ROAMING ISSUES FOR SERVICE PROVISIONING OVER 3RD GENERATION MOBILE NETWORKS

S. Panagiotakis[1], E. Gazis[1], M. Koutsopoulou[1], N. Houssos[1], Z. Boufidis[1], A. Alonistioti[1]
[1]Department of Informatics and Telecommunications, University of Athens,
TYPA Buildings, Panepistimioupolis, Ilisia, 157 84 Athens, Greece,
e-mails:{spanag, gazis, mkoutsop, nhoussos, boufidis, nancy}@di.uoa.gr

ABSTRACT

3rd generation systems such as UMTS will support the enrichment of the traditional service provision schemes via partnering of mobile network operators with other players in the marketplace, such as value added service providers and content providers. These partnerships will raise the bar on service provision requirements as well as roaming configurations. Roaming requirements for future mobile telecommunication networks suggest that the user of the mobile terminal should be readily able to discover and select any of the applicable services within the combined capabilities of the mobile terminal and the network infrastructure, independent of the network he has currently been registered. The present contribution attempts to address the challenging issue of roaming in the 3rd generation mobile telecommunication systems, as well as to underline the technical requirements that a Release 99 UMTS platform have to fulfil so that generic service portability across networks can be achieved.

1 INTRODUCTION

3rd generation systems such as UMTS will support the enrichment of the service provision with additional value, which will be contributed by market players other than the mobile network operator. These players will typically come in the form of value added service providers (VASPs), content providers and content aggregators, to name but a few. Each of these players will compete with the mobile network operator for a portion of the user revenue. To sustain a line of business, the mobile network operator will have to take up the new business opportunities via partnering with the other players in the marketplace, such as VASPs and content providers

These partnerships will raise the bar on service provision requirements as well as roaming configurations. Roaming requirements for future mobile telecommunication networks suggest that the user of the mobile terminal should be readily able to discover and select any of the applicable services (i.e. within the combined capabilities of the mobile terminal and the network infrastructure) [1], [5]. The VHE [2] concept further underlines the aforementioned requirement by stating that the user should experience the same “look and feel” while enjoying service availability “anywhere, anytime, anyplace”. From a functional point of view, roaming is an issue that involves a number of important service provision aspects:

- Technical and business oriented relationships between network infrastructure operators and service providers regarding access by the latter to capabilities from the network
- Automatic network detection and selection
- Authentication procedures between the mobile terminal and the visited network as well as between the user and the visited service provision platform
- Authorization of access, i.e. “right to use”, to the visited network infrastructure
- Automatic discovery and selection of service platform
- Service invocation procedures, i.e. authentication, authorization, etc.

The present contribution attempts to address the challenging issue of roaming in the 3rd generation mobile systems, as well as to underline the technical requirements that have to be fulfilled from a Release 99 UMTS platform [3], [4] so that generic service portability across networks can be achieved. Proposed solutions and aspects have been studied within the scope of the IST project MOBIVAS [6].

2 UMTS NETWORK ROAMING CAPABILITIES

In UMTS architecture [3], [4] two kinds of backbone networks are defined:

- the intra-PLMN backbone network, which is the IP network interconnecting GSNs within the same PLMN through the Gn interface, and
- the inter-PLMN backbone network, which is the IP network interconnecting GSNs and intra-PLMN backbone networks in different PLMNs. When SGSN (Serving GPRS Support node) and GGSN (Gateway GPRS Support node) are in

different PLMNs, they are interconnected via the Gp interface. The Gp interface provides the functionality of the Gn interface, plus security functionality required for inter-PLMN communication.

Figure 1 illustrates the Intra- and Inter-PLMN Backbone Networks.

