Mobile IP and Cellular IP Integration for Inter Access Networks Handoff

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Abstract

In this contribution two solutions for the management of cellular intranet, based on the Mobile IP and Cellular IP protocols integration are investigated. The first solution adopts a centralized architecture build over the gateway and the home agent. It is most suited for security needs and client/server traffic. The second solution utilizes the mobile IP with routing optimization for macro mobility management. It offers optimized routing, speeds-up the handoff procedures, supports real time traffic and is therefore oriented toward the Quality of Service.

I. INTRODUCTION

The Internet Protocol (IP) represents today's standard in internet networking. Moreover, the IP technology has recently been improved with the introduction of new services such as Voice over IP (VoIP) and best effort/QoS enhancements which represent key features of wireless networks. Thus, the ability to handle data and voice services in an integrated form as well as the possibility of employing the same protocol when accessing the system through a wired or a wireless subnetwork, make extremely attractive solutions based on extensions of the standard IP protocol, for mobility management in third generation cellular systems [1]-[3].

In essence, the objective is to dispose of a whole set of efficient mobility management features at the IP layer (Network). This will make the access network nearly-independent from radio interfaces access. Only the base stations (BS) will be connected by radio-link (layer 2 and lower) with the mobile station (MS).

To obtain such an integration, the first step is the management of a Cellular Intranet, i.e., a subnets system able to supply a coverage to a mobile host similar to the one presently available in cellular systems (GSM, DCS, and PCS).

The overall system must be able to manage the handoff between cells within the same access network as well as between different access networks.

As already specified by the Internet Engineering Task Force (IETF), the reference network architecture is based on access domains, representing different sub networks, managed by the Mobile IP protocol [4]. This architecture is based on the concept that most of the mobility can be managed locally within one domain without loading the core network [4]-[11].

In this paper an infrastructure for an IP wireless network for the cellular internet, see fig. 1, is proposed. This architecture uses the standard Internet for the core network. The Mobile IP (MIP) is used as an inter-subnet mobility protocol for macro-mobility management; while Cellular IP (CIP) is employed for the intra subnet mobility as support to the micro-mobility and paging management (see [12]-[20]).

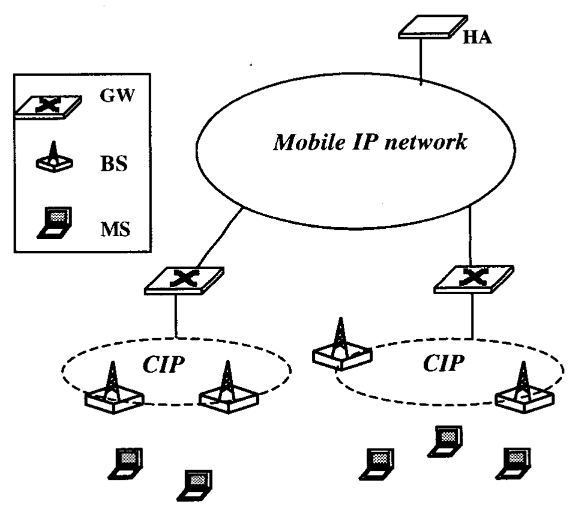

Fig.1: Mobile IP/Cellular IP Architecture

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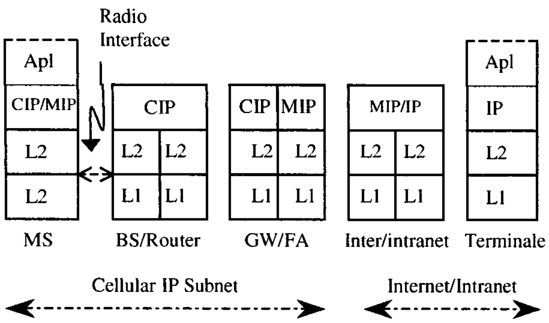

Fig. 2: MIP/CIP protocol stack Architecture

II. CELLULAR INTRANET

The cellular intranet integrates two levels of mobility management, the local (Cellular IP) and the global (Mobile IP/Cellular IP). Fig. 2 shows the architecture of the protocols of the CIP/MIP co-existence. The CIP and MIP can operate simultaneously in macro-mobility management.

