Agent Selection Algorithm in Hierarchical Mobile Networks

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Abstract — **In the future's IP-based mobile networks the mobile users require special support to provide connectivity, although they change their place of attachment to the network frequently. The task of mobility management is to provide this support. It consists of two parts: location- and handover management. The first one enables to originate and receive calls for the mobile terminals; the second is responsible for administering base station changes. These administrative messages may cause significant overload reducing the efficiency. In this paper, we introduce an agent (GMA/MAP) router selection algorithm in Regional Registration and Hierarchical Mobile IPv6 to optimise the handover management in IP-based next generation mobile networks.**

I. INTRODUCTION

In the Next Generation mobile systems the mobility management [1] will be handled in the Network Layer, unlike the currently used mobile systems, where this problem is solved in the second layer (Data Link Layer) [2]. According to the ”all IP” trend, IP will be responsible for mobility support in future mobile networks.

This support must be transparent to mobile users and also has to be scaleable. Scalability means that despite the growth of the number of mobile terminals, the amount of signaling overhead must not increase significantly.

The reduced radio cell sizes increase the number of handovers causing frequent handovers. This means that additional signaling overhead appears. The new services in next generation mobile networks increase the signaling overhead too, causing significant signaling delay. This is critical in the case of timing-sensitive real-time media applications that call for mobile QoS [3].

Mobile IPv6 [4] is an extension to IP to manage the mobile node's mobility, but not capable of supporting real-time handovers. The IETF developed new protocols to solve this problem. These protocols are Hierarchical Mobile IPv6 [5] and Regional Registration [6]. The basic idea of these hierarchical approaches is to use domains organised in the hierarchical architecture with a mobility agent in the domain. The standard does not address the realisation considerations. To plan an effective network we need to know the behaviors of the users. Of course these properties are not the same, hence the best solution is to adapt the network elements to each user.

In our work we present a method, showing how to configure network in order to reduce signaling traffic. We propose an algorithm, which can help to locate the Mobile Agents (GMA/MAP) in the hierarchical domain according to the mobile terminal's movement model. The mobile node agent selection algorithm introduces guidelines for mobile terminals on how to select the optimal agent from the agents available on the agent advertisement lists

The paper is organised as follows: in Section 2 we give a short description of Mobile IP, Hierarchical MIPv6 and Regional Registration. Principles of our agent-locating algorithm are introduced in Section 3. Explanation of our results follows in Section 4. The conclusion and the plans of our future work is reviewed in the last section.

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II. HIERARCHICAL MOBILE IPv6 AND REGIONAL REGISTRATION

A. Mobile IPv6

In Mobile IPv6 the mobile terminals have two addresses. They have a Home Address, which does not change, and a Care-of Address (CoA). The second one changes whenever the mobile node moves to a new access router.

Packets addressed to the terminal are delivered directly to the home link if the terminal is in its home network (like conventional IP routing). The Home Agent (HA) provides address mapping between the terminal's constant Home Address and the changing CoA. This association is called binding. If the mobile terminal is in a foreign network and a packet arrives for the mobile node, the HA transparently forwards it to the actual CoA.

Upon movement to a new access router, when the CoA changes, the Home Agent and the correspondent nodes have to be notified. For this end the mobile node must send a Binding Update message to the HA. It takes time to complete the administration of the CoA change because several messages are exchanged between the mobile and its HA/Correspondent Nodes. The delays will interrupt active connections every time a handoff is performed to a new access router.

B. Hierarchical Mobile IPv6 (HMIPv6)

Hierarchical Mobile IPv6 is an extension of Mobile IPv6, aimed at reducing the number of signaling messages and reducing the signaling delay by performing registrations locally in a regional network.

HMIPv6 utilizes a hierarchy of distinct routers in visited networks called Mobility Anchor Points (MAP) [7]. The deployment of MAP concept will further reduce the signaling load over the air interface produced by Mobile IPv6.

The mobile node (henceforward MN) has two kinds of care-of addresses: the Regional Care-of Address (RCoA) and the On-link Care-of Address (LCoA). MN obtains the RCoA from the MAP of the visited network, which remains unchanged as long as the mobile terminal is roaming within the given domain. The LCoA identifies the current position of the terminal, and if it changes within the logical domain, it must update it only to the MAP (by sending a Binding Update). The Home Agent and Correspondent Nodes are not aware of this change; the visible Care-of Address (RCoA) remains the same for them while the MN keeps changing its point of attachment inside the visited domain.