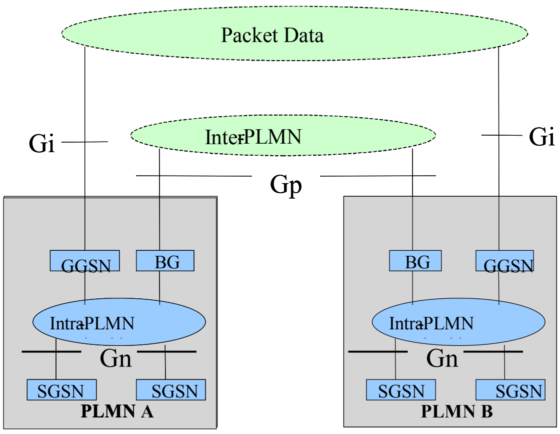

Figure 1. The Inter- and Intra- PLMN backbone networks

Two intra-PLMN backbone networks are connected via the Gp interface using Border Gateways (BGs) and an inter-PLMN backbone network. The inter-PLMN backbone network is characterised by a roaming agreement that includes the BG security functionality. The BG is not defined within the scope of the packet domain. The inter-PLMN backbone can be a Packet Data Network, e.g., the public Internet, or a leased line.

The UMTS packet transport service abstracts the entire UMTS network infrastructure as a virtual link that terminates at a GGSN, a switch interconnecting the PLMN with external IP networks [4]. When a mobile terminal requests the activation of a packet transport service from a UMTS network, the network selects a GGSN to serve the request and establishes a virtual link to that GGSN. From an external IP network's point of view, the entire UMTS network is seen as a single IP access network with the GGSN acting as a first hop router. As the user moves around, the network dynamically reestablishes this virtual link to track the current location of the mobile terminal. However, the overall concatenated virtual link remains anchored at the originally selected GGSN.

For roaming users, this virtual link is established over the inter-PLMN backbone network, interconnecting different UMTS core networks. To be more specific, with UMTS (or GPRS) roaming, we mean roaming via the Gp interface and the use of a GGSN in the home network, which is necessary when the visited network does not offer its GGSN to visiting users. However, in those cases where the visited network offers such a convenience, either a GGSN in the visited or in the home network can be utilized, providing thus GPRS roaming to visiting users by deploying the Gn and Gp interfaces respectively.

The GGSN selection criteria, in general, depend heavily on two parameters: the APN (Access Point Name), essentially an identifier for a specific external data network a GGSN is connected to, that is provided from the mobile terminal to the serving SGSN upon the PDP context activation procedure, and the VPAA (VPLMN Address Allowed) flag. The latter is included among the information kept in the HLR' s PDP context subscription records for each subscriber of an operator and determines whether the subscriber is allowed to use the visited network's GGSNs for accessing external PDNs or not. In case VPAA has been set to YES the subscriber is allowed to use a GGSN not only in the domain of the Home PLMN (HPLMN), but additionally in the domain of the Visited PLMN (VPLMN).

Whenever a user requests connectivity with a specific APN using logical names as addresses, the mapping of those logical names to IP addresses in the UMTS intra- and inter-PLMN backbone networks is accomplished through the DNS (Domain Name System) functionality of those networks. The DNS has the ability to map APNs to GGSN IP addresses. Each SGSN has access to the inter- and intra- PLMN backbone's DNS functionality to be able to address GGSNs.

If the requested APN in a PDP context activation request specifies only the Network identifier part of the APN (which means that it does not specify the operator identifier) [4], the PDP context is established with a GGSN of the serving network, assuming VPAA has been set to YES. The exception to that is a network identifier that cannot be found in the visited network. If that holds, a GGSN in the home network providing that service is sought, independently what the value of the VPAA flag is. Example APNs of that type include those comprised by a single label (e.g. "vasm"), which represent a service provided by specific GGSNs. Another VPAA-independent case is that of a PDP context activation request that specifies a full APN (that is of type "network_ identifier.operator_identifier"). Full APNs designate, additionally, the operator network, a GGSN of which the user wishes to provide him access to external PDNs.

Issues pertaining to the establishment of that virtual link with the assigned GGSN are determined, apart from the user subscription with the UMTS network, by the network configuration and inter-operator business and technical roaming agreements as well. However, although these agreements concern solely the packet transport service of UMTS, as well as access permissions to particular resources of the visited network, they greatly affect relationships between service providers and network operators regarding service provision to roaming users. Consequently, for operators wishing to provide differentiated service offerings via intelligent service provision platforms for IP based services, roaming issues are of paramount importance. Roaming and user subscription details may render an artificial reduction on the set of available (discovered) service platforms, thus providing a mechanism for “steering” users towards a specific operator’s service provision platform. To support efficient service discovery mechanisms and seamless provision schemes, these issues must be taken into account when designing service provision architectures for 3G networks.

