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Design and evaluation of signaling protocols for mobility management in an integrated IP environment ☆

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Abstract

In the future mobile network, satellites will operate alongside cellular networks in order to provide seamless connectivity irrespective of the location of the user. Such a service scenario requires that the next generation of mobility management (MM) procedures are able to ensure terminal and user mobility on a global scale. This paper considers how the principles of Mobile-IP can be used to develop MM procedures for a heterogeneous access network, comprizing of satellite and cellular elements, connected to an IP core network.

Initially, the system architecture is described. This is followed by a discussion of issues related to MM, where location, address and handover management are considered. A description of the signaling protocols for macro-mobility using Mobile-IP is then presented, emphasizing the need to minimize the change to the existing access network procedures. Finally, the performance of the protocols is analyzed in terms of the additional signaling time required for registration and handover. © 2002 Elsevier Science B.V. All rights reserved.

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1. Introduction

Mobility management (MM) essentially can be divided into two main categories: location management, which incorporates address management, and handover management. Different approaches to MM are available depending on the type of system in operation. This paper presents the design and evaluation of signaling protocols for managing inter-segment mobility using Mobile-IP.

In the following, the heterogeneous network is considered to be made up of three wireless access segments, two of which represent terrestrial cellular networks, the other being a satellite network. The satellite-terrestrial integration scenario, where the satellite provides complementary service coverage to the terrestrial network by either 'filling in the gaps' or extending coverage on a regional or global basis, formed the basis of the Satellite-Personal Communications Network (S-PCN)

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concept conceived at the start of the last decade. Unfortunately for the satellite communications industry, by the time that S-PCN became a reality, the dominance of the terrestrial cellular market resulted in little opportunity for satellite operators to make any substantial market in roads. While there appears to be little opportunity for developing significant markets for voice-type services over satellite, especially in the developed parts of the world, the introduction of the next generation of Internet-type services could provide the opportunity for satellites to fulfill their role alongside their terrestrial counterparts. In this case, satellites could be used in an operational climate that would be very different from that faced by S-PCN operators. Terrestrial mobile Internet access is now only starting to roll-out via evolved second-generation networks such as General Packet Radio Service (GPRS), and coverage is likely to be restricted to built-up, metropolitan areas in the first few years after introduction. The use of satellites to provide similar services over a much larger coverage area could provide a much more attractive business case in comparison to S-PCN. Certainly, satellite coverage could be introduced in a similar time frame to that of cellular packet-oriented networks, thus ensuring that neither system has a significant market lead over the other. Of course, satellites may also be able to provide services at a higher data rate than that envisaged over the cellular network and the wide area coverage could allow innovative broadcast or multi-cast services to be distributed on a regional or global basis.

The cellular networks considered in this paper are represented by the GPRS and the Universal Mobile Telecommunications System (UMTS). These networks represent an evolved second-generation network and a third-generation network respectively. Both support packet-oriented services. The satellite network is based on the mobile-EuroSkyWay network (M-ESW) which can be considered a further evolution, in the field of mobility services, of the EuroSkyWay system currently being developed for fixed environments [1].

An access network tends to have its own set of MM procedures, designed specifically with that particular system in mind. As a consequence, this provides serious design difficulties when considering the need for inter-segment roaming between what are essentially independent access networks. In systems such as GPRS and UMTS, which undergo lengthy standardization procedures to facilitate global market take-up, the need to modify existing protocols should be avoided or at least kept to a minimum. It can be seen that the need for change would have an impact on a global scale, which could prove commercially unattractive and technically impractical to implement. It can be imagined that the requirement to perform major modifications to an established network, such as UMTS in a few years time, in order to accommodate a niche market network, such as that provided by a satellite segment, would not have the backing of the terrestrial network operators. In the following, it is shown that by using the concepts of Mobile-IP, the required modifications to existing access segment protocols are slight, thus ensuring that a truly global access network is feasible, both from a commercial and technical perspective.

2. System architecture

The system architecture is shown in Fig. 1. Here, it can be seen that the access networks are connected to the IP core network via edge routers.

GPRS provides non-real-time services using an efficient packet mode technique to transfer data at speeds ranging from 9 kbps to about 170 kbps per user. GPRS has evolved from the GSM network, incorporating a new packet-based interface, and extending the GSM architecture by the addition of two new network nodes: the serving GPRS support node (SGSN), which tracks the position of a terminal, as well as providing security functionality; and the gateway GPRS support node (GGSN), which performs interworking with external packet-switched networks [2]. It can be seen in Fig. 1 that the GGSN provides the physical connectivity to the edge routers.

UMTS is a member of the IMT-2000 family of third-generation mobile systems defined by the International Telecommunications Union (ITU). It is capable of delivering low cost, high capacity mobile communications offering data rates up to