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Comparative Performance Evaluation of MIP, DHMIP and MHMIP

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Abstract— Abstract—In wireless networks, efficient management of mobility is a crucial issue to support mobile users. The Mobile Internet Protocol (MIP) has been proposed to support global mobility in IP networks. Several mobility management strategies have been proposed which aim reducing the signaling traffic related to the Mobile Terminals (MTs) registration with the Home Agents (HAs) whenever their Care-of-Addresses (CoAs) change. They use different Foreign Agents (FAs) and Gateway FAs (GFAs) hierarchies to concentrate the registration processes. For high-mobility MTs, the Hierarchical MIP (HMIP) and Dynamic HMIP (DHMIP) strategies localize the registration in FAs and GFAs, yielding to high-mobility signaling. The Multicast HMIP strategy limits the registration processes in the GFAs. For high-mobility MTs, it 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 outperforms the DHMIP and MIP strategies in almost all the studied cases. The main contribution of this paper is the analytic model that allows the mobility management approaches performance evaluation.

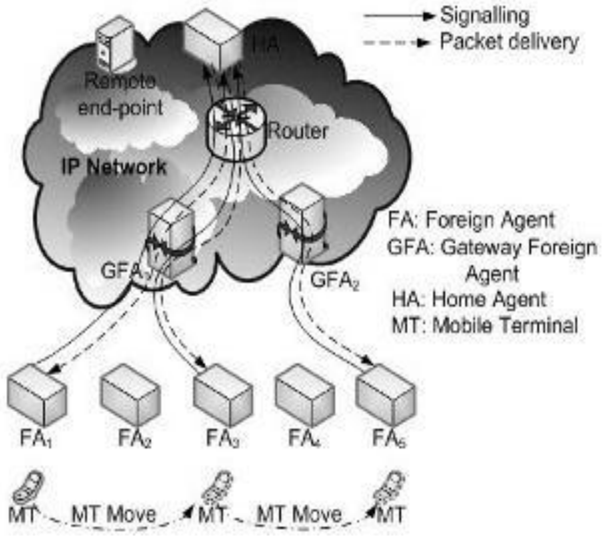
Index Terms—Mobile IP, mobility approach, performance evaluation.

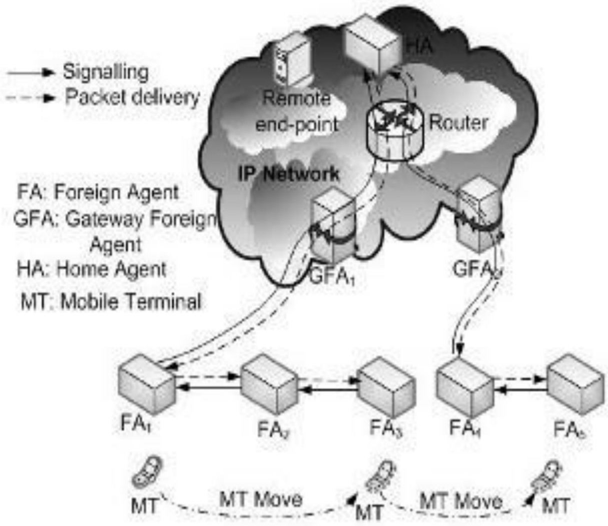
I. INTRODUCTION

IP multimedia applications are becoming popular in the packet-based wireless networks. The integration of these applications in wireless networks requires the support of seamless terminal mobility. Mobile IP (MIP) has been proposed by the Internet Engineering Task Force (IETF) to provide global mobility in IP networks [1]. It allows maintaining mobile terminals ongoing communications while moving through IP network [1], [2].In the MIP protocol, Mobile Terminal (MT) registers with its home network from which it gets a permanent address (home address). 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. The HA delivers to MT the intercepted packets by tunneling them to the MT's current point of attachment.IP mobility in wireless networks can be classified into macro- and micromobility. The macromobility is the MT mobility through different administration domains.

The micromobility is the MT movements through different subnets belonging to a single network domain. For micromobility where the MT movement is frequent, the MIP concept is not suitable and needs to be improved [3]. Indeed, the processing overhead related to location update could be high specifically under high number of MTs and when MTs are distant from the HAs yielding to high- mobility signaling delay [4].