3 THE MOBIVAS SERVICE PLATFORM FOR INTELLIGENT SERVICE PROVISION

The MOBIVAS project [6] focuses on the introduction of an integrated software reconfigurable platform for the dynamic and personalized Value Added Services (VAS) discovery and provision to mobile users, while enables service provision across networks. Subscribers of a MOBIVAS platform, while roam outside their home network, shall be able to discover and execute services that have been registered not only in their Home platform but also in each visited MOBIVAS network. Figure 2 presents an UMTS network architecture enhanced with such a service provision platform.

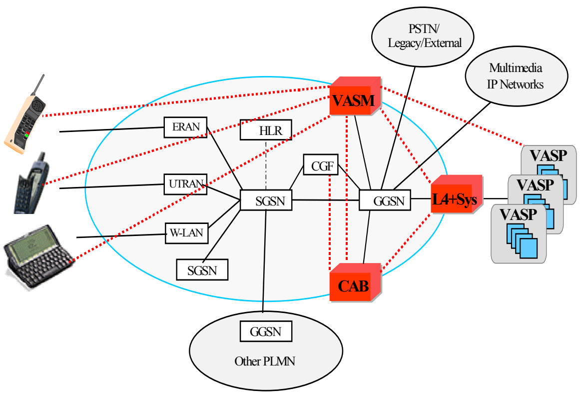

Figure 2. MOBIVAS-enhanced UMTS Release 99 network architecture for VAS provision

The MOBIVAS VAS provision paradigm consists of three basic entities: the mobile user, the Network Operator (NO), and the VASPs, which offer their services by connecting their network infrastructure to the network operator (Figure 1). The user maintains a subscription with the operator and has access to the services offered by the operator and its contracted VASPs. Thus, business level agreements exist only between user-NO and NO-VASP. There is no need for direct agreement between user and VASP. There is still, of course, the possibility of a direct business agreement between mobile subscriber and VASP, but this is totally transparent to the platform.

In addition to existing access and core network components, additional software modules are introduced, such as the Value-Added Service Manager (VASM), the Charging-Accounting and Billing (CAB) system and the L4+ systems (L4+Sys).

The VASM [7] is typically hosted in an IP network node outside the core UMTS network of the operator and is responsible for the management of value-added services (VAS) and of a database containing VAS-related data, named VAS DB. Since services should be registered in the VAS DB before they can be made available to mobile users, service registration is dynamically performed by the corresponding VASPs. Service related records in the VAS database hold information including VAS network location, VASP identity, minimum terminal feature requirements for running the service and service tariffs. The VASM is then able to provide the subscribers with the ability to discover the available services and choose the ones they desire to use. This is accomplished through a service discovery user interface, which, at a minimum, offers the users options such as viewing listings of the registered services, classified in subject categories, performing keyword-based searches for VAS and accessing the user’s “favorite” services. The list of the requested services is presented to the user after filtering the VAS DB records according to the current terminal capabilities, the user location and the user preferences specified in his user profile. Each VAS in such a list is associated with a short description and indicative tariffing information.

Adaptation to terminal capabilities is required, since a subscriber may access the network from different terminals with highly varying characteristics. To this end, a universal, flexible format for representing terminal capabilities, as well as an efficient, interoperable way for their announcement to the serving VASM is introduced [8][9][10]. Furthermore, by maintaining a user profile for each subscriber customization of service provision according to the personal, generic user preferences is achieved.

The Layer 4+ system [11] uses transport layer information, e.g. TCP or UDP port numbers, to forward packets. This allows collecting additional information about source and/or destination of a data frame, so that apart from the destination machine, the type of program transmitting and receiving the data units via well-known ports can also be determined. In the proposed architecture the L4+Sys device is located at the border between the VAS provider network and the operator network so that all traffic from the VASPs towards the users passes through the L4+Sys. The VAS manager configures the L4+Sys with information on how to classify IP traffic flows and on the services whose usage should be monitored. The L4+Sys examines all arriving packets in order to give each one an appropriate treatment. The aim of L4+ detection is to filter traffic entering the operator‘s network, to support for billing and charging, and to support QoS provisioning. The L4+Sys collects the information about source and destination of data packets, the application and the amount of payload. This information is subsequently formatted into VAS Detail Records (VASDRs) and sent to the CAB system, which has the responsibility to calculate the total charges for network and service usage.

