An Application-Driven Mobility Management Scheme for Hierarchical Mobile IPv6 Networks

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***Abstract*— Mobile users are expected to be highly dynamic in next generation mobile networks. Additionally they will be served a wide variety of services with different transmission rates and expect high Quality of Service (QoS). Since the number of mobile subscribers is rapidly increasing and given the limited resources of any robust network, guarantee of high QoS is possible only by the deployment of network elements that optimally allocate network resources and instantly adapt to dynamically changing conditions of the network. In attempt of supporting mobility in IP networks, the Hierarchical Mobile IPv6 (HMIPv6) has been proposed. An important issue that has been highly overlooked in the design of HMIPv6 consists in its lack of a mechanism that can efficiently control and distribute traffic among multiple Mobility Anchor Points (MAPs). In the absence of such mechanism, some MAPs may get congested while others remain underutilized. In such scenario, mobile users connecting to congested MAPs may experience significant packet drops and excessive queuing delays. This ultimately affects QoS. In this vein, this paper proposes an application-driven mechanism for selection of MAPs. The key idea behind the proposed scheme consists in the reference of access points to the transmission rate of the users' applications to decide which MAP visiting users should be registering with. The decision of MAPs is performed in a way that the load variance of all MAPs, serving the access point in question, is minimized. Issues related to the frequency of binding update messages are also considered in the selection of MAPs. The performance of the proposed scheme is evaluated via computer simulations. In terms of QoS, encouraging results are obtained; better traffic distribution among MAPs and lower handoff delays.**

I. INTRODUCTION

The universality of the Internet Protocol (IP) has changed the path for wireless networks into an all-IP configuration. To accommodate global mobility in IP networks, the Mobile IP Working Group within the Internet Engineering Task Force (IETF) proposed a packet-based mobility management protocol, called Mobile Internet Protocol version 6 (MIPv6) [1]. In mobile networks where users have high mobility features and exhibit tendencies to roam far away from their home networks, applying MIP results in the generation of a storm of binding update requests along significantly long signaling paths. To overcome the excessive delay and signaling, the Hierarchical Mobile IPv6 (HMIPv6) [2] protocol has been introduced. The key concept behind HMIPv6 consists in a local handling of handovers using a number of entities called Mobility Anchor Points (MAPs) and located in a hierarchical pattern.

In next generation wireless networks, users are expected to be highly dynamic. They will be served a plethora of advanced services with different transmission rates. Guarantee of Quality of Service (QoS) will become then a must. This is possible only by finding efficient ways to reflect the network conditions in the user mobility management strategy.

As stated above, HMIPv6 is considered to be efficient for mobility management. However, its underlying drawback consists in its lack of a mechanism that can efficiently distribute the traffic and processing loads over multiple MAPs in a large mobile network. In the absence of such mechanism, it is easily possible that users register with specific MAPs. As a result, in many cases the selected MAPs become overloaded and the others remain underutilized. This causes extensive queuing delays and significant packet drops at the congested MAPs. Such a performance obviously results in a poor QoS and affects the credibility of the system. A remedy to this issue is possible only by the deployment of agents that can adapt to network dynamics and optimally allocate the resources of the most appropriate MAPs to visiting mobile users.

In this vein, this paper presents an application-driven cross layer design (at mobile nodes) that assists access points to select the most appropriate MAP for communication. At mobile nodes, the considered cross layer design involves three layers, namely physical, application, and network layer. The physical layer monitors signal strengths and detects an impending handoff. It then advertises the event to the application layer. In its turn, the application layer refers to personal information on the mobile user, history on its mobility patterns, and if possible information on the topology of the wireless network to locate the next access point. The application layer computes also an average of its data transmission or reception rate. Information on the application transmission or reception rate is written in a Router Solicitation (RS) message that is sent to the next access point. In response to the RS message, the access point refers to the data transmission/reception rate to decide the MAP with which the user should be registering. The selection of MAPs is performed in a way that the load variance of all MAPs, serving the access point, is minimized. The proposed cross layer design is dubbed "Application-Driven MAP Selection" (ADMAPS). The performance of the proposed system is evaluated through computer simulations. The results demonstrate that the proposed approach is vital for the guarantee of QoS in mobile networks as it maintains a fair and efficient distribution of the network load, and accordingly assures a fast handoff management and a reduced packet drop rate.

