HIERARCHICAL MOBILE IPV6 AND REGIONAL REGISTRATION OPTIMIZATION

Vilmos Simon, Árpád Huszák, Sándor Szabó

Budapest University of Technology and Economics
Department of Telecommunications
Mobile Communications and Computing Laboratory
Magyar Tudósok krt.2, H-1117. Budapest, HUNGARY
E-mail: svilmos@hotmail.com, huszak@freemail.hu

Abstract

While IP is declared as the key technology of the future's wired and mobile communication, the currently used version of IP, IPv4 itself is not suitable to be used in mobile scenarios.

Mobile Internet users need 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, which consists of two parts: location management and handover management [1]. The first one enables to originate and receive calls for the mobile terminals, the second is responsible for administering base station changes [2].

As a result of our work, we have created a network design algorithm to optimise the handover management in the next generation mobile networks, in order to reduce the signalling overhead.

INTRODUCTION

While mobility management in current systems, like GSM, is handled in the second layer (data link layer), the new tendency is to solve such problems in the network layer [3], according to "all IP", and IP is responsible for that.

This support in future systems must be transparent to the mobile users and also has to be scaleable, which means that despite the growth of the number of mobile terminals, the amount of signalling overhead must not increase significantly [4].

Reduced radio cell sizes (increasing the number of handovers) and more complex protocols and services in next generation mobile networks increases the signalling overhead, causing significant signalling delay. This is critical in the case of timing-sensitive real-time media applications that call for mobile QoS [5]. Mobile IPv6 [6] is not capable of supporting real-time handovers [7], so the solution is to make Mobile IPv6 responsible for macro-mobility, and to have a separate protocol to manage local handovers inside the micro-mobility domains, for example Hierarchical Mobile IPv6 [8], or Regional Registration [9]. This hierarchical approach is necessary, which differentiates the local and global mobility. The basic idea is to use domains organised in hierarchical architecture with a mobility agent on the top of the domain hierarchy (hierarchical tree).

The standard is not dealing with the realisation of the hierarchical tree during the network design, and we also couldn't find any testbed or paper on this topic in the literature. The implementation of the hierarchy is entrusted to the engineer. We gave planning principles, which can help to plan optimal networks. In our work we presented a method, showing how to configure these hierarchy levels in order to reduce signalling traffic.

In planning a network it is not the same if a network is implemented over a campus or over a busy highway. In the first case, low speed movement is dominant, in which handover is rare, so signalling traffic is lower. On a busy highway high speed movement causes more frequent handover events, thus the handling of increased signalling load must be solved [10].

The important questions arising: what kind of principles must be used to configure the hierarchical levels, how to group cells under a given router, and in which hierarchical level is it advisable to implement the MAP/GMA function. We propose a graph-theory algorithm, taking into consideration the Mobile Node's mobility model.

This paper is organised as follows: in Section 1 we give a short description of HMIPv6 principles and a presentation of our domain forming algorithm, in Section 2 the exposition of our results follows, and in the Section 3 we draw some conclusions from the obtained results.

1. THE HIERARCHICAL MOBILE IPV6 OPTIMIZATION

1.1. Hierarchical Mobile IPv6

Hierarchical Mobile IPv6 is an extension of Mobile IPv6, aimed at reducing the amount of signalling overload and speeding up handovers in cases when the Mobile Node (MN) is located far away from its Home Agent and Correspondent Nodes.

HMIP utilizes a hierarchy of distinct routers in visited networks called Mobility Anchor Points (MAP) [11]. The deployment of MAP concept will further reduce the signalling load over the air interface produced by Mobile IPv6.

The 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 MN 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 (it sends 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 signalling messages leaving the domain is reduced significantly, and so is the resulting delay.

According to this concept, we have created a network optimizing algorithm, which helps us to form the domains in Hierarchical Mobile IPv6, where the amount of administrative messages leaving the domain can be reduced to minimal.

1.2. Model assumptions

We have decided to choose the Random Walk Mobility Model [12], because it is a simple and universal model.