The CAB system deals with the charging, billing and accounting operations induced by the service downloading and access procedures. The proposed approach breaks the cost of a VAS-usage related chargeable event into two parts [12]. The transport part, which is the basic, VAS - independent charge for the allocation and usage of the resources provided by the mobile operator and the service part, which is a premium rate, VAS specific, charge for use of services provided by a VAS provider. The CAB calculates the service part of the charge using the VASDRs received from the L4+Sys, while, the information provided by the operator for the usage of its network resources is used for calculation of the transport part of the charge. These processes take place at the Billing component, while the Accounting component apportions that revenue among the home operator and the other parties (visiting operators, VAS providers). The charging process for a specific VAS session is initiated after the execution of a service in the terminal has begun.

3 ROAMING SCENARIOS

3.1 General requirements

Admittedly, an ideal service discovery mechanism should provide users with a means to discover all the value-added services that are applicable to their current status, i.e. terminal capabilities, user preferences, location, access network, etc. That implies a distributed signaling mechanism that is capable of interacting with the home and visited network infrastructures for the execution of intelligently formulated queries. The approach adopted in the proposed platform provides such a mechanism for intelligent and seamless service discovery and provision that builds on the capabilities of the UMTS network to provide a single point of entry for roaming users. More specifically, the proposed architecture is able to provide VAS access to roaming users even if the VAS provision platform is not installed in the visited network.

In the following, two cases are separately examined:

i) The case where the serving operator does not support the proposed VAS provision platform (section 3.1).

ii) The case where the serving operator supports the proposed VAS provision platform (section 3.2).

In both cases it is assumed that when the user switches on his mobile phone outside the coverage area of its home operator, an appropriate serving network is found using standard signaling interactions and a serving VASM is discovered (either in home or visited network). A business level agreement should exist between the home and serving operators for providing data transport services to roaming users, along with the ability to discover and execute services in both home and visited networks.

The proposed solution requires from the MOBIVAS operators to:

- register in the name list of the DNS servers that serve the mobile terminals the following labels corresponding to the VASM IP address(es):
    - "vasm"
    - "vasm.operator_FQ_domain_name", where operator_FQ_domain_name is the fully-qualified domain name of the home operator, typically registered with the public Internet DNS system.

  To communicate with the (home or visited) VASM and activate the associated PDP context, a mobile terminal shall retrieve the appropriate IP address through a standard DNS query, using one of the labels above.
- set for all MOBIVAS subscribers the VPAA flag in their HLR' s PDP context subscription records to YES so that roaming users are allowed to contact and use the visited network's service platform (if any).
- permit other MOBIVAS operators and their contracted service providers to access their network resources (databases, open interfaces, location servers, etc.) so that users are able to select and execute desired services of either home or serving MOBIVAS platform.

Moreover, connectivity of the home and serving PLMNs via the inter-PLMN backbone network is required to enable access to home VASs over the home GGSN and L4+ systems. The latter is necessary for the collection of charging information. The technical and business level issues that have to be negotiated between operators so that agreement on aforementioned connectivity is achieved, include:

- The configuration of the Border Gateways as far as the Border Gateway protocol that will be used and the exchange of authentication and ciphering information are concerned.
- Agreement on the billing policy for roaming users, as well as on whether the exchange of billing info shall take place directly or via some clearing house.
- The proper configuration of DNS systems with appropriate mappings for addresses and single labels.
- The all-GSM configurations, such as the mapping of IMSI user identifiers to specific HLR addresses.

In both roaming scenarios the user shall be charged for VASs usage and the resulting revenue shall be apportioned between the involved VASP and the home and serving network operators [13]. In any case, the user shall receive a single bill from its home operator, which additionally shall include the charges for service usage while he was roaming. The following technical issues are crucial for this to be achieved:

- All VAS usage traffic between the MS and the VASP should be transited via the network to which the VAS is registered. That is, access to a VAS available from an operator's network (home or visited) should be realised via a GGSN in the same (home or visited) network, so that all traffic between the MS and the VASP is transited by the appropriate (home or visited network) L4+systems. The latter are configured to monitor all flows related to usage of VAS registered with a specific operator and produce usage records necessary for user billing. If this rule does not hold, e.g. access to a home operator VAS is performed via a GGSN and L4+ system of the serving network, VAS usage traffic will not be tracked and the user will not be billed for VAS usage.
- Data related to VAS usage and user charges should be exchanged between operators. This data should be encoded in a common format, so that the receiving operator is able to correctly recognise and process it. The use of a format based on the TAP 3 specification with the necessary enhancements for VAS billing is suggested.