The remainder of this paper is structured as follows. Section II highlights the relevance of this work to the state-of-art in the context of mobility management and application driven cross layer approaches. Section III describes the proposed scheme. The simulation environment and results are reported in Section IV. The paper concludes in Section V.

II. RELATED WORK

The MIP protocol has been the focus of extensive research work since its standardization. The main post-standard improvement that has been devised to improve the performance of MIP in mobile networks consists in the adoption of hierarchical management strategies using local agents. While most of the strategies proposed earlier in the literature attempt to solve the macro-mobility issues, to reduce the binding update traffic by localizing handoff signaling, and to provide fast transition performance, they have created a complex landscape for network traffic management. Indeed, in large networks with multiple local agents, some agents are overly overloaded with traffic and consequently exhibit higher packet delivery delays, while others are underutilized. To tackle this issue, an efficient management strategy of the load of local agents is required. Based on this strategy, mobile users residing in hierarchical mobile networks should be able to select the most appropriate agent for communication based on the current resources utilization of agents.

In this regard, Pyo *et al.* propose a dynamic and distributed domain-based mobility management scheme [3]. In this scheme, a group of Access Routers (ARs) forms a domain. A "*domain list*" indicating the ARs that belong to the same domain is stored at each AR. Mobile nodes residing in a given domain maintains that *domain list*. If a mobile node changes its point of attachment to a new AR within a different domain, the node then updates its *domain list* to that of the new AR and the latter serves as a MAP for the node. Ma *et al.* propose another dynamic hierarchical mobility management scheme for mobile networks [4]. In the proposed scheme, when a mobile host connects to a new subnet via a new AR, the new AR notifies the new Care-of-Address (CoA) of the host to the previous AR. The new AR serves then as a new location management hierarchical level for the node. One major drawback of the two schemes is that they both deliver packets to users via multiple levels of ARs, a fact that leads to long packet delivery delays and congestion of the selected ARs with redundant traffic. One possible solution to this issue is to reduce the size of subnet domains. However, this would lead to frequent inter-domain handoffs and consequently excessive binding update cost.

Another approach to solve mobility management in HMIPv6 is possible by referring to the mobility pattern of users. In [5], users are classified based on their velocity. Users receive thresholds from the network and compare their velocity to them. Users with velocity exceeding the propagated thresholds simply register with higher levels of the MAP hierarchies. While this idea is straightforward, it still does not solve the issues of traffic distribution among MAPs. Indeed, in case all users have the same feature of mobility, they end up by registering with specific MAPs. This will intuitively overload the selected MAPs with traffic whereas other MAPs remain underutilized. As a solution, the authors recently proposed a dynamic and efficient technique to select the most appropriate MAP with the lightest traffic load for communications [6]. The MAP selection is based on an estimation of MAP load transition using the exponential moving average method. Information on load transition is notified to access routers via the transmission of MAP option messages. The proposed selection scheme is referred to as *Dynamic and Efficient MAP Selection (DEMAPS)* throughout this paper. In contrast to the aforesaid schemes, in this paper we consider an application driven cross layer approach for an efficient management of traffic over mobile networks with multiple MAPs.

As originally specified, the traditional Open Systems Interconnections (OSI) layered architecture did not allow any interaction among its layers. A cross layer design aims to enable such an interaction for the sake of better performance and prompt adaptation of the stack functionality in the presence of changing network conditions. Based on the involved layer, different cross layer proposals have been presented in the recent literature [7], [8]. At the physical layer, the transmit power can be tuned by the Medium Access Control (MAC) layer to increase or decrease the range of the transmission. Information on the channel condition, such as the bit error rate, can inspire the error control mechanisms of the link layer adequate measures. Similar information can help the application layer to adapt its sending rate to the conditions of the channel. The number of packet retransmissions at the link layer can serve as a metric for evaluating the channel condition. Handoff events at the link layer can be used to anticipate imminent handoffs at the network layer and to accordingly reduce the MIP handoff latency. Information on packet drops, available at the transport later, can be used by the application layer to adjust its sending rate. The application layer can also give the transport layer an indication of an impeding disconnection so as the transport layer temporarily freezes its data transmission.

In the recent literature, different cross layer architectures and frameworks have been proposed. They can be categorized based on whether they are generic in their design or not. Generic approaches add significant complexity to the original design of the protocol stack. In non-generic cross layer approaches, layers simply exchange information among themselves to optimize the protocol behavior. In this paper, we consider such kind of cross layer approaches.