The MAP captures the messages sent to the MN's RCoA, and forwards them to the MN's LCoA using local routing mechanism. As a result of this, the amount of signaling messages leaving the domain is reduced significantly, and so is the resulting delay.

C. Mobile IPv6 Regional Registration (RegReg6)

Regional Registrations is also an optional extension to Mobile IPv6. It reduces the Binding Update signaling latency and the signaling load for a mobile node moving within the same visited domain.

The mobile node has a Regional CoA that is seen from outside the visited domain as the mobile node's primary care-of-address. This address is controlled by one of the visited-domain routers. This router is the gateway through which traffic for the mobile node enters the local domain. This router (GMA) is selected by the mobile node from a list of Regional CoA extensions attached to the Router Advertisement.

When a mobile node is performing a regional registration, the Crossover Router is the router where the data path between the gateway and the old access point crosses the path between the gateway and the new access router. The main advantage is reducing the binding update signaling not only outside the region.

The main difference between the two hierarchical solutions is that in Regional Registration the Binding Update travels only to the Crossover Router, while in HMIPv6 up to the MAP router.

III. AGENT-SELECTOR ALGORITHM

There are several potential mobility agent (GMA/MAP) routers inside a RegReg6/HMIPv6 capable domain. The MN chooses one GMA/MAP from the list attached to the Router Advertisement. In the list there is one or several RCoAs (GMA/MAP addresses). While the mobile node is moving in the domain area, it can choose another GMA/MAP router if the other one can serve the MN more efficiently.

For example if the mobility agent is too far from the mobile terminal, the MN can choose a closer one from the Router Advertisement message. So the incoming packets get to the mobile host in a shorter way, because the packets enter into the local domain area at the mobility agent if it is a border router. Every GMA/MAP change must be reported to the Home Agent.

For the best result the selection of the GMA/MAP must depend on the movement speed of the mobile node. Let's analyse the case of a fast moving and a slow moving mobile node!

If the MN often changes its Access Router, a high level GMA/MAP must be chosen while a mobility agent on low hierarchical levels advertises Binding Updates too often.

For a slow moving mobile host the situation is the opposite. It is advisable to choose a GMA/MAP near the Access Router. Because of the slow moving, the change of the Regional CoA is rare, and the incoming packets arrive to the MN in a shorter way.

Two other problems come up:

1. How to detect MN's movement speed?
2. How to detect mobility agent's hierarchical level?

If the MN can count the number of handovers within a time interval, its relative speed can be computed. If there are many handovers, the MN moves fast, in case of rare handover events, the mobile's speed is slow. This method works only if the sizes of the cells are near the same. The maximum number of handovers during the measurement time period is upper-bounded by the applied radio access technology. Counting the handovers can be carried out easily, because mobile terminals are storing recent handover events.

To solve the second problem, the MN must know where the GMA/MAP can be found in the hierarchy. We give an answer to the problem using the list attached to the Router Advertisement. The highest router in the hierarchy originates this message, and moves downwards in the hierarchy. When the message arrives at a GMA/MAP router, it attaches its own RCoA. So the list contains the advertisement in the order of the agent's hierarchical level (Fig. 1.). Of course not all the routers need to be assigned as a mobility agent. Hence routers that are not GMA/MAP capable should also add a special address to the Router Advertisement list, but the MN should not choose this address. The MN must to recognise the address and should not select it from the list.

0 … 31

Type	Length=2	Preference	Index
Lifetime			
Regional Care-of-Address 1			
Regional Care-of-Address 2			
…			
Regional Care-of-Address n			

Fig. 1. Router Advertisement - Regional CoA Extension in RegRegv6

The MN has no information on the other branches of the hierarchical network. The Router Advertisement informs it only about that one which runs from the highest router to the Access Router. (Fig. 2.) The protocols become useless if there is no GMA/MAP located on a branch. It is practical to deploy a mobility agent in the highest router in the hierarchy to avoid this situation. Of course not all the routers need to be assigned as a mobility agent.

