mobility, because when a host moves to another physical location, it has to change its IP address. However, the higher level protocols require IP address of a host to be fixed for identifying connections. **The Mobile Internet Protocol (Mobile IP)** is an extension to the Internet Protocol proposed by the **Internet Engineering Task Force (IETF)** that addresses this issue. It enables mobile computers to stay connected to the Internet regardless of their location and without changing their IP address. More precisely, Mobile IP is a standard protocol that builds on the Internet Protocol by making mobility transparent to applications and higher level protocols like TCP.

Figure 1: Mobile IP

Mobile IP supports mobility by transparently binding the home address of the mobile node with its care-of address. This mobility binding is maintained by some specialized routers known as mobility agents.

Mobile IP Terminology

1.1. Mobile IP

Mobile IP [1] is an internet protocol designed to support host mobility. Its goal is to provide the ability of a host to stay connected to the internet regardless of their location. Mobile IP is able to track a mobile host without needing to change the mobile host's long-term IP address [2].

1.2. Care-of Address

The care-of address of a mobile device is the network-native IP address of the device when operating in a foreign network.

1.3. Foreign Network

Any network other than the mobile node's Home Network. It delivers information between the mobile node and the home agent.

1.4. Home Address

A permanent IP address, that is assigned to a mobile node. It remains unchanged regardless of where the mobile node is attached to the internet.

1.5. Home Agent (HA)

A home agent is a router on a mobile node's home network which tunnels datagrams for delivery to the mobile node when it is away from home. It maintains current location (IP address) information for the mobile node. It is used with one or more foreign agents.

1.6. Foreign Agent (FA)

A router that assists a locally reachable mobile node that is away from its home network. It delivers information between the mobile node and the home agent.

II. RELATED WORK

2.1 MIP

In the MIP [1],[2], Mobile Terminal (MT) registers with its home network from which it gets a permanent address (home address)[6]. This address is stored in the Home Agent (HA). It is used for identification and routing purpose. If MT moves outside the home network visiting a foreign network, it maintains its home address and obtains a new one from the Foreign Agent (FA). This Foreign address is called Care-of-Address (CoA). To allow continuity of ongoing communications between the MT and a remote end point, the MT shall inform the HA of its current location when it moves outside the home network [7].

2.2 HMIP

Hierarchical Mobile IP (HMIP) [5],[8] has been proposed to reduce the number of location updates to HA and the signaling latency when an MT moves from one subnet to another. In this mobility scheme, FAs and Gateway FAs (GFAs) are organized into a hierarchy. When an MT changes FA within the same regional network, it updates its CoA by performing a regional registration to the GFA. When an MT moves to another regional network, it performs a home registration with its HA using a publicly routable address of GFA[10]. The packets intercepted by the HA are tunneled to a new GFA to which the MT is belonging. The GFA checks its visitor list and forwards the packets to the FA of the MT.

This regional registration is sensitive to the GFAs failure because of the centralized system architecture. Moreover, a high traffic load on GFAs and frequent mobility between regional networks degrade the mobility scheme performance. In order to reduce the signaling load for interregional networks, mobility dynamic location management approaches for MIP have been proposed: A Hierarchical Distributed Dynamic Mobile IP (HDDMIP) and Dynamic Hierarchical Mobile IP [8].

2.3 DHMIP

DHMIP [9] approach has been proposed to reduce the location update messages to the HA by registering the new CoA to the previous FA and building a hierarchy of FAs. Hence, the user's packets are intercepted and tunneled along the FAs hierarchy to the MT. The hierarchy level numbers are dynamically adjusted based on mobile user's mobility and traffic load information. If the MT becomes attached to FA4 the level number reach the threshold and the MT will set up a new hierarchy.

III. OUR APPROACH

3.1 Multicast-Based Mobility Approaches:

The multicast has been proposed to be used for mobility support and specifically in wireless networks with small radio cells and high mobility of MTs. Several multicast based mobility approaches have been proposed [11]. They can be classified into multicast-based mobility in connection oriented and connection-less networks. For connection oriented networks, Acampora and Naghshineh propose a virtual tree concept, where a multicast connection tree is pre-established. This tree is a collection of radio base stations and ATM network switches connected to the tree's root. The signaling delay is limited to the activation and deactivation of pre-established branch in the tree. For Connection less network, Seshan, in

proposes to apply a multicast to Mobile IP to reduce the handoff delay. The HA encapsulates the intercepted packets into multicast packets and sends them to the targeted MT over multiple FAs. Ghai and Singh propose to divide the wireless network into regions controlled by a supervisor host. Each region includes groups of cells such as each cell may be part of several of these groups.