Traditional non-generic cross layer approaches focused on joint optimization of the physical layer and data link layer or focused on optimizing the working of a single layer, e.g., adapting one layer to the characteristics of another either in a bottom-up or top-down fashion. However, recent researches have considered the inclusion of the application layer in the cross layer optimization [9], [10], [11]. Most of these application-driven cross layer approaches either force the access points to adapt their transmission strategies to the user perceived quality and their power consumption, or request end-terminals to dynamically adjust their data transmission/reception rate (e.g., encoding format, compression, etc) to the current network capabilities. In this aspect, our proposed cross layer design is novel. Indeed, end-terminals refer to their application layer to predict the next access point to which they will likely attach after handoff. Simultaneously, they compute an average value of their data transmission/reception rate and handle this information to the access point in a router solicitation message. Upon reception of the RS message, the access point chooses the most appropriate MAP for communication in a manner that maintains the QoS of users and efficiently distributes traffic among all MAPs. In this regard, neither end-terminals nor access points are required to adapt their transmission strategies to the current conditions of the network. In fact, this operation can be adopted as the last solution. In other words, only when the traffic is evenly distributed among all MAPS and network resources become genuinely scarce. Users or access points will be then requested to adjust their transmission requirements to meet the new conditions of the network.

III. APPLICATION DRIVEN MAP SELECTION SCHEME

A. Cross Layer Design at End Users

A cross layer optimization can be implemented at the end-devices or the intermediate nodes in the network, such as access points or routers. Given the relative easiness and feasibility of the former, this paper focuses on implementing changes on mobile hosts. Concerning the type of communication to be used in exchanging information among layers, a wide library of communication types exists. The proposed cross layer design can consider implementation of the most adequate one taking into account the required computational load and the communication delay that may result from interactions among the layers.

At the mobile host, the physical layer of a mobile host instantly measures the radio strength or link quality. When the mobile node moves into the overlapping area of two or more wireless cells, and different signals are consequently detected by the physical and data link layers, a warning message notifying an imminent handoff event, along with a list of the new possible access points, are sent to the application layer. In case of multiple access points, the application layer refers to a set of tools to sort out the access point to which the mobile node is most likely going to be connected. Indeed the application layer may use history on the user's mobility pattern to predict the new access point. Referring to a spatial conceptual map, along with the user's personal information, its current position, and its velocity heading, the application layer can make an accurate prediction of the most probable future access point [12]. Prior knowledge on the topology of the wireless network [13] can further increase the accuracy of the prediction. Simultaneously with the prediction of the next access point, the application layer computes an average value of the data transmission/reception rate. Once the next access point is decided, the application transmission/reception rate is written down in a RS message that is sent to the access point similar to HMIPv6. In this regard, it should be stressed out that there are two types of mobile networks. In the first type, mobile nodes are allowed to submit RS messages. Whereas in the second type, mobile nodes receive router advertisement (RA) messages from access points on a regular basis. This research work considers the first type of mobile networks. It should be emphasized also that the ADMAPS does not generate any new signaling messages, does not modify the HMIPv6 protocol itself, nor does it require any major modifications at the end terminals.

B. MAP Load Notification Approach

Similar to HMIPv6, the proposed scheme adopts the dynamic MAP discovery approach. Indeed, each access point receives MAP option messages from high-layer MAPs every $\varDelta T$ period of time. Unless otherwise specified, $\varDelta T$ is set to 1s similar to DEMAPS [6]. In the ADMAPS, we consider the inclusion of information on instant loads of MAPs in the MAP option messages. Examples of parameters that can define a MAP load are memory size, CPU processing power, used bandwidth, etc. For the sake of simplicity, we define the load of a MAP as the integer part of the percentage of ratio of the number of processed packets to the total number of packets that can be processed by the MAP during the computation period of time ($\varDelta T$), as shown in the following equation.

$$l_i = \lfloor (p_i + W \cdot p_i')/C_i \times 100 \rfloor \tag{1}$$

where C_i denotes the processing speed of the i^{th} MAP. It should be noted that a network element along the communication path can function as either a MAP or a mere router. The former case concerns packets destined to mobile nodes that are registering with the network element as their MAP, whereas the latter case relates to packets destined to nodes having other network elements as MAPs. In this vein, p_i and p_i' denote the total number of data packets forwarded by the i^{th} MAP as a mere router and the number of data packets destined to mobile nodes registered with the i^{th} MAP, respectively. Intuitively, the computational load required by a mere router to forward a data packet and that required by a MAP to transmit a data packet to a node registered with it are different. W is a weight factor that is used to reflect the difference in these two computational loads. It is assumed that access points have prior knowledge on the two parameters C_i and W. Upon computation of their loads, MAPs notify access points of this information via the seven bits of the reserved (RES) field carried in the packet header of MAP option messages.