The first node interacting with the mobile terminal by means of the MIP, is the Gateway (GW/FA). Using the Foreign Agent (FA) function, (see Fig. 1), the GW filters the micro-mobility traffic within the CIP network. In macro-mobility management the MS directly exchanges datagrams with its FA and is indirectly engaged with the Home Agent (HA) via FA. Figure 2 shows the layer 3 protocols' architecture to ensure needed internal cellular mobility and Internet visibility.

Please note that the MS is globally visible only if it is registered with the HA (macro-mobility) and the cache maps of the cellular IP nodes serving the MS are updated.

Using CIP/MIP simultaneously is inefficient and redundant, especially for mobility management, ref. [20], since CIP uses two IP packets (ICMP for registration and IP for Ack) and MIP uses four UDP/IP packets.

It is possible to efficiently utilize CIP/MIP simultaneously if a separation between the two protocols is imposed, such as having an intranet with heterogeneous cellular access subnets.

Since the CIP architecture is centralized the MS macro-mobility operations management can be left within the GW operations management. In this situation the MS utilizes only the CIP and the GW performs the FA function with some modifications in the access network interface.

The most important operation of macro-mobility is the handling of the migration between two cells managed by two different access subnetworks. The terminal detects this situation by reading the "beacon" packet received from the new BS, ref. [12]. The registration request (MS -> new BS) prepares the new access CIP network for routing to the MS. The remaining path (core network) is organized by the mobile IP, and is managed by GW/FA and HA.

The GW/FA that constitutes the interface node between the mobility cellular network and the core network, also represents the interface between the CIP and MIP. The IP packets within the cellular network are processed by the layer 3 entities of GW/FA depending on their IP address.

Generally, the GW/FA can manage two states of the mobile station: the active state with consequent priority on operation management on the core and then access network, and the idle state without priority needs.

III. CELLULAR IP AND MOBILE IP ROUTING OPTIMIZATION

The cellular intranet (end-to-end IP network) presents an architecture which is poorly suited to manage the cellular mobility system. Any active MS connected to the cellular IP network generates a larger throughput than the one generated by a fixed station in the Internet network. Furthermore two MS's connected to two different access networks generate twice as much traffic as that generated by two fixed stations in two different Internet subnets , because of the traffic overload in the core network produced by the triangular routing.. Specifically, let η_{IP} be the effective throughput of the traffic produced by two fixed sources residing in two different IP subnets, and let $\eta_{CIP-MIP}$ by the effective throughput of the traffic produced by two mobile sources residing in two different CIP domains, when using the CIP-MIP protocol pair. Then the routing efficiency $\eta_{CIP-MIP}$ is related to the routing efficiency of the IP protocol η_{IP} as follows:

$$\eta_{CIP-MIP} = \frac{1}{2}\frac{1+\alpha_f}{1+\alpha_m}\eta_{IP}\,, \qquad (1)$$

where α_m and α_f ($0<\alpha_m \leq \alpha_f \leq 1$) respectively relate to the mobile host and the fixed host; Their values represent the percentage of acknowledged traffic introduced by the upper layers and, consequently, the applications respectively used by the mobile and the fixed host.

Mobile IP with routing optimization (MIP-RO) represents a viable solution to increase efficiency. MIP-RO introduces the utilization of the "binding cache" to

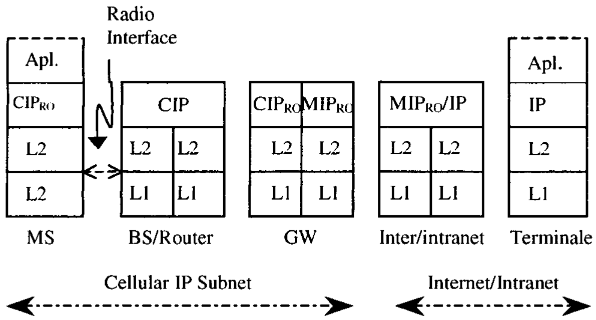

Figure 3: MIP/CIP protocol stack Architecture

eliminate the triangular routing. In addition, this enhancement enables the "smooth handoff."

Fig.3 shows the protocol architecture of a cellular intranet managed by the CIP and MIP-RO pair. This protocol requires the use of mobile stations with additional functions such as packet encapsulation (tunneling), and the utilization of binding cache. Consequently, a mobile station must utilize supplemental functions of the CIP protocol. A mobile station interfacing the core network via GW-FA can manage the mobility using either the MIP-RO protocol or the above-mentioned supplemental functions (CIP_{RO}), which will enable the MS to utilize the core network with routing optimization.

