Seamless Multimedia Services Over All-IP Based Infrastructures: The EVOLUTE Approach

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ABSTRACT

The increasing amount of roaming Internet users in combination with the evolution of IP-based applications has created a strong demand for wide-area, broadband access to a number of IP multimedia services. Wireless LANs can complement the next-generation cellular networks, by offering a cost-efficient, wireless broadband data solution for hot spot areas. By combining the wide coverage of next-generation cellular systems with the speed and capacity advantages of wireless LANs, users can make the most out of wireless IP communication. Towards this direction, IST project EVOLUTE implements an all IP network infrastructure aiming to provide seamless multimedia services to roaming users. EVOLUTE addresses and attempts to resolve issues, such as, multilayer mobility management, vertical handoffs, fast and scalable Authentication-Authorization-Accounting (AAA) mechanisms, and ubiquitous service provisioning among heterogeneous environments. User trials have been defined and VoIP applications have been selected among others, to test and validate the capabilities of the EVOLUTE architecture.

I. INTRODUCTION

Today two major technological forces drive the telecommunication era: the wireless cellular systems and the Internet. As these forces converge, the demand for new services, increasing bandwidth and ubiquitous connectivity continuously grows. The next-generation mobile systems will be based solely, (or in a large extent), on IP protocol.

EVOLUTE explores some of the trends driving these developments and investigates their impact on the provisioning of real-time and non-real-time multimedia services, such as, mobile telephony, multimedia conferencing, or mobile web access in ubiquitous environments. The objective is to offer seamless multimedia services to users who access an all-IP infrastructure via a variety of heterogeneous access technologies, meeting the demands of both enterprise and public environments anywhere and anytime. A key role of IP in next-generation mobile systems will be the efficient and cost-effective interworking between overlay networks for the seamless provisioning of current and future applications and services. IP is assumed to act as an adhesive to provide global connectivity, mobility among networks, and a common platform for service provisioning across different types of access networks.

For the next generation networks, such as, all-IP networks and beyond, to make the transition from the vision and idea stage to reality, they need to be based on solid technological and economical basis. To provide for such a basis at least the three following aspects need to be considered:

1. Support for mobile communication not only in terms of terminal mobility, as is currently the case, but also for session, service and personal mobility. Further this mobility must be available over heterogeneous networks such as UMTS, WLANs, as well as, fixed networks.
2. Integration of simple yet efficient AAA mechanisms with the service architecture. Without such integration providers will not have the necessary means to control their provided services and make revenue from the users.
3. Support of flexible yet powerful service creation architectures. Next generation networks will not only distinguish themselves from current network through higher bandwidth rates but through a wider range of services. Such a variety of services can only be realised by using distributed and simple to use and enhance service creation paradigms.

EVOLUTE investigates issues such as, multilayer mobility management, vertical handoffs among heterogeneous access networks (UMTS and WLANs), deployment of AAA functions for fast access granting, ubiquitous service provisioning and seamless roaming in different environment (indoor/outdoor) and intelligent and personalised multimedia services. EVOLUTE architecture is illustrated in Figure 1.

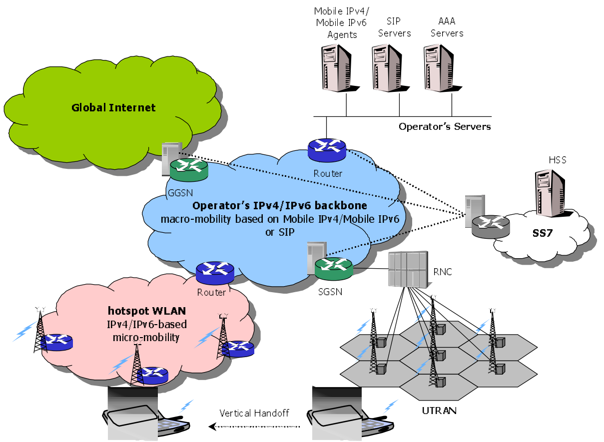

Figure 1: EVOLUTE architecture

II. SYSTEM OVERVIEW

Motivated by the necessity to provide seamless multimedia services to users while they are moving across the globe, EVOLUTE focuses on a completely IP-centric approach that is anticipated to further drive the notion of constituting IP the dominant transport technology of the future. On this basis, EVOLUTE tackles the following research issues:

A. Multilayer mobility management

Currently the IETF standardizes the Mobile IP protocol in order to support dynamic mobility between Internet domains for mobile hosts. There are two variations of Mobile IP, applicable to IPv4 [1] and IPv6 [2] networks respectively.