C. Load Variance Computation and Update

Let M be the number of MAPs an access point is connected to. Upon receiving MAP option messages from all MAPs, the access point computes the average load of all MAPs ($\bar{l}$) and their load variance (V) as follows.

$$\bar{l} = \frac{1}{M}\sum_{k=1}^{M} l_k, \quad V = \frac{1}{M}\sum_{k=1}^{M} (l_k - \bar{l})^2 \tag{2}$$

The access point updates these two parameters whenever the load of MAPs changes. Let assume that the load of the k^{th} MAP changes from l_k to l_k'. The change in the load variance of MAPs, $\varDelta V$, can be computed as follows.

$$\varDelta V = \varDelta\bar{l}\left(2\left(l_k - \bar{l}\right) + (M-1)\,\varDelta\bar{l}\right) \tag{3}$$

where $[\varDelta\bar{l} = (l_k' - l_k)/M]$. Accordingly, the load of the k^{th} MAP, the load average and variance of all MAPs will be updated as follows.

$$l_k \leftarrow l_k', \quad \bar{l} \leftarrow \bar{l} + \varDelta\bar{l}, \quad V \leftarrow V + \varDelta V \tag{4}$$

D. MAP Selection Mechanism

The key philosophy behind the MAP selection procedure in the ADMAPS consists in selecting the MAP that renders the load variance of all MAPs minimum. To best explain the mechanism of the ADMAPS, we consider the case of a single handoff. We consider a scenario where a mobile node (MN) performs handoff to an access point (AP). Prior to handoff, MN transmits a router solicitation (RS) message informing AP of its average data reception/transmission rate b^1 and the IP address of the MAP (MAP$_i$) it has been registering with. Using these information, AP envisions all possible scenarios where MN shifts its registration from MAP$_i$ to MAP$_j$ and estimates the load variance of MAPs in each scenario. The MAP with the lowest load variance value is selected as next MAP (nMAP) for MN. To illustrate the idea at hand, we consider the scenario where MN registers with MAP$_j$. Assuming that routing is performed in a static manner over the hierarchical MAP network, the change in the load of MAPs, $\Delta\overrightarrow{l_{ij}}$, will be

$$\Delta\overrightarrow{l_{ij}} = b\left(\frac{\alpha_{1,j}-\alpha_{1,i}}{C_1},\ \cdots\ ,\frac{\alpha_{M,j}-\alpha_{M,i}}{C_M}\right) \tag{5}$$

where

$$\alpha_{k,i} = \begin{cases} 1 & \text{MAP}_k \text{ exists on route to MAP}_i \\ W & k = i \\ 0 & \text{otherwise} \end{cases} \tag{6}$$

Hence, the corresponding change in load variance ΔV_{ij} is

$$\Delta V_{ij} \simeq \frac{2}{M}\sum_{k=1}^{M}(l_k-\bar{l})(\Delta l_k(i,j)-\Delta\overline{l_{ij}}) \tag{7}$$

where $\Delta\overline{l_{ij}}$ denotes the average value of the load variation when MN quits MAP$_i$ and registers with MAP$_j$. Ideally, a fair distribution of traffic among all MAPs is possible only when next MAP is selected in a way that ΔV_{ij} is minimum. However, when the loads of MAPs are not that dispersal, change of MAP may put limitation on the performance of the ADMAPS. Indeed, a mobile node may be requested to register with a new MAP, different than the old MAP it was previously using, whereas it could have kept using the same old MAP without fearing any congestion of the latter. Such a scenario will ultimately oblige the MN to register again with its Home Agent (HA) and Corresponding Node (CN). All of these steps are admittedly unnecessary and may defeat the purpose of having HMIPv6 in the first place. As a remedy to this issue, MNs should be requested to register with new MAPs only when the old MAP is not accessible from the new access point or its load is relatively higher compared with other MAPs accessible from the new access point. In the ADMAPS, if a mobile node can keep registering with the same old MAP, MAP$_i$, and the load of the latter is not higher by L_{th} than the load of other MAPs, MN is exempted from changing its MAP. When the network traffic is dispersal among MAPs, MN will be requested to register with the new MAP (nMAP) that results in the minimum value of the variance of MAPs load.