The second solution is preferred since it partially disengages the MS from the macro mobility management and simplifies the inter access network handoff operation.

The traffic exchanged between two mobile stations using the MIP-RO at steady conditions (after the binding cache update) is nearly equivalent to the traffic between two fixed terminals connected by two different subnets. In order to achieve this performance, the terminal must utilize tunneling within the access network. That is, after receiving the binding cache advertisement, the source MS knows the IP address of the GW/FA of destination MS. Therefore, the source MS can encapsulate the packets, by addressing them directly to the GW/FA, thus, bypassing HA. The network nodes do not need any of the supplemental functions since they use the "hop-by-hop" routing, which ignores the packet destination address.

Downstream traffic is unmodified, and the GW/FA, representing the end of the tunnel, routes the simple packets within the access network.

Figure 4 shows the packet traffic generated by two mobile stations residing in two CIP networks at steady conditions.
The packet traffic generated by the MS y is represented by Y_1, Y_2, Y_3, and the traffic generated by the MS x is

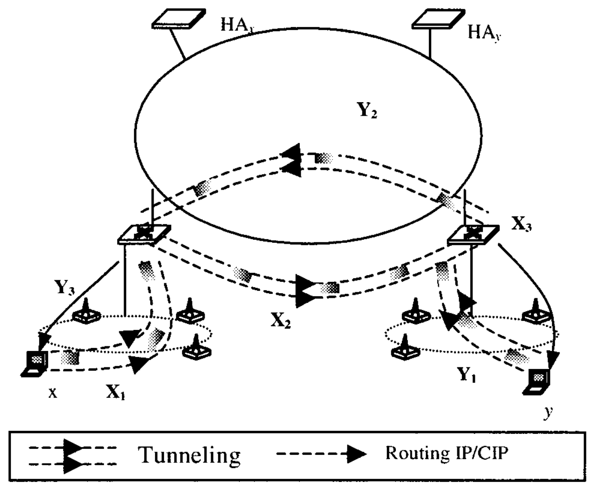

Figure 4: Traffic path between two MS

denoted by X_1, X_2, X_3. The two traffic flows have the same properties. Please note that the optimized routing of two mobile terminals and the IP routing for two fixed terminals is similar.

Since the overload produced by the tunneling is limited to the doubling of the IP header, the protocol efficiency of the pair (CIP_{RO}-MIP_{RO}) is practically equal to the IP protocol efficiency, i.e.:

$$\eta_{CIP_{RO}MIP_{RO}} \cong \frac{1+\alpha_f}{1+\alpha_m}\eta_{IP} \qquad (2)$$

Thus, from (1) and (2) it follows that the introduction of the Mobile IP with routing optimization improves the architecture efficiency for any application utilizing it .

The major advantage of the proposed architecture is that the traffic generated by MS in different access networks at steady conditions is confined to a routing which depends only on the distance between the GW's.

The integration of the CIP_{RO}-MIP_{RO} protocols leads to an architecture similar to the one of the GSM system where the BSC and MSC are the same entity and are represented by the GW/FA side of the cellular IP gateway and by the FA side respectively.

IV. INTER CELLULAR IP (INTER-CIP) HANDOFF

The handoff between two Cellular IP networks, as defined here, means the migration of an active MS between two cells managed by different CIP networks and all the operations associated with it (fig. 5).

Updating the handoff within one cellular IP networks requires, at the most, updating of the full path to the

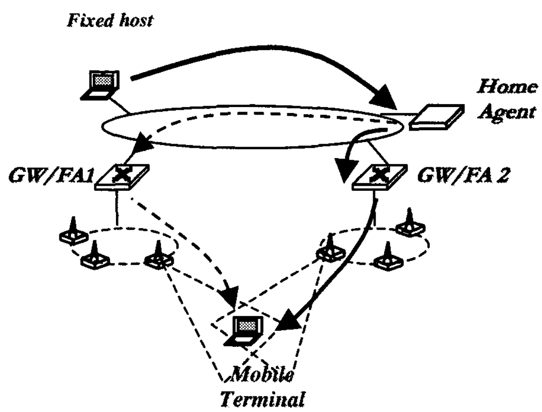

Figure 5: Handoff

gateway. With reference to the subject case, the path update must reach the HA, and the protocol time (time to update the path), ref. [15], is longer.