It is noted, however, that VAS access from roaming users shall not be possible without the existence of the aforementioned transport and business level agreements.

3.2 Roaming to a non-MOBIVAS network

In case the user roams to a visited UMTS network which does not provide a MOBIVAS platform, the MT should only communicate with the VAS Manager of its home operator to obtain a personalised listing of applicable VASs (Figure 3). This can easily be achieved, if the terminal issues a PDP context activation request message with the reserved label "vasm" in the APN parameter's field.
More specifically, in such cases the PDP context activation procedures of UMTS play a critical role in establishing a communication session between a mobile terminal and an external node. The standard GGSN selection procedures of UMTS ensure that whenever an appropriate GGSN in the visited network cannot be used, a GGSN in the home network will be employed to serve the request [4]. This is achieved through the use of the inter-PLMN IP backbone network and the corresponding, properly configured, DNS system. In the proposed scenario, each time the user attempts to connect to the VAS provision platform, the reserved label "vasm" will be provided by the mobile terminal as the APN parameter of the PDP context activation request of standard UMTS signalling. Hence, when the mobile terminal roams to a UMTS network that does not provide a MOBIVAS platform, its request is redirected towards the home UMTS network of the roaming user (Figure 3, route 1). This is due to the fact that the visited UMTS network is incapable of selecting any of its GGSNs to serve a PDP context activation request with the label "vasm" as APN.

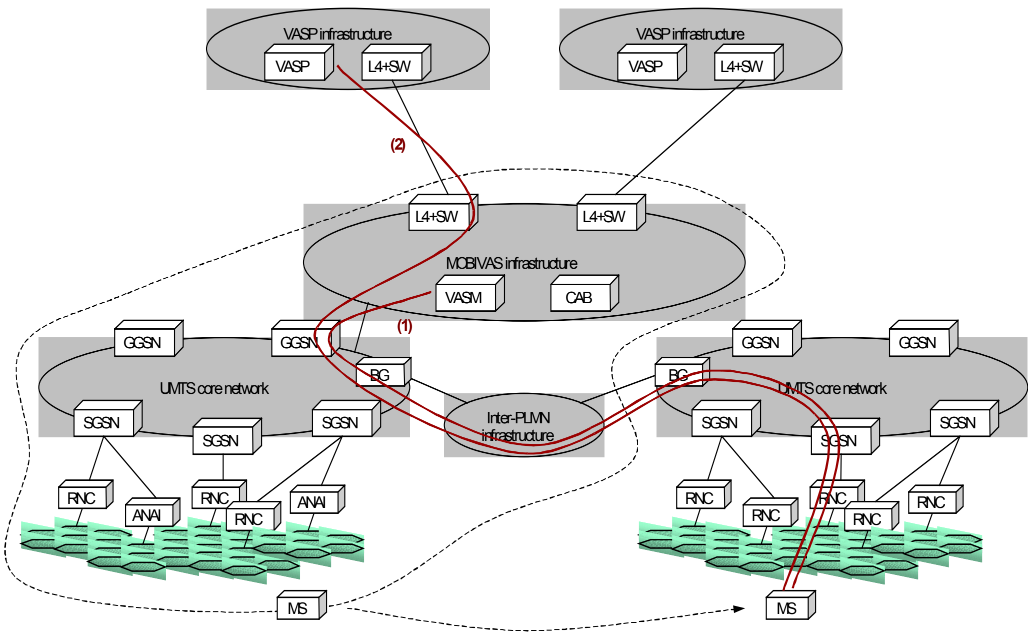

Figure 3. Roaming to a non-MOBIVAS UMTS infrastructure

The underlying assumption is that the UMTS DNS server(s) of the home operator, similarly to any MOBIVAS operator's UMTS DNS servers, are configured to translate the reserved label "vasm" to the IP address of a GGSN that provides connectivity with the VASM. In such a case the interactions that take place are independent of the value of the VPAA flag in the subscriber's profile, since the visited network is incapable of locating a GGSN within its borders to serve the requesting user.