Mobile IP provides roaming capability to users by utilising agents in each domain. When a mobile host visits a foreign network, a temporary address (care-of address) is given to the host. This is used to receive IP traffic in the foreign domain. An agent in each foreign network, (the foreign agent) handles the registration of visiting hosts. Registration is accomplished by using an agent that resides in the host's home domain (the home agent). This binds the users' real IP address with the temporary IP care-of address. Any traffic bound for the roaming host is then forwarded by the home agent to the correct foreign network. A route optimisation option for Mobile IP [3] allows roaming hosts and corresponding IP hosts to bypass the home agent.

A new version of the Internet Protocol, version 6 has been standardised which gives mobility advantages. Most notably, a foreign agent is no longer needed since the reason that exists in Mobile IP is to reduce the number of extra IP addresses needed to support routing in the foreign domain. Specifically, with foreign agent care-of addressing, every mobile host connected to a single foreign agent uses the foreign agent's address for it's own care-of address. With Mobile IPv6 address space is no longer an issue, so the use of the foreign agent is eliminated and packets are always directly tunnelled to the mobile host. Furthermore, route optimisation rather than being an option in Mobile IPv6, is built into the protocol itself.

However, Mobile IP is not sufficient for real-time connections because it incurs high jitter, long latency and disruptive handoffs. Mobile IP with route optimization solves these problems at the price of changing the protocol stack of each correspondent host. However, by having an application level protocol like SIP handling mobility, gives more flexibility, and likely jitter and handoff latency is reduced. The Session Initiation Protocol (SIP) [4] is an emerging protocol, designed to provide basic call control and application-layer signaling for voice and multimedia sessions in a packet-switched network. Several wireless technical forums (e.g., 3GPP, 3GPP2, MWIF) have agreed upon SIP utilization to provide session management and means of personal, as well as, service mobility. Moreover SIP extensions have been proposed to extend the protocol in order to support terminal mobility [5], alleviating some of the shortcomings associated with Mobile IP and its route optimization variants. However, this approach applies only for real-time communications over UDP, as it breaks TCP connections. Therefore the best solution would be a hybrid scheme (SIP for real-time and Mobile IP for non-real-time mobile communications) based on a policy table. Supporting terminal mobility for TCP with SIP [6], requires a tracking agent on the mobile host to maintain a record of its ongoing TCP connections, as well as, IP encapsulation capabilities on each correspondent host.

Although Mobile IP and SIP could work complementary as mentioned above to support inter-domain mobility (mobility across administrative domains), they are both unsuitable for handling intra-domain mobility (micro-mobility). With the advent of WLAN and IP-based cellular networks, high mobility within a single domain or Intranet is becoming common. Therefore, a solution is needed to allow hosts to move between wireless access points, or base stations without informing the distant home agent or redirect server for every movement, while keeping connections, performing handoffs and allowing idle movement. The intra-domain mobility problem, being local to each domain, is being solved in many research fronts. It is foreseeable that multiple standardised options will be available in the future, rather than the Internet wide Mobile IP. Currently researched protocols, being a research issue of EVOLUTE, include Hierarchical Mobile IP [7] and Hierarchical Mobile IPv6 [8], HAWAII [9], Cellular IP [10] and Cellular IPv6 [11]. Furthermore, the seamoby IETF working group is working towards the development of a solution that will support basic routing to mobile hosts, IP paging, soft handoff, quality of service and context transfer capabilities.

EVOLUTE proposes a domain-based approach to support transparent Internet mobility by integrating the powerful features of various protocols operating in different layers. This composite, multilayer mobility management scheme utilises network layer solutions to support fast handoff and paging within an administrative domain, while wide-area mobility is supported by a hybrid scheme based on the interworking of Mobile IP with SIP.

B. *AAA services*

The support of wireless data services has become increasingly challenging to many wireless operators, whether they have implemented a 2G, GPRS, 2.5G, or 3G UMTS infrastructure. An AAA server is an important component of the wireless infrastructure that not only handles the critical task of authenticating wireless users onto the network, but plays also a key role in wireless operators' ability to offer differentiated products and to bill incrementally for these services. An AAA server plays the following key roles in a 3G environment:

1. *Authentication*. Authentication is the process of identifying a user attempting to access a network through a network access server. Typically this is accomplished based on the user's established credentials, which may include user identification number, handset serial number, username, or password. To authenticate a wireless user, an AAA server must match the user's credentials with credentials stored in a database or directory residing on the wireless provider's network.
2. *Interworking with the mobility management protocols.* Once the wireless user is authenticated to the foreign domain, the local AAA server (AAAF) must interwork with the mobility agents in order to assign a care-of IP address to the roaming user [12]. This address functions as the user's identity on the Internet and is maintained for the length of the Internet session. Maintaining the IP address poses a special challenge, given the user may be moving within a network or roaming between provider networks.
3. *Interworking with SIP servers.* This work is still in progress in various groups including the IETF SIP WG and 3GPP SDOs. EVOLUTE will investigate the interworking of SIP REGISTER and INVITE methods with the AAA functionality.
4. *Service delivery*. The AAA server must also determine, deliver, and enforce the level of service granted to the wireless user. It does this by 1) authorizing the user to access certain resources on the network, and even set restrictions (i.e., time-of-day, maximum bandwidth, timeout lengths); and 2) sending connection information to other devices on the network, such as WAP gateways, that can deliver any personalized content to which the user is entitled.
5. *Accounting.* Finally, the AAA server must log all remote access activity, in a format that the wireless provider's billing, provisioning, and customer care systems can handle.

Next-generation mobile networks are a huge opportunity for the wireless service providers. To ensure the fastest and highest return on their infrastructure investment, an AAA infrastructure is required, that combines the necessary authentication, Mobile IP, service delivery and accounting technology with the raw performance, ease of integration, manageability and scalability.

C. *AAA handover scenarios*

We can distinguish the following AAA handover scenarios:

1. *Authentication for media access.* This involves actually giving the user the permission to connect to some network. A provider supporting networks with different technologies might have to choose among one of the following scenarios:
    - Choose one AAA technology for all network technologies.
    - Support different technologies and integrate them in one way or the other.

    Moving from one network to the other might trigger AAA actions that might cross the boundaries of the AAA technologies of each network.
2. *Authentication for service access.* This involves giving the user the permission to use some services (e.g., update a SIP registration or change a CPL script). With the differentiation between media access provider and service provider we have further two scenarios:
    - A user wishing to get access to the network and use some services needs to authenticate himself with two entities (the network provider and the service provider).
    - Only one entity is providing both service and media. In this case this entity needs to couple the media usage with the service usage.

D. *Multimedia service provisioning*

Currently services are provided in the telecommunication networks in a so-called walled garden attitude. That is the services are provided in a vendor specific manner and are managed and extended only by the network provider and its vendors. This way of providing services prevents independent entities from providing innovative services and due to the propriety manner of providing and creating new services, providing innovative services is time consuming and complicated.

Using SIP in an all-IP networks allows for a separation between network and service providers. Through the provisioning of well-defined application programming interfaces, such as, SIP JAIN or PARLAY, independent providers (third parties) can offer their own SIP services. As these APIs are well-defined and already wide spread, there is a significant level of experience in providing new applications for such an environment. Traditional network providers can also provide SIP services by utilizing the same APIs. By combining the service creation possibilities of SIP, such providers could have the advantage of providing innovative value-added services to the end-users.

SIP can be considered as a key technology in Next Generation Networks. Furthermore, the SIP architecture allows for distributing the service intelligence between the end devices and the service provider. Parts of the service logic can be created by using a scripting language such as the Call Processing Language (CPL) for determining the rules for call handling [13]. Such rules can then be managed and executed by either the SIP proxies or the end devices.

In the context of EVOLUTE the aspects of service creation using SIP will be investigated and the integration of SIP service components with AAA and mobility components will be discussed. The aspects of secure service provisioning and protection of provider's resources will be of utmost importance. Through the interaction of the SIP signaling and AAA it would be possible for the service provider to determine the eligibility of a user to use a specific service and the collect necessary information for enabling different methods of charging. Further, the interaction between different service providers will be investigated so as to allow a user to utilize the SIP service components from one provider and possible gateways and connections to other networks from another provider in a transparent manner.

E. VoIP services in a mobile environment

The interaction and harmonization of Mobile IP with VoIP signaling schemes requires further study, in order to determine the best approach of combining the salient features of Mobile IP terminal mobility with the corresponding SIP terminal mobility features. This necessitates spoof constant endpoints for TCP connections and support TCP as is without any modifications and require applications that use RTP to accept packets with same synchronisation source but different IP address.

One other important issue regards the alternatives regarding user's registration at the network and verification of services that the user is entitled to. There are several alternatives. As a first option, the user employs Mobile IP to register with the network and then uses the SIP REGISTER option to register with a SIP registar that provides location service as well. Another alternative is the use of SIP REGISTER method and possible interactions of SIP registrars of different domains through the AAA entities of the home and visited networks to verify a user's identity and rights and grant or deny the registration.