The performance of multicast mobility approaches has been evaluated through simulation or through analytic models. A set of performance metrics (such as handoff delay, packet loss, and bandwidth overhead due to handoff) have been identified and evaluated for multicast mobility approaches that have been simulated using NS2 network simulator.

3.1.1. Multicast Hierarchical Mobile IP

In this approach, we propose to build hierarchical multicast groups. In each group, FAs are connected to each other through a GFA. A set of GFAs are connected to an HA. When an MT moves through FAs belonging to the same group, the GFA of this group multicasts the received packet (coming from the HA) to the MT. When the MT moves outside a group, the new CoA is registered to the GFA of the new group to which the MT is currently belonging. This GFA sends this CoA to the HA. This latest tunnels the packet to the new GFA which will multicast the received packets within the new FAs group. This approach reduces the frequency of the location update to the HA. This update is performed every inter-GFAs mobility rather than every inter-FAs mobility limiting the location update processing only at the GFA. In this example, the group creation is static in the sense that the numbers of groups and FAs do not change and remain fix [11]. In Fig, when the MT moves from FA2 to FA5, the location registration is performed between HA and GFA2. GFA2 multicasts packets to FA4, FA5, and FA6. Thus, when MT moves to FA6 or

FA4 there is no need for the MT location registration. Hence, this approach allows reducing the mobility signaling delay compared to the HMIP and DHMIP mobility approaches specifically for high-mobility MTs. However, it is network resources consuming approach due to multicast protocol use. Consequently, it is required for comparison purpose to evaluate the performance not only in term of handoff signaling delay but also in term of bandwidth use. This latest is the bandwidth used for signaling transfer and packet delivery. If we take the same MIP network architecture for the three mobility management approaches, the bandwidth used by MHMIP signaling is smaller than that of MIP or DHMIP approaches because the path reestablishment is performed only between HA and GFAs. However, the bandwidth used by an MT for packet delivery is high because several connections are used for packets' transfer to the MT. It is clear that the total bandwidth used for signaling and packet delivery in MHMIP approach is higher than that used by the other approaches. Nevertheless, in case of MTs with high mobility (high handoff requests), the multicast resource in the GFA groups are reused by the MT every handoff event that occurs during its call holding time. Consequently, we expect that the MHMIP mean bandwidth per call for MTs with high mobility is no greater than that of the DHMIP and MIP mobility approaches. We also expect that the MHMIP mean handoff delay (including signaling and packet delivery delays) is smaller than that of the DHMIP and MIP mobility approaches. Hence, we propose to derive an analytic model that allows computation of mean bandwidth and mean handoff delay per call for MIP, DHMIP, and MHMIP mobility approaches. These performance measurements are computed according to the MTs mobility type (high or low) and the call holding time duration.

IV. ANALYTIC MODEL

4.1 MHMIP Analytic Model

The MHMIP mobility approach is based on the path reestablishment and the multicast protocols. When the MT moves within a GFA group, the mobile connection is maintained using the multicast protocol. When the MT moves outside this hierarchy, a combination of the path reestablishment and the multicast protocols allows maintaining the call's connection. Events that may occur at each time $i=1,2,\dots$ are 1) path reestablishment and 2) call termination [11].

- We define q'_a as the probability that there is an inter-GFAs handoffs and thus path reestablishments such as $q'_a = \theta q_a$ with $0 \leq \theta \leq 1$. θ is the fraction of inter-GFAs MHMIP handoffs on the whole possible handoffs q_a (intra and inter-GFAs).

The inter-GFAs handoff arrivals are modeled using a Bernoulli process. For each mobile connection, we define, L^h as the number of links between the GFA to which the mobile is currently attached and the remote end point with which the MT is communicating,

- L^{hp} as the number of links between the HA and the GFA to which the mobile is currently belonging, and,
- L^{hr} as the total number of links in the GFA hierarchies.

L^h , L^{hp} , and L^{hr} are random variables with general distributions and with means $\overline{L^h}$, $\overline{L^{hp}}$, and $\overline{L^{hr}}$, respectively. The mean bandwidth per call is

$$\overline{B^h} = \frac{1}{q_f} \overline{L^h} B^{PD} + \overline{L^{hr}} B^{PD} + \frac{q_a}{q_f} B^{PR}.$$

Here the first term $\frac{1}{q_f} \overline{L^h} B^{PD}$ is the bandwidth used on the original path and the re-established paths.

The second term $\overline{L^{hr}} B^{PD}$ is associated to the multicast resources used by the call in the GFA

hierarchies. The last term $\frac{q_a}{q_f} B^{PR}$ is the signaling bandwidth due to the path re-establishment following the GFA handoffs.