Hierarchical Mobile IP (HMIP) 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 [5], [6]. 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. The packets intercepted by the HA are tunneled to a new GFA to which the MT is belonging (e.g., GFA2 following MT handoff from FA3 to FA5 in Fig. 1). The GFA checks its visitor list and forwards the packets to the FA of the MT (FA5 in Fig. 1). This regional registration is sensitive to the GFAs failure because of the centralized system architecture [7], [8]. Moreover, a high traffic load on GFAs and frequent mobility between regional networks degrade the mobility scheme perfor- mance [4]. In order to reduce the signaling load for interregional networks, mobility dynamic location manage- ment approaches for MIP have been proposed: A Hier- archical Distributed Dynamic Mobile IP (HDDMIP) and Dynamic Hierarchical Mobile IP (DHMIP).





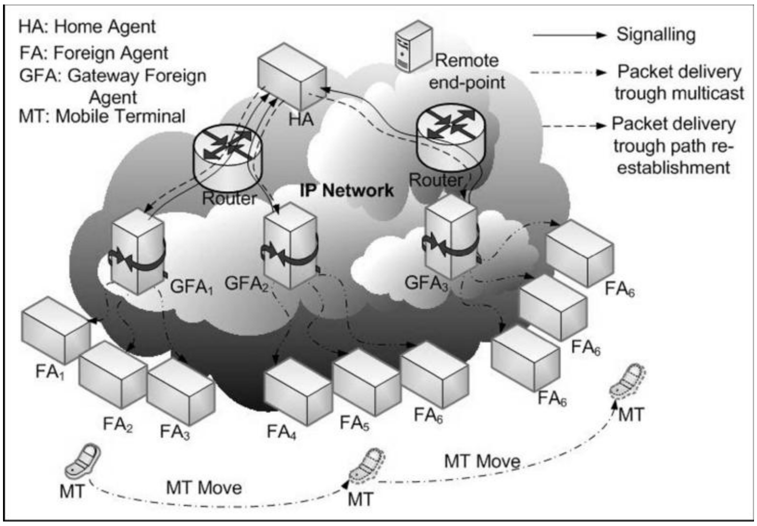
II. MULTICAST-BASED MOBILITY APPROACHES

2.1 Overview

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 multicastbased mobility approaches have been proposed. They can be classified into multicast-based mobility in connectionoriented and connection-less networks. For connectionoriented networks, Acampora and Naghshineh propose a virtual tree concept, where a multicast connection tree is preestablished. 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 preestablished branch in the tree [16]. For Connection-less network, Seshan, in [17], 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. In [18], 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. A unique IP multicast ID is assigned to each of these groups. In [19], authors extend this work by considering multiple wireless networks and cases where mobile device is not able to use channel characteristics to trigger handoffs due to the frequent network interface change. Different Mobile IP multicast protocols have been proposed. In [20], Mobility Supporting Agents (MSA)-based architecture has been proposed using IGMPv2 and PIM SM IP multicast protocols. In [21], an Core Based Trees (CBT)- based multicast mobile IP approach has been proposed for micromobility. In [22], authors propose a set of multicast mobility protocols called Candidate Access Router set (CARset). The performance of multicast mobility approaches has been evaluated through simulation or through analytic
models [22], [23]. In [22], 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. In [23], a software platform, set up testbeds, has been used to analyze multicast mobility protocols in terms of handoff delay, packets losses and duplications, and relative TCP throughput. There is a large number of multicast approaches that could be used to implement mobility into MIP networks. The analysis of these approaches and their design is not the focus of this paper.We refer the reader to [23], where four case studies for multicastbased mobility are presented based on different multicast service models and protocols. In this paper, we focus on usage of the multicast hierarchical architecture for IP
mobility support and its performance in terms of bandwidth usage and handoff delay. The example used in this paper of such architecture is given in Section 2.2.

2.2 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. In Fig. 3, 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. The model description and the performance comparison of the three mobility approaches are discussed in the following sections.



II. ANALYTIC MODEL

This section describes the analytic model and the set of established assumptions.