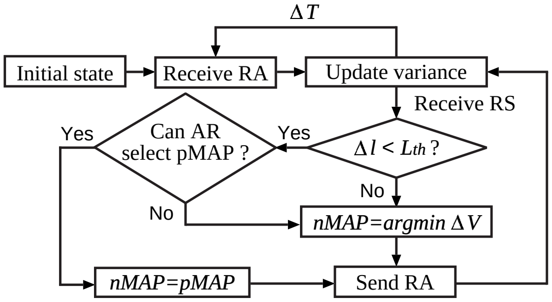

Fig. 1. Flowchart of the ADMAPS.

$$\text{nMAP} = \underset{j}{\arg\min}\,\{\,\Delta V_{ij}\,|\,j\in\{1,\,\dots\,,M\}\} \tag{8}$$

The average and variance of all MAPs' loads are then updated as follows.

$$\bar{l} \leftarrow \bar{l} + \Delta\overline{l_{ij}}, \quad V \leftarrow V + \Delta V_{ij} \tag{9}$$

The working of the ADMAPS is summarized in the flowchart of Fig. 1. Access points first refer to information on MAPs loads sent in MAP option messages to update the load variance of MAPs. Upon handoff of a mobile node receiving or transmitting data at a particular rate and registering with a particular MAP (pMAP), the access point in question firsts decides whether the mobile node should change its current MAP based on the load dispersion among all MAPs. If yes, it considers all possible scenarios for the mobile node to change its MAP and estimates the corresponding load variance of MAPs in each scenario. The MAP (nMAP) that leads to the minimum value of the load variance is selected and is advertised to the mobile node. result in a better and fair distribution of traffic among all MAPs as will be shown in the next section.

IV. PERFORMANCE EVALUATION

In this section, we evaluate the performance of the ADMAPS via simulations using the Network Simulator (NS) [14]. To simulate mobile users with frequent handoffs at random times in random directions, we consider the case of pedestrian mobile users roaming within crowded areas, such as university campuses or Central Business Districts (CBDs). The mobility pattern of such a population of users is modeled using the "*Outdoor to Indoor Pedestrian*" model [15]. In this model, upon walking a distance of five meters, users change their moving speed. The speed of a user follows a normal distribution with an average and a standard deviation value equal to 3km/h and 0.3km/h, respectively. As for the moving directions, the probabilities of users to turn right, turn left, or continue moving straight forward are set to 0.25, 0.25, and 0.5, respectively.

The considered network topology consists of a two-layer MAP (three-tiered) network with cross-links as shown in Fig. 2. In addition to its generality and simplicity, this three-tiered network topology represents the optimum hierarchy level for hierarchical mobile environments [16]. In the high hierarchy, two MAPs (MAPs 1 and 2) are placed. They are connected to HA and CN. The low hierarchy is formed of four MAPs, each serving four access points with transmission range equal to 75

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[1] Note that any value of b can be expressed as [$b = \sum_{i=0}^{m}(\beta_i 10^{m-i})$ where $m = \lfloor\log_{10}(b)\rfloor$, $0 \le \beta_k \le 9$]. Given the usually high value of b and since the length of RS messages is limited, rate b can be approximated to [$b \simeq \sum_{i=0}^{p-1}(\beta_i 10^{m-i})$ where $p \le m$]. In RS messages, only parameters m and $(\beta_0, \beta_1, \cdots, \beta_{p-1})$ are written. (e.g., $p = 3, b = 128396276$ bps $\rightarrow m = 8, \beta_0 = 1, \beta_1 = 2, \beta_2 = 8$)

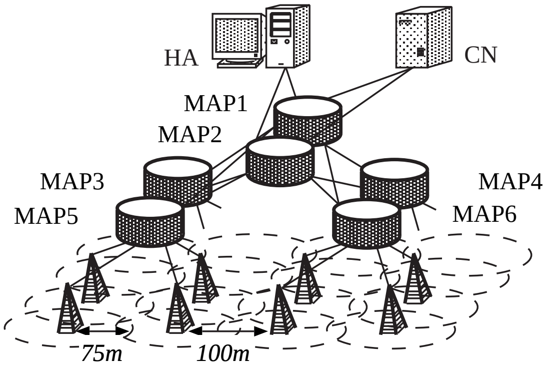


Fig. 2. Simulation environment.