The mean duration per call is

$$\overline{D^h} = \frac{q_a}{q_f} [\overline{L^{hp}} D^{PD} + D^{PR}].$$

Here the term $\frac{q_a}{q_f}$ is the mean number of handoffs of a call. The second term $[\overline{L^{hp}} D^{PD} + D^{PR}]$ is the handoff delay which is the sum of the delay of resource allocated on the re-established path $(\overline{L^{hp}} D^{PD})$ and the signaling delay (D^{PR}).

V. NUMERICAL RESULTS

We propose to compare the performance of the MHMIP handoff approach with those obtained with DHMIP and MIP approaches in terms of mean bandwidth and mean handoff delay per call. For summarization purpose, we compute the ratios $\frac{B_{PR}^p}{B_{PR}^h}$, $\frac{B_{PR}^r}{B_{PR}^h}$, $\frac{D_{PR}^p}{D_{PR}^h}$ and $\frac{D_{PR}^r}{D_{PR}^h}$.

These ratios [11] allow a simple and direct reading of the different performance between the tree mobility management approaches. Figs. 3 and 4 give an example of mean bandwidth variation per call $\frac{B_{PR}^p}{B_{PR}^h}$ and $\frac{B_{PR}^r}{B_{PR}^h}$ for the DHMIP and MHMIP handoff approaches. Fig. 3

illustrates the mean bandwidths per call for MHMIP and DHMIP mobility management approaches. It shows that the MHMIP mean bandwidth per call is smaller than that obtained with the DHMIP approach.

Fig.3 Mean bandwidth per call $\frac{B_{PR}^p}{B_{PR}^h}$ and $\frac{B_{PR}^r}{B_{PR}^h}$ for voice traffic with $1/q_f = 60$ and $B^{PD}/B^{PR} = 0.5$.

Fig.4 Mean bandwidth per call variation $\frac{B_{PR}^p}{B_{PR}^h}$ for voice traffic with $1/q_f = 60$ seconds $B^{PD}/B^{PR} = 0.5$.

This mean bandwidth represents a performance measurement that an IP network operator can use to determine the needed resources to be deployed in the network to service a certain number of MTs. The MHMIP mobility management approach is the method that allows cost reduction in terms of resources usage compared to the DHMIP approach.

Fig. 4 illustrates the $\frac{B_{PR}^p}{B_{PR}^h}$ ratio variation for different values of the probability p. We note that lower is p higher is the mean bandwidth per call. Moreover, we note a different behavior of this bandwidth between the intervals $0 \leq q_a \leq 0.3$ and $0.3 \leq q_a \leq 1$. For $0.3 \leq q_a \leq 1$, the mean bandwidth value decreases while it increases in the interval

$q_a \leq 0.2$ for different values of p ($p = q_a/6, q_a/4, q_a/2$) and still increasing in the interval $0.2 \leq q_a \leq 0.3$ for $p = q_a/6$. This is in fact due to the low probability of path reestablishment p and the frequent use of path extension in the interval $q_a \leq 0.3$. Hence, less frequent path reestablishment usage for DHMIP mobility management approach involves a high mean bandwidth per call consumption.

5.1 Mean Bandwidth

Fig. 5. Mean bandwidth ratio $\overline{B_{PR}^p}/\overline{B_{PR}^h}$ and $\overline{B_{PR}^r}/\overline{B_{PR}^h}$ for voice traffic with $p = q_a/2, B^{PD}/B^{PR} = 0.8$.

Fig.6. Mean bandwidth per ratio $\overline{B_{PR}^p}/\overline{B_{PR}^h}$ and $\overline{B_{PR}^r}/\overline{B_{PR}^h}$ or data traffic with $p = q_a/2, B^{PD}/B^{PR} = 0.8$.

Figs. 5 and 6 show examples of the mean bandwidth ratio Variation $\overline{B_{PR}^p}/\overline{B_{PR}^h}$ and $\overline{B_{PR}^r}/\overline{B_{PR}^h}$ for the realistic and critical cases respectively.