According to this mobility model, the Mobile Node moves from its current location to a new location by randomly choosing a new direction and speed of travelling.

The new speed and direction are both chosen from pre-defined ranges, [v_{min}, v_{max}] and the Mobile Node can move in north/east/west/south directions. Each movement is done at a random interval determined by an exponential distribution.

If the cell capacity is W, and a router can manage an $M \cdot W$ traffic (assumed as upper bounded or constant traffic rate, in order to have uniform distribution), the one router covered area will consist of M number of cells.

Handovers within this domain are handled locally, so the RCoA remains unchanged, but if the Mobile Node crosses the domain boundary, the RCoA will change, which needs global handling, according to hierarchical solutions, as in our case HMIPv6.

In any cases the best solution seems to be to join adjacent cells into domains, the grouping of the cells will be performed in that way, but on which principles can we do that?

We have chosen the two most important parameters, which will help us to create the hierarchy forming algorithm: the probability of moving the Mobile Node in the given direction and the Mobile Node's speed. The probabilities determine how to join the adjacent cells together, forming the lower hierarchy, while the Mobil Node's statistic speed ranges determine the upper hierarchy.

Thus for the design of the network, we need preliminary information about the mobile users movement scenario and mobility models. Naturally, it is impossible to design the network for individual scenarios, but we can do it on territory-dependent criterion and the average mobility informations regarding the users, because the behaviour of Mobile Nodes inside a local geographically coherent area shows significant similarities. For example, on the highway there are only two directions with significant probabilities and the speed is high, too. Within a building, the position of the rooms determines the possible moving directions, because of a wall the users will move in that direction with zero probability. To have those informations, it requires measurements and observations, which is not a problem for mobile service providers, because for them mobility scenarios are available in their databases (statistics derived from already operating systems, like GSM), before the design and installation of next generation networks.

For every cell, we have defined a direction probability vector, which contains the probabilities of the mobile users choosing the four given directions (north: P_N , south: P_S , west: P_W , east: P_E) to cross the cell boundary. We need that, because if we join the cells with the identical moving direction (for example: avenue) in one domain, the signalling messages, produced by handovers, do not go up to higher hierarchy levels, so in this way we can reduce the administration overhead.

1.3. The Domain Forming Algorithm

We have modelled the network with a graph, the cells are the nodes of the graph (V) and the possible directions of the cell boundary crossing between adjacent cells will be the edges (E). v_1 and v_2 are adjacent points (cells), if $\{v_1, v_2\} \in E$.

We must divide the $G = (V, E)$ graph into $G' = (V', E')$ subgraphs, so that the subgraphs contain the maximal weight spanning tree.

Adjust weights to the graph's edges, not negative real numbers in the range [0,1], based on the probability vector, namely the weights of edges will be equivalent to the proper probabilities of the moving directions (Fig. 1.).

We choose the edges one by one in the following manner: first we choose one of the edge with the biggest weight: $e_{\max} = p_{\max}$. The two nodes (cell), which are connected with this edge, $\{v_1, v_2\} \in e_{\max}$ (Fig. 2.), can be joined, and after that we manage them as if they are one, $V' = \{v_1, v_2\}$. From the six edges (eight edges come out from two nodes, four direction two times, but one edge is common) outgoing from the two joined nodes, we must choose one with the biggest weight value, $\max(E')$, and the belonging node becomes the member of the common set, $V' = \{v_1, v_2, v_3\}$. From the eight edges (twelve edges come out from three nodes, but two edges are common) belonging to the nodes, which are in the common set, we choose the next one so as to make a circle in the graph, namely if we have an $(v_1, e_1, v_2, e_2, ..., v_k, e_k, v_{k+1})$ edge series, then $v_1 = v_{k+1}$. In this way, we can avoid the domains becoming too entangled and far-reaching. We can continue this algorithm, until the element number of V' reaches M , $N(V') \leq M$, because the router can manage the traffic of only M number of cells, so one domain will consist of M cells. When we cover the entire G graph with not-connected $G'_1, G'_2, ...G_N$ subgraphs, the algorithm of forming domains is finished.