TABLE I
MAP CHARACTERISTICS.

Parameter	Value
Processing speed of the upper/lower MAP	$25000 pkts/s, 10000 pkts/s$
W	1.5

meters. The distance between adjacent access points is set to 100 meters. The one-way propagation delay from HA or CN to high hierarchy MAPs is set to 30ms. The delay between two MAPs or a MAP and an AR is set to 4ms. The wireless link delay is set to 2ms. To avoid packet drops due to congestion of links, all links are given a sufficiently large capacity (e.g., 155Mbps). The simulation is run for 1800s. The first 200s are used for stabilizing the system. They are thus not used in the evaluation. 100 MNs are randomly dispersed over the coverage areas of the access points. 80 MNs receive packets at a rate of 200 pkts/s and the remaining 20 MNs receive data at a rate of 100 pkts/s. The packet size is set to 1 kB. To investigate the performance of the system in case of sudden changes in network dynamics, 10 MNs, residing in MAP3, are simulated to simultaneously perform handoff at 1000s after the start of the simulation. The simulation is run for 30 times and the presented results are an average of the total simulation runs. The MAP characteristics are summarized in Table I. In the performance evaluation, HMIPv6 [2], DEMAPS [6], and HMIPv6-UP [5] are used as comparison terms. To avoid load concentration at high hierarchy MAPs, maximum of 50 MNs are allowed to register with them. Other nodes have to register with low hierarchy MAPs. In HMIPv6-UP, users with velocity exceeding a specific threshold register with high hierarchy MAPs. In the simulation, this threshold is set to the average velocity of users 3km/h. In the ADMAPS, the threshold L_{th} is set to 10%. In the performance evaluation, the frequency of binding update messages sent to HA and the load transition of MAPs are used as quantifying parameters. The ratio of binding update messages is defined as follows.

$$\text{“BUs to HA ratio”} = \frac{\text{Number of BUs to HA}}{\text{Total number of BUs}} \times 100 \quad (10)$$

It should be noted that by ensuring small values of this ratio, short handoff delays can be guaranteed and packet drops can be avoided during the handoff operation. Table 2 shows the BU ratios in case of the four simulated schemes. The results indicate that DEMAPS and HMIPv6-UP generate the highest number of BU messages to HA. The reason behind the performance of HMIPv6-UP underlies beneath the setting of the velocity threshold. Indeed, as the velocity of users changes during the simulation time and goes beyond or above the threshold, users frequently change the hierarchy level of their MAPs. This incurs high BU messages. In case of DEMAPS, the high ratio of BU messages is attributable to the frequently changing conditions of the network. Effectively, in DEMAPS, mobile users performing handoff register with the MAP that has the lightest load. As the load of MAPs frequently changes as well, mobile nodes end up by frequently registering with different MAPs. This ultimately results in a high number of BU messages. Compared to the other schemes, the proposed scheme exhibits the lowest ratio of BU messages. This is attributable to the fact that the ADMAPS intriguers users to register with new MAPs only when the MAPs show significant variance in their load distribution. As for HMIPv6, the relatively small ratio of BU messages is due to the ability of high hierarchy MAPs to manage half the simulated population of users.

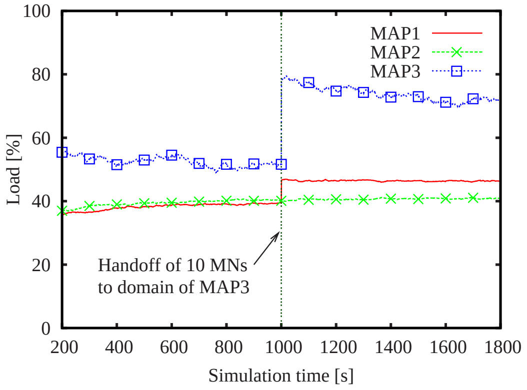
TABLE II
BUS TO HA RATIO.