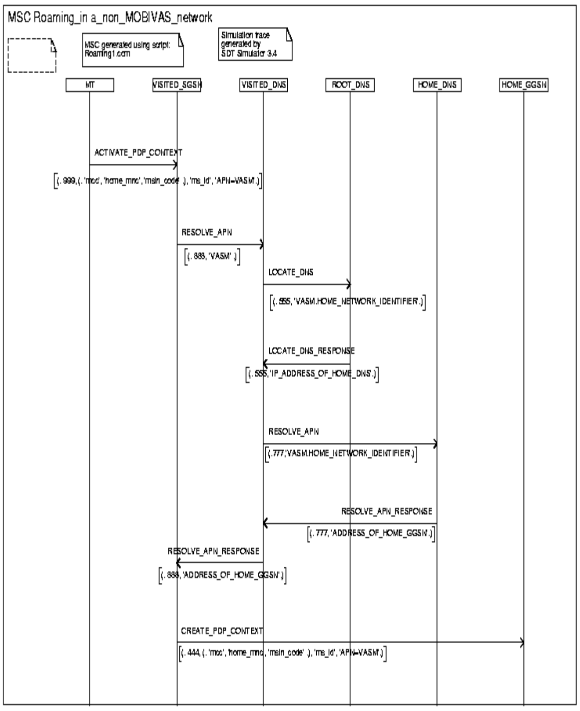

Figure 4. MSC with the interactions regarding "vasm"-label resolution in a non-MOBIVAS visited network

Figure 4 illustrates the steps that take place upon PDP Context Activation with VASM, so that the APN "vasm" is resolved and associated with a GGSN in the home network. In more detail, the interactions that take place are:

1. The visiting user requests the activation of a PDP context specifying label "vasm" as APN.
2. The visited SGSN asks the visited DNS for the GGSN IP address using APN as the key.
3. Since the visited DNS is incapable of resolving the label "vasm" it asks the GPRS root DNS: "which DNS knows the IP address for this name?"
4. The GPRS root DNS replies with the address of the home DNS System to the visited DNS.
5. The visited DNS asks the home DNS for GGSN address.
6. The home DNS resolves the requesting label and replies with the GGSN IP address.
7. The visited DNS replies to the visited SGSN.
8. The visited SGSN creates a PDP context with the home GGSN via the Gp interface.

Since, in this case, the user may access only VASs available from its home MOBIVAS platform, it is important that VAS access is performed only via GGSNs of the home network for charging reasons (see section 3.1). Thus, the terminal should create a PDP context with an appropriate home network's GGSN for accessing a home VAS (Figure 3, route 2). To this end, the corresponding PDP context activation request should specify a full APN indicating the home operator of requesting user. The information on whether a VAS is registered with the home or visited operator is contained in the received Service listing presented to the user by the home VASM.

As far as charging for network and VAS usage is concerned, the interactions that take place [1] between home and visited network are:

- The records that concern the allocation and usage of network resources are generated by both home and visited network. The home network's CAB module combines this information to incorporate the total transport charge in the user's bill.
- The home network's CAB module bills the user for VAS usage based on the VASDRs received by the L4+ systems of the home network and the respective tariffs.
- Finally, the home CAB calculates the revenue that is due to the VAS provider for the usage of its VAS, as well as the revenue that is due to the visiting network operator for the consumption of its resources.

As prerequisites for this scenario to work are the aforementioned in section 3.1 business and transport level agreements between home and serving operators for providing data transport services, as well as connectivity of the home and serving PLMNs via the inter-PLMN backbone network, to have been established. These agreements must provide home MOBIVAS operator and its contracted service providers with access to the visited network resources, so that users are able to select and execute services of either home or serving MOBIVAS platform.

3.3 Roaming to a MOBIVAS network

In case of roaming to a visited UMTS network where a MOBIVAS platform is provided/supported (Figure 5) by default the mobile terminal communicates initially with the VASM of the serving network, which provides users with access to both the VASs in the serving and the home MOBIVAS platform.