By that way the lowest hierarchy level can be formed, covering every cell.

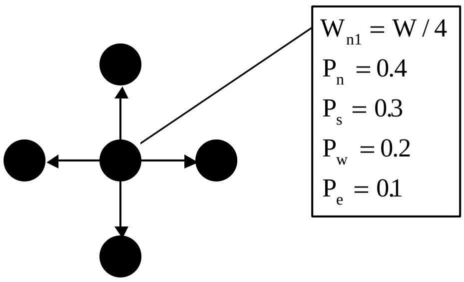

Fig. 1. The graph with weighted directions

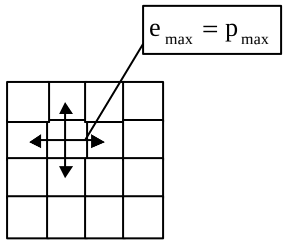

Fig. 2. Forming the domain

2. ANALYTICAL EXAMINATION

We have examined analytically, how the number of signalling messages changes using a randomly formed lowest hierarchy level and the one, which is formed by our algorithm, to see if the algorithm really decreases the administrative overload generated by the handover.

The comparison was made in the following environment: in our examination we have modelled the cover of a busy avenue and its surroundings. In our model we have approximated the cells with quadrates, because of easier calculation. One router managed four cells, $M = 4$, and we had 36 cells in the modelled network, so we needed nine routers.

We adjusted probabilities to the handover directions, modelling a realistic traffic on the given system of roads (avenue and its side streets). The probabilities gave us the information in which direction (north/south/west/east) and with what relative frequency the mobile users will cross the cell boundary, based on online measurements. For such probabilities preliminary measurements, observation and then processing of measured values (databases of mobile providers) are needed.

It was noticeable, that in the cells, which are covering the avenue and the side streets, the dominant moving direction corresponds to the road.

The forming of domains from the 36 cells was done in the above mentioned two ways.

The required bandwidth, if the Mobile Node changes a domain, is:

$$B = K \cdot N \cdot L + 2 \cdot L = L \cdot (K \cdot N + 2) \tag{1}$$

where N is the number of the foreign Correspondent Nodes, L is the size of the Binding Update message, and K is the number of Binding Updates which was sent to one foreign Correspondent Node.

As $M = 4$, the domains consisted of four cells.

In the first case, we made a random arrangement of four cell groups and we calculated how many domain handovers it causes when the Mobile Node is travelling on significant routes on our system of roads. One change of domain requires $K \cdot N + 2$ number of Binding Updates, and the bandwidth defined by Eq. (1).

In the second case we used our domain forming algorithm to see whether it really reduces the number of domain changes for the same significant routes.

The results are given in Table 1.

Table I. Number of domain changes

Route	*Random*	*Algorithmic*
(a)	5·L·(K·N+2)	3·L·(K·N+2)
(b)	3·L·(K·N+2)	2·L·(K·N+2)

Based on the results obtained (the domain changing update traffic was calculated for other significant routes, too) with the help of the domain forming algorithm, the handover signalling load can be reduced (by 30-40% in average, see Table I.), which makes it possible to improve the QoS parameters (for example in real time applications).

3. CONCLUSIONS

The development of Hierarchical Mobile IPv6 and Regional Registration has not been finished yet. There are details that the existing versions are not dealing with: the optimal network structure and the selection of GMA/MAP routers. We gave an algorithm on the first problem, and analysed the efficiency of a simple network. We have compared the traffic of a network designed by us and a random designed network.

We recognised that significant results were attained reducing the signalling traffic, which helps us to support global QoS in next generation networks.

In the future we would like to use computer simulations (NS2 and Omnet++) to analyse algorithms, which will help us to get more results.

Also, we have been working to give an algorithm for the second problem. We want to compare numbers of re-registration of the MN using our GMA/MAP selection algorithm, which is in progress, with the random GMA/MAP selection.

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