Note that the ratio $\overline{B_{PR}^p}/\overline{B_{PR}^h}$ is much higher than the $\overline{B_{PR}^r}/\overline{B_{PR}^h}$ for different call holding time duration ($1/q_r = 60, 90, 120$ seconds) specifically for small probability q_a . This means that the combination of the path extension and the path reestablishment for handoff management involves higher mean bandwidth per call than that used by the approaches based only on the path re-establishment (such as MHMIP and MIP). This behavior is noticed in all the analyzed cases. The main obtained results are summarized in Table 1 that give the ratio values of the mean bandwidth per call for the Realistic Case (RC) and the Critical Case (CC) for both Types of Configuration (ToC). These values represent the arithmetic average of the ratios $\overline{B_{PR}^p}/\overline{B_{PR}^h}$ and $\overline{B_{PR}^r}/\overline{B_{PR}^h}$ over the set of q_a values ($0 \leq q_a \leq 1$). These results show that the MHMIP mean bandwidth is smaller than those of the DHMIP and MIP approaches. This bandwidth difference is higher in the configuration 2 than in the configuration 1 because the MHMIP reestablishment is performed over small number of links in the configuration 2, yielding to a smaller mean bandwidth per call than that computed with the configuration 1. However, this mean bandwidth difference is small in the critical case than in the realistic case because the partial reestablishment is more frequently used due to the high probability q_a of inter-GFAs handoffs.

Table 1
Mean Bandwidth

ToC	Bandwidth ratio		Bandwidth			
			Voice traffic for $B^{PD}/B^{PR} =$		Data traffic for $B^{PD}/B^{PR} =$	
			0.5	0.8	0.5	0.8
1	$\overline{B_{PR}^p}/\overline{B_{PR}^h}$	RC	1.80	1.77	3.62	3.59
		CC	1.56	1.62	2.93	3.12
	$\overline{B_{PR}^r}/\overline{B_{PR}^h}$	RC	1.36	1.30	2.41	2.32
		CC	1.16	1.18	1.87	1.96
2	$\overline{B_{PR}^p}/\overline{B_{PR}^h}$	RC	2.66	2.64	8.95	9.0
		CC	2.18	2.30	5.87	6.66
	$\overline{B_{PR}^r}/\overline{B_{PR}^h}$	RC	2	1.93	5.93	5.79
		CC	1.60	1.66	3.58	4.00

Table 2
Mena delay

ToC	Delay ratio	Delay			
		Voice and data traffic for			
		$D^{PD}/D^{PR} = 0.5$		$D^{PD}/D^{PR} = 0.8$	
		RC	CC	RC	CC
1	$\overline{D_{PR}^p}/\overline{D_{PR}^h}$	8.00	0.72	8.48	0.76
	$\overline{D_{PR}^r}/\overline{D_{PR}^h}$	20.00	1.80	21.57	1.94
2	$\overline{D_{PR}^p}/\overline{D_{PR}^h}$	13.33	1.20	16.00	1.44
	$\overline{D_{PR}^r}/\overline{D_{PR}^h}$	33.33	3.00	40.74	3.66

5.2 Delay Comparison

The ratio values of the mean delay per call $\overline{D_{PR}^p}/\overline{D_{PR}^h}$ and $\overline{D_{PR}^r}/\overline{D_{PR}^h}$ are summarized in Table 2 for the Realistic Case (RC) and the Critical Case (CC). These values represent the arithmetic average of the ratios $\overline{D_{PR}^p}/\overline{D_{PR}^h}$ and $\overline{D_{PR}^r}/\overline{D_{PR}^h}$ over the set of q_a values. In the realistic case, the MHMIP mean delay is smaller than those of the DHMIP and MIP approaches. The mean delay differences are 8 and 21 compared to DHMIP and MIP, respectively. They become high, if we consider the configuration 2 where this difference reaches 40.

This result was expected because in the MHMIP approach, the path reestablishment is performed through a shorter path than that of the DHMIP and MIP approaches. The mean delay per call of the MHMIP approach in the critical case is smaller than that of the MIP and DHMIP approaches unless for configuration 1 where this delay is greater than that of the DHMIP approach, because the path reestablishment is not only more frequent ($q'_a = q_a$) but also the number of links involved in the path reestablishment is greater than that of configuration 2 ($L^h = 3$ compared to $\overline{L^h} = 1$).

VI. CONCLUSION

In this paper, we have proposed an analytical model which evaluates the mean handoff delay per call and the mean bandwidth per call of three mobility management approaches: MIP, DHMIP, and MHMIP. Our analysis gives in almost all cases a lower mean handoff delay per call and a mean bandwidth per call than those offered by the DHMIP and MIP approaches. It also shows the robustness of the MHMIP approach, this approach essentially yields to 1) a lower mean bandwidth per call than the DHMIP and MIP approaches; 2) a lower mean handoff delay per call than that offered by the MIP approach; 3) a lower mean handoff delay than that offered by the DHMIP except in case of frequent inter-GFAs handoffs with a network configuration having a high number of links involved in MHMIP path reestablishment such as the configuration 2. Since we expect a diversity of multimedia applications for future

IP mobile networks, we recommend using the MHMIP approach in networks parts carrying delay sensitive and/or low mean bandwidth consumption type of applications and this according to the mobility type.

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