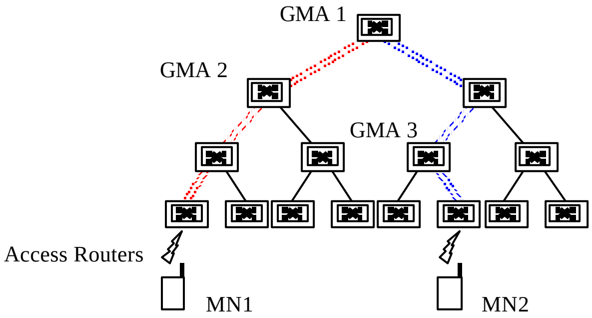

Fig. 2. Mobility agents in the hierarchy

We suggest an algorithm, which selects the optimal RCoA (GMA/MAP) from the list. Let us assume that the mobile node has a minimal (v_{min}) and a maximal (v_{max}) speed

$$v_{\min} \le v < v_{\max} \,. \qquad (1)$$

It has minimal speed if the MN does not move. The speed can easily be converted to number of handovers (2). For this we must know the cell's diameter (*D*). Using these parameters, we can calculate how long the MN stays in the cell (let us assume that the movement direction and the speed is constant). Let us define a time interval denoted by *T*, while the MN counts the handovers. Variable *n* stands for the number of the handovers in interval *T*. The mobile terminal must select the mobility agent router from the Router Advertisement's list depending on this number:

$$n = \frac{T}{\frac{D}{v}} = \frac{T \cdot v}{D} \,. \qquad (2)$$

Hence the number of the handovers belonging to the maximal speed is:

$$n_{\max} = \frac{T \cdot v_{\max}}{D} \,, \qquad (3)$$

so n=0..n_{max} .This interval must be partitioned to smaller intervals, depending on the number of the addresses (*c*) in the list attached to the Router Advertisement (see Figure 3). The selected RCoA's ordinal number is c_{sel}. The ordinal number of highest GMA/MAP router in the hierarchy is c_{sel}=1, the number of closest GMA/MAP to the MN is $c_{sel}=c$

$$c_{sel} = c - \left\lfloor \frac{n}{n_{\max}} \cdot c \right\rfloor . \qquad (4)$$

If there is no GMA/MAP on the selected layer, the MN must choose the closest one as illustrated in Figure 3. In this example *c*=7.

It is noticeable that increasing the movement speed, the probability of the GMA/MAP changing is increasing too, if the MN selects the mobility agent on random way. The effect is the same, if the number of the hierarchy levels is increasing. Using the algorithm, the GMA/MAP router must be chosen only once in the ideal situation. In a router hierarchy, which has three levels, up to 50% gain can be achieved.

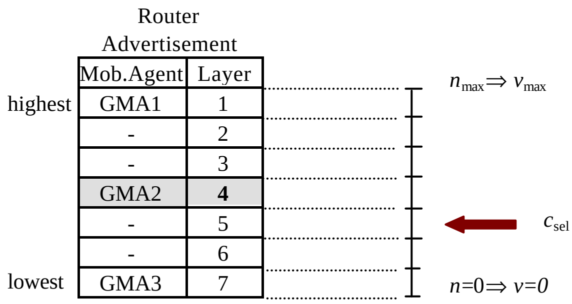

Fig. 3. GMA/MAP selection from the Router Advertisement

IV. RESULTS AND DISCUSSION

We have examined how the number of re-registrations at the Home Agent changes using a random GMA/MAP selection and our selection algorithm. For simplicity all of the routers are GMA/MAP capable routers.

The agent selection algorithm has been examined both analytically and by means of a simulator program. Since analytical examination was too complex for large networks, hence we developed a simulator program in C/C++.

We analysed a hierarchical network with three levels, where all the routers are GMA/MAP capable. In this case, the MN receives a Regional Care-of-Address Extension message with three selectable RCoAs. In random mode the MN chooses the optimal GMA/MAP in our sample network with p=1/3 probability.

In this sample the whole speed interval is partitioned into four smaller intervals (v_a, v_b, v_c, v_d). If we knew in which interval the speed-rate is, we are able to choose the optimal GMA/MAP router. We have calculated the probability of GMA/MAP changes in case of random GMA/MAP selection. As the results show, the probabilities (p_i) that the MN changes its GMA/MAP router once, twice, and so on (x_i) are given in Table I. The expected number of GMA/MAP changes (î) depending on the movement speed can be calculated with (5) using the probability values from Table I:

$$M(x) = \sum_{i=1}^{n} p_i \cdot x_i \qquad (5)$$

Table I.