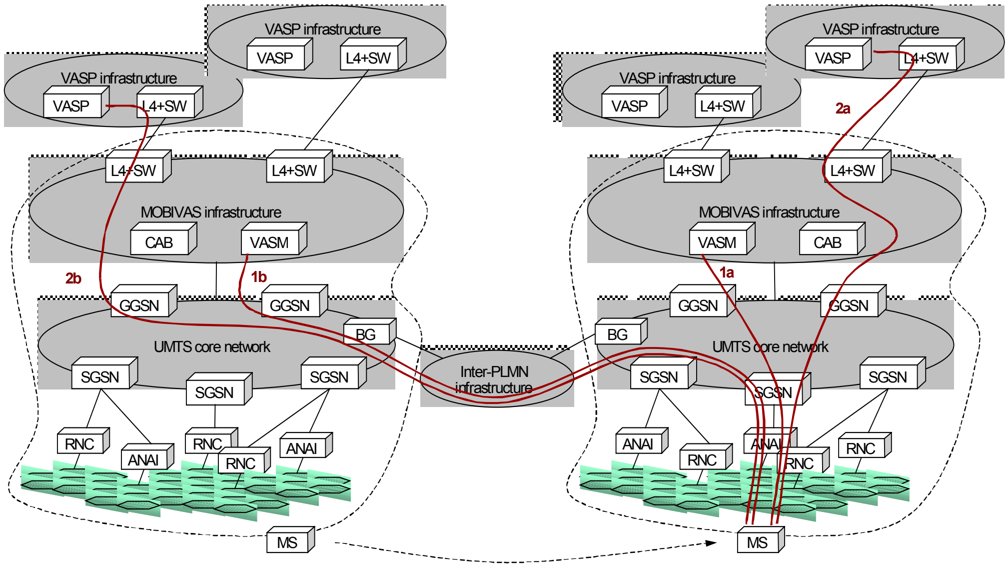

Figure 5. Roaming to a MOBIVAS UMTS infrastructure.

In order for this to be achieved the visited VASM communicates directly with the VASM in the home network of the requesting user to obtain the necessary information for such an interaction (e.g. available VASs, user-specific info, etc.).

In order for users to establish communication with the visited VASM the model described in section 3.2 works properly. To this end, the only requirement is the requesting terminal to issue a PDP context activation request message with the reserved label "vasm" in the APN parameter's field. Since the visited UMTS network is MOBIVAS-enabled its local DNS will be aware of the reserved label "vasm" and corresponding IP address mapping, so that the PDP context to be created with an appropriate GGSN of the visited network. Thus, by default the mobile terminal will communicate initially with the VASM of the visited network (Figure 5, route 1a).

Figure 6 illustrates the interactions that take place upon PDP Context Activation with VASM, so that the APN "vasm" is resolved and associated with a GGSN in the visited network. In more specific:

1. The visiting user requests the activation of a PDP context specifying label "vasm" as APN.
2. The visited SGSN asks for GGSN IP address (using APN as the key) from visited DNS.
3. Taking into account that the VPAA flag of the requesting user has been set to YES, the visited DNS resolves the requesting label and replies with the IP address of a GGSN in the visited network.
4. The visited SGSN creates a PDP context with the visited GGSN via the Gn interface.

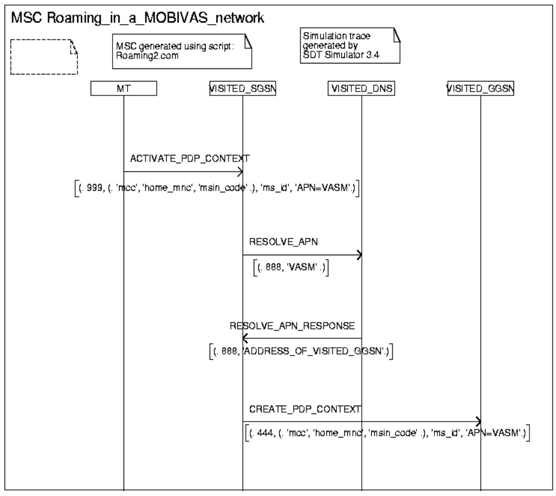

Figure 6. MSC with the interactions regarding "vasm"-label resolution in a MOBIVAS visited network

In case, however that the user wishes to contact the VASM of his home network, this can be achieved by giving the label "vasm.operator_FQ_domain_name" as APN in the activate PDP context request, instead of just "vasm". According to the procedures described in section 3.2, this will lead to communication with the home VASM, via a GGSN in its home network (Figure 5, route 1b).