3.1 Assumptions

Generally, during each handoff, a path reestablishment is required to maintain or to improve call quality. This reestablishment uses signaling messages and involves change in the number of links of the mobile connection. Note that the three mobility approaches described here are based on a mobile connection path reestablishment which leads to perform the following operations: CoA update with the HA,new path establishment from HA to FA for DHMIP and MIP, and from HA to GFA for MHMIP, user data traffic transfer from the previous path to the new one, previous path discard. The DHMIP uses also path extension which requires additional signaling messages to establish the path part that extends the mobile connection from the previous FA to the new one when the mobile move and becomes attached to this latest. Each connection is subjected to a certain number of handoffs through its life duration (call holding time). This latest is divided into n time intervals enough small to allow the occurrence and the end of only one handoff during this interval. In each time interval, we define 1) qa as the probability that an FAs handoff (handoff between two FAs) occurs and ends in this interval and 2) qf as the probability that the call ends in this interval. The number of handoffs that could occur during a call holding time depends on the MT dwelling time in a radio cell and the traffic type: voice or data. Several voice traffic researches have supposed that the dwelling time in a radio cell is an exponential distribution [24], [25]. In fact, this assumption depends on the shape of the radio cell and the specific distributions of the mobile's speed and direction which are difficult to characterize. In [26], [27], [28], [29], [30], authors have demonstrated that the exponential distribution for the dwelling time in radio cell is not appropriated. They propose to replace it with complex distributions such as Phase-Type, Lognormal, Hyperexponential, and HyperErlang requiring the identification of several parameters related to the selected traffic model. In order to simplify the computation of the mean bandwidth and mean delay per call, we consider that the time between the handoff events and the call duration is a geometric distribution of mean 1=qa 1 and 1=qf , respectively. For data traffic, researches have addressed the problem of the persistent congestion periods with non-negligible packet losses [31], [32], [33], [34]. They show that these losses do not allow the usage of Poisson model to model the TCP traffic. In [33], [34], authors have demonstrated that the Self- Similar processes are better models for TCP traffic modelization than the exponential ones. However, in this study, we are interested by the data session arrivals rather than the data packet generation in the sessions. Hence, we propose that the assumption made for the voice traffic remains valid for the data traffic. The proposed discrete time model is a generalization of the one proposed in [35]. The novelty of this model consists in the definition of generic analytical model that applies to more than one handoff approach and that allows to compute not only mean bandwidth due to handoff but also mean handoff delay of the analyzed handoff approaches. The temporal diagram given in Fig. 4 is used to compute these means. First, we compute the bandwidth and the delay within each interval and their means over the handoff events. Then, we compute the bandwidth and the delay sums over the total call holding time. Finally, we evaluate their means over all the call durations. In order to understand the modelization mechanism, we illustrate by taking as an example the mean bandwidth computation. In this figure, the holding time of ongoing call is divided into time intervals small enough that we may assume that in each time interval

IV. RESULT ANALYSIS

we compare the performance in terms of mean bandwidth and mean handoff delay per call of the three mobility management approaches MHMIP, DHMIP, and MIP.

4.1 Numerical Data

The mean call holding time is a random value chosen between 60 and 120 seconds for voice traffic and between 900 and 1,200 seconds for data traffic. For simplification purpose of the mean number of links computation ($\overline{L}^{n}$, L, H, $\overline{L}^{h}$, $\overline{L}^{hp}$ and $\overline{L}^{hr}$), a symmetric hierarchical IP network architecture is considered (Fig. 5). Symmetric architecture means that the number of links between the HA and each FA is the same (e.g., there is five links between the HA and each FAi; i=1; . . . ; 32g in Fig. 5).