	HMIPv6	HMIPv6-UP	DEMAPS	ADMAPS
BUs to HA ratio	33.3%	63.2%	65.9%	26.2%

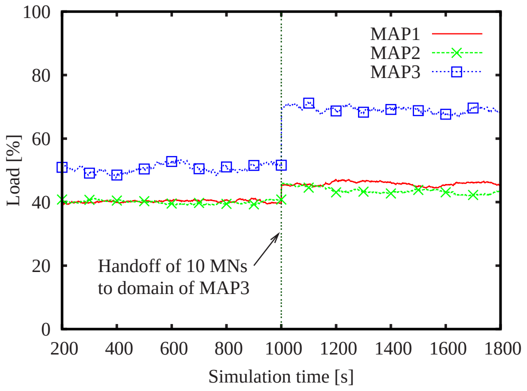
Fig. 3 plots the load transition of MAPs. For the sake of illustration, we consider the load transition of the two high hierarchy MAPs, MAP1 and MAP2, and only MAP3 from the low hierarchy MAPs. Here, it should be emphasized that MAPs 4, 5, and 6 exhibit the same behavior as that of MAP 3. The figure demonstrates that DEMAPS and the ADMAPS distribute well traffic among the two hierarchies of MAPs. In case of HMIPv6, the number of users that register with high hierarchy MAPs is limited to 50 and that put constraints on low hierarchy MAPs as they have to deal with high traffic load. In case of HMIPv6-UP, mobile nodes register with different MAPs as their velocity become beyond or above the velocity threshold. This operation leads to dispersion in the traffic load among all the MAPs. This dispersion can be managed by dynamic setting of the velocity threshold to optimum values. However, a successful setting of the velocity threshold depends on different factors related to the mobility patterns of users and is, in most cases, not possible. In contrast to these two schemes, DEMAPS and the ADMAPS exhibit a good distribution of traffic load among MAPs. This is attributable to their strategy to select the MAP with the lightest load or the one that leads to minimum variance in traffic loads among all MAPs. This operation avoids then the concentration of traffic load at only specific MAPs. Moreover, to avoid unnecessary BU messages, the ADMAPS advertises new MAPs to users only when their data transmission/reception rate results in a load variance of more than 10% among all MAPs. In the figure, we observe that the load variance among all MAPs is maintained at this value in case of the ADMAPS.

V. CONCLUSION

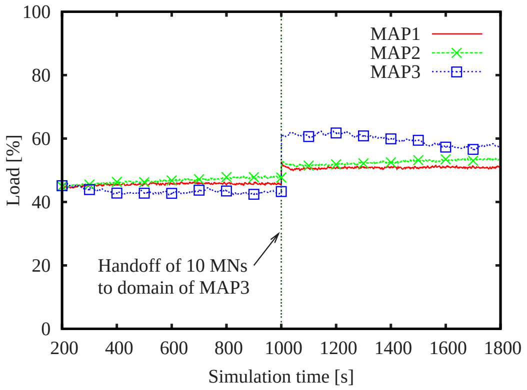
This paper purposed to solve the issue of traffic distribution among MAPs in HMIPv6. The proposed mobility management strategy is an application driven cross layer approach. In



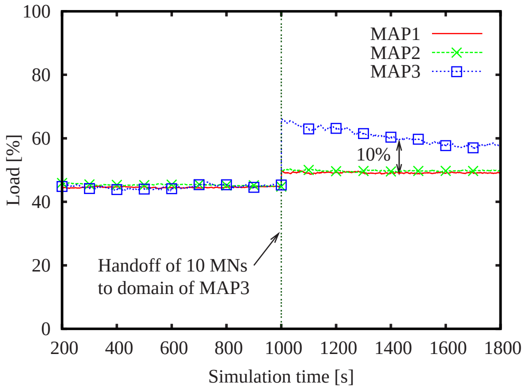
(a) HMIPv6



(b) HMIPv6-UP



(c) DEMAPS



(d) ADMAPS

Fig. 3. MAP load variation.

the proposed strategy, access points receive information on the data transmission/reception rate of users through minor changes in the RS messages. Simultaneously, access points receive information on the MAP loads on a periodic basis. Upon handoff of a mobile user to an access point, the access point refers to the transmission/reception rate of the user's application to decide which MAP the user should be registering with. The selection of MAPs is performed in a way that the load variance of all MAPs is maintained minimum. The efficiency of the ADMAPS in distributing traffic among MAPs is verified and confirmed by simulations. While the obtained results are encouraging, a major drawback of the ADMAPS may consist in its processing power required for computing load variance at access points for each newly arriving mobile user. In this regard, it should be noted that the computational load is in order of $O(M^2)$ where M is the number of MAPs an access point is connected to. Given the small value of M in general cases, the computational load can be considered minimal.

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