The protocol time and the bit rate represent the approximate number of lost packets during handoff. A terminal in a handoff state can interrupt transmitting packets but cannot stop routing. That is, the handoff is a procedure that the terminal can partially manage by itself and partially in cooperation with the network. While the routing update within the CIP is performed by the update packets sent by the MS, the rest of the intranet needs additional entities (FA, HA).

The inter-CIP handoff technique uses only four IP packets; however, the execution time could be more lengthy. While the registration path within the CIP is well defined (tree topology), the path between FA and HA is not. Consequently, the packet travel time could be subjected to large variations and network traffic congestions.

The use of this architecture does not assure quality of service (QoS) during the handoff inter-CIP procedure.

The introduction of the routing optimization also improves the performance of the handoff inter-CIP. The handoff CIP_{RO}-MIP_{RO} solution introduces an intermediate "soft state" during which the MS is served by the new BS with a rerouting by the old BS cellular IP gateway (forward handoff) ref. [21].

The "soft state" is an important element for the QoS since it allows the handoff management of the FA's level, resulting in levels close to the Cellular IP.

Macro mobility management can be optimized to plan the gateways' interconnection by analyzing the global configuration of the access networks. The objective is to construct architectures, which manage access networks with bordering cells either physically (MAC) or virtually (VPN) connected. This solution confines most of the macro mobility traffic in the CIP networks. Encapsulated traffic between gateways and update packets does not overload the core network. This results in a flexible architecture for the inter-CIP migration.

V. SEMI-SOFT INTER-CIP HANDOFF

Using the CIP_{RO}/MIP_{RO} pair the gateway can be interpreted as the cross node of the CIP. As a result the semi-soft handoff procedure can be extended to the inter-CIP handoff procedure.

With reference to figure 5, it can be noted that the gateway (GW/FA1) serves the old BS access network (CIP1). The gateway GW/FA2 serves the new BS access network (CIP2). During the inter-CIP handoff, the GW/FA1 continues routing the packets toward the old path (BS1) while it is tunneling the packets toward the CIP2 since it has received a smooth handoff request from the gateway GW/FA2. This allows two paths toward the access network for a limited time, whose duration is function of the mapping cache gateway timeout, and the update time of the transmitting terminal (fixed or mobile) binding cache. At timeout the mapping associated with the MS vanishes and it cannot continue routing within the access network. Moreover, the packets are routed toward the new gateway when the MS binding cache is updated by the HA.

The semi-soft inter-CIP procedure is important because it extends the semi-soft handoff intra-CIP using the smooth handoff of the mobile IP, which generates a model of the forward handoff.

By using this extension the terminal performs similar operations unless it has to communicate the old gateway IP address to the new gateway and it has to request the smooth handoff procedure.

The cellular IP network does not need new operations since all changes are within the macro mobile network, and these changes are managed by the gateways. There is no need to introduce any delay (as it happens in the cellular IP cross nodes) since this delay is generated by the new tunneling operation between gateways.

VI. CONCLUSIONS

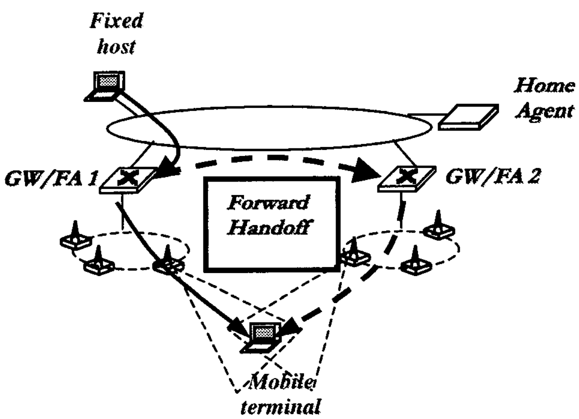

Fig. 6: semisoft handoff extension

This work analyzes two solutions for the management of cellular intranet. The first is an architecture managed with mobile IP (macro mobility) and cellular IP (micro mobility). The second utilizes the mobile IP with routing optimization for macro mobility management.

In the first solution (CIP-MIP) the architecture is centralized on the gateway and the home agent. It is most suited for security needs and client/server traffic models.

In the second solution (CIP_{RO}-MIP_{RO}) the cellular intranet is oriented toward QoS since it offers optimized routing and it speeds-up the handoff procedures. It also extends the semi-soft handoff. This system may support real time traffic and could be a first step towards future work on the organization of an IP architecture for cellular wireless communication.

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