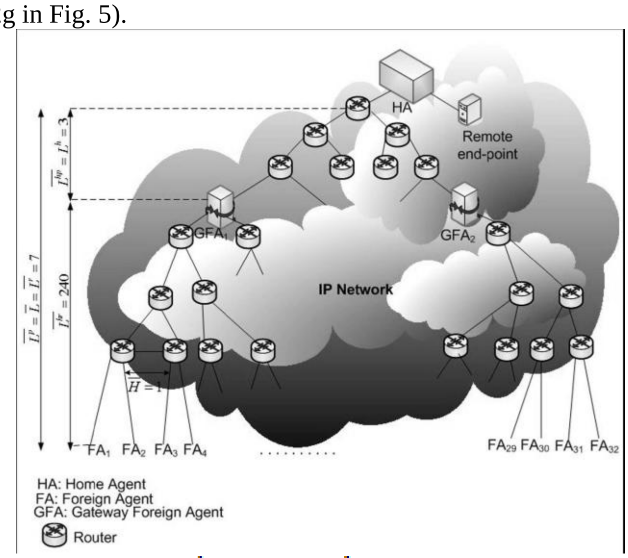
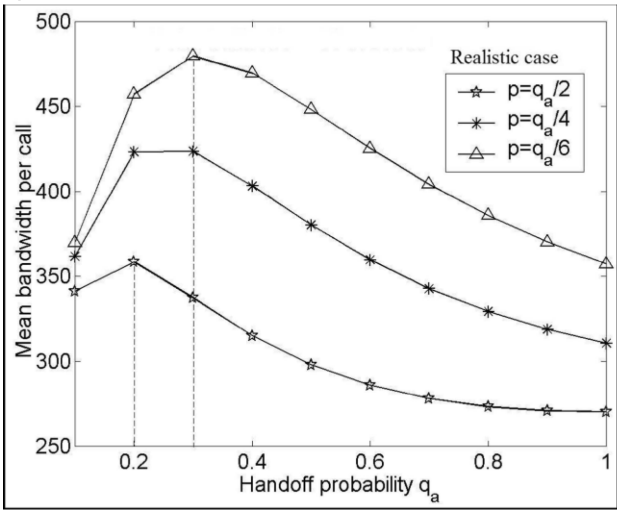
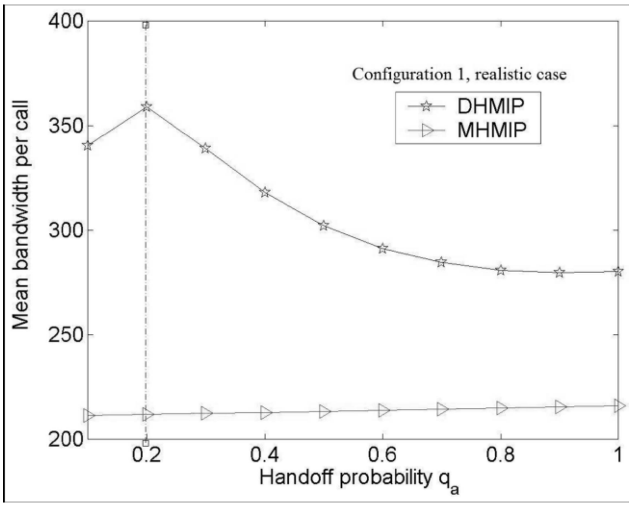


Fig. 5 shows an architecture with $\overline{L}^{p} = \overline{L}^{n} = 7$, $\overline{L}^{hp} = 3$, and $\overline{L}^{hr} = 240$. For comparison purpose, we take the number of links between the HA and the end point the same for the three mobility management approaches. For a fixed remote end point, the number of links between the HA and this end point do not change for an ongoing call of an MT. Then, we consider that the end point is directly connected to HA (e.g., $\overline{L}^{n} = \overline{L}^{hp} = 3$ and L = $\overline{L}^{p} = \overline{L}^{n} = 7$ for the example given in Fig. 5). Two types of configurations are considered for the network given in Fig. 5: . Configuration 1: the average number of links are $\overline{L}^{n} = \overline{L}^{hp} = 3$ and = $\overline{L}^{n} = \overline{L}^{p}$ = L = 7. These value result in the number of link where the resources were allocated $\overline{L}^{hr} = 240$. . Configuration 2: the average number of links are $\overline{L}^{n} = \overline{L}^{hp} = 1$ and $\overline{L}^{p} = \overline{L}^{n}$ = L = 7. From these values, we obtain $\overline{L}^{hr} = 252$. For each configuration, two





cases are analyzed: realistic and critical. In the realistic case, the inter-GFAs handoffs may occur less frequently than the intra-GFAs handoffs (q0a = 0:1 _ qa). In the critical case, the intra- and the inter- GFAs handoffs may occur with the same probability (q0a ¼ qa, where qa and q0a are variables). For both cases, the path extension for the DHMIP mobility management approach should occur after each handoff and the path reestablishment should occur after each two consecutive handoffs (p = qa=2). For p > qa=2, the mean bandwidth and mean delay is higher than that get with p = qa=2 (see Section 4.2). We suppose that the MT handoff to a new FA involves a path extension of mean length H = 1. For length greater than this value, the mean bandwidth and the mean handoff delay are high. We rewrite (8), (12), (10), (9), (13), and (11) to obtain the ratios Bj PR = Bj=BPR and Dj PR = Dj=DPR, where j = p; r; h.

V. 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. Numerical results show that the MHMIP mobility approach compares very favorably with the previously considered mobility approaches. More specifically, 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 in the sense that for critical scenario corresponding to the extreme situation where all handoff events are localized at the multicast group borders, 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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