The 3G radio access supports a handoff procedure which allows a mobile terminal to receive and accept signals from both new and old associated base stations simultaneously during the handoff period. In order to utilise this feature, the macro and micro mobility scheme must emulate a virtual soft handoff at the IP layer via forwarding the session's packets to the old as well as the new location of the soft handoff procedure. Accordingly, SIP must be extended so that an on-going session must be transferred to the new location of the mobile terminal and the old location is dropped after a limited period of time.

SIP can be also used to provide means of personal and service mobility in a mobile Internet environment:

1. The first approach assumes that call states are maintained and stored within the network and the home network always controls calls and services of its subscribers. In order to support service mobility, end users always register with their home networks. In this scenario, the call state is stored in stateful proxies within the network. The mobile terminal registers with the home network that always controls the calls and provides all services to the mobile terminal regardless of its current location. A key open issue that needs further study is how a mobile terminal discovers its home registrar while it is in a visited network.

2. In the second approach, the mobile terminal always registers with a local registrar in the visited network. The control of ongoing sessions is transferred to the visited network upon roaming, and the visited network also controls new sessions of the visiting users. Additionally, in this scenario:

   - Both home and visited networks share identical agreed upon private keys for call state encryption.

   - An encrypted and signed copy of the user's registration with the home registration is stored in the mobile terminal.

The call states of ongoing sessions are encrypted, signed and maintained in the mobile terminal.

III. WLANs in next-generation cellular networks

There are different scenarios towards the integration of WLANs with next-generation cellular networks:

1. *Open Coupling*. In this scenario (Figure 2), an open standard is used for access and roaming. No specific WLAN access is required and a separate authentication procedure is used from the WLAN network.

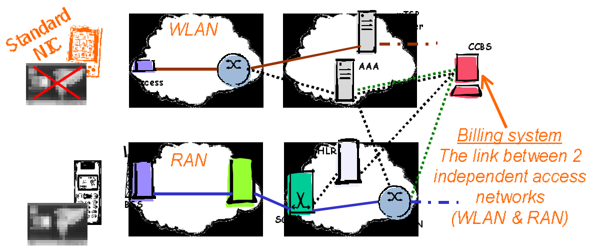

Figure 2: Open Coupling scenario

2. *Loose Coupling.* In this scenario (Figure 3), no specific WLAN access network is required. There is a common customer database and authentication procedure. The AAA-HLR link requires standardisation (i.e. Radius/DIAMETER to MAP translation).

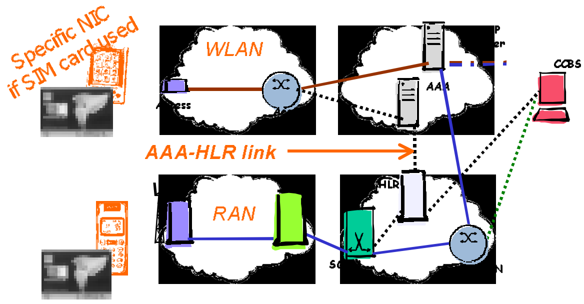

Figure 3: Loose Coupling scenario

3. *Tight Coupling.* The key characteristics of this scenario (Figure 4) includes seamless handover between 3G and WLANs, as well as, WLAN access similar to UTRAN (3GPP radio protocols). As an effect, this approach requires additional standardisation versus loose coupling.

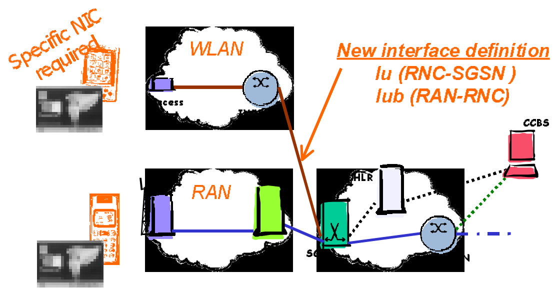

Figure 4: Tight Coupling scenario

4. *Very Tight Coupling.* This scenario (Figure 5) is quite similar comparing to the previous one, regarding the seamless handover. However, WLANs can be viewed as a cell managed at the RNC level.

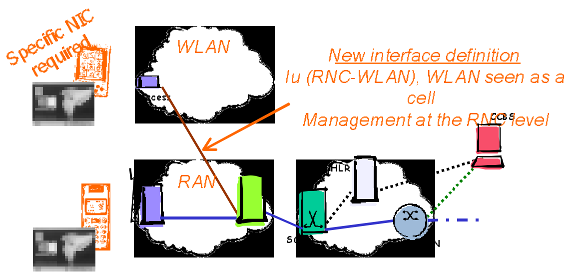

Figure 5: Very Tight Coupling scenario

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