Probabilities and expected values of GMA/MAP changes

GMA changes	v_a	v_b	v_c	v_d
1	1	2/3	1/3	1/3
2	-	1/3	4/9	1/3
3	-	-	2/9	7/27
4	-	-	-	2/27
Σ	1	1	1	1
$M(x)$	1	1,3	1,8	2,07

For example the expected value of GMA/MAP changes when the speed is in interval v_d is 2,07. Using our algorithm only one GMA/MAP registration is needed achieved 50% gain.

The developed program simulates mobile nodes mobility. We can define the mobile hosts' maximum and minimum speed. The hierarchical structure of the network is also adjusted by the user.

The mobile terminals are changing their Access Router while moving randomly in the network. The program examine whether GMA/MAP change is needed and counts the number of the Binding Updates. Every router has a maximum capacity, for this end the number of the attached mobile hosts is limited. This limit is also set by the user.

We analysed four different agent selection methods. The mobile terminal can choose the GMA/MAP from the lowest layer, from the highest layer, randomly and according to our algorithm. The measured load of the administrative messages (Binding Update), the number of the GMA/MAP changes and the number of overload events at the mobility agent router is shown on Table II.

Table II.

Simulation results

Algorithm	HMIPv 6	RegReg	GMA/MAP changees	Overload
Hihgest	97996	31050	0	19464
Lowest GMA/MAP	16264	8432	3991	0
Random	57664	23184	2663	4000
Algorithm	51026	21818	1228	0

The administrative load in Regional Registration is about the half compared with Hierarchical Mobile IPv6. The Crossover Router causes this significant difference. The message forwarding mechanism is not the same in these protocols. In HMIPv6 the router in the domain only forwards the packets and doesn't change any parameter in the packet header. A RegRegv6 router encapsulates the packets and overwrites the destination address according to its database, because the destination address is not the real address of the MN. It is the address of the next router toward the mobile terminal. Without this mechanism the Crossover Router could not be determined.

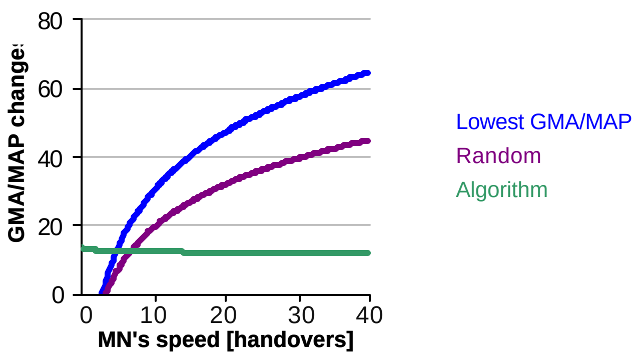

Fig. 4. GMA/MAP changes depending on MN's speed

Figure 4. illustrates the number of mobility agent changes depending on the number of handovers in a given time interval.

It is noticeable that in case of random agent selection, as the speed of the terminals increases (or when the hierarchical tree has more levels), the number of GMA/MAP changes also rises. As a result, the amount of signaling overhead is increasing significantly compared to the optimised scenario.

V. CONCLUSIONS

The seamless mobility management in IP is an important task. It become obvious that Mobile IP (MIP) in itself is not capable of supporting real-time handovers under mobile scenario: the long lasting address registration processes resulting in an intolerable interruption to user's data flow during handoff. Among the solutions to handle mobility in the IP layer more effectively, the micro-mobility standards are well tested and several test-beds exist. The demand for global QoS support has brought the more enhanced hierarchical solutions (like HMIP and Regional Registrations) into being. However these proposals are quite recent: less data is available on testing and optimisation. There are details that the existing versions of the proposals are not dealing with, like the optimal selection of GMA/MAP routers.

We gave an algorithm on this problem, and analysed the efficiency of our solution in several test networks. The agent selection algorithm's advantages are studied in comparison with a random agent choosing method. These results help to support global QoS in next generation networks.

Our future plan is to consider how should the hierarchy designed to make our algorithm more efficient because the QoS provision is the key to the next generation mobile systems.

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