Since users may access VASs available from the home or visited MOBIVAS operator, it is important, for billing reasons, that all VAS usage traffic between MT and VASP transits the network to which the VAS is registered. This means that for all VASs the PDP contexts should be established with GGSNs of the operator (home or serving) they have been registered. So, VASs registered in the home network of requesting user must be accessed through GGSNs of their home network (Figure 5, route 2b), while VASs of the visited network must be accessed through GGSNs of the visited network (Figure 5, route 2a). To this end, for accessing VASs in the former case the corresponding PDP context activation requests should specify full APNs indicating the home operator of requesting users. The information on whether a VAS is registered with the home or visited operator is contained in the received Service listing, presented to the user by the visited VASM, which in this scenario includes all available VASs from both home and visited network.

As far as charging for network and VAS usage is concerned, the interactions that take place between home and visited network are:

- In case that the VAS usage concerns a VAS registered in the home network of the user the charging and billing procedures are the same with those described in section 3.2.
- In case of a VAS registered in the visited network, the procedures regarding the transport part of charging remain the same with section 3.1, since both home and visited networks generate associated records, while the home network calculates the total transport charge for the user. The difference concerns the service/application part of the charging, since in this case it is the visited network's CAB module that bills the user for VAS usage based on the VASDRs received by the L4+ systems of the visited network and the respective tariffs. However, it is the home CAB module that combines the transport and service charge to bill the user accordingly. Finally, the home CAB system calculates the revenue that is due to the visiting network operator for its resources usage, while the visited CAB system calculates the revenue share of the VAS provider.

Providing that the data transport and business level agreements described in section 3.1 have been established between home and visited network operators, the VASs both in the serving and the home MOBIVAS platform will be accessible by roaming users. These agreements must provide home MOBIVAS operator and its contracted service providers with access to the visited network resources, so that users are able to select and execute services of either home or serving MOBIVAS platform.

4 CONCLUSIONS

Present contribution discussed some critical technical issues on the provision of services to roaming users in the context of 3rd generation mobile communication networks. An innovative platform architecture enabling flexible VAS provision to mobile subscribers was introduced and the methods that it adopts to support the provision of services to roaming users was described.

All scenarios and interactions between various MOBIVAS components presented in this contribution have been validated and successfully simulated on the Simulator of the Telelogic SDT tool, following the SDL specification of the proposed architecture. In parallel, a prototypical implementation of the proposed platform is currently under development. In the near future extensive experiments will be performed to provide proof of concept for the presented architecture and shape the base for further research on issues such as system performance and scalability.

ACKNOWLEDGMENTS

This work was partially supported by the IST project MOBIVAS (IST-1999-10206, web home page http://mobivas.cnl.di.uoa.gr). The content of this paper expresses solely the opinion of the authors. The authors would like to acknowledge Mr. Dimitris Alexandrou and Mr. Spyros Pantazis for their valuable contribution to implementation of the presented platform prototype.

REFERENCES

[1] N. Houssos et al., “A VHE architecture for advanced value-added service provision in 3rd generation mobile communication networks” GLOBECOM2000 Workshop on Service Portability, December 2000, San Francisco, USA.

[2] 3G TS 22.121 V4.0.0 (2001-03) : “3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Service aspects; The Virtual Home Environment (Release 1999)”.

[3] 3G TS 22.060: “3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; General Packet Radio Service (GPRS); Service description; Stage 1 (3G TS 22.060 version 4.0.0)”.

[4] 3G TS 23.060: “3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; General Packet Radio Service (GPRS); Service description; Stage 2 (3G TS 23.060 version 3.3.0)”.

[5] 3G TR 22.971: “3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Automatic establishment

of roaming relationships (3G TR 22.971 version 3.1.1)".

[6] N. Alonistioti et al., "An application platform for downloadable VASs provision to mobile users", IST Mobile Communications Summit 2000, October 1-4, Galway, Ireland.

[7] S. Panagiotakis et al., "Generic architecture and functionality to support downloadable service provision to mobile users" 3GIS Symposium 2001, Athens, Greece, July 2001.

[8] Extensible Markup Language (XML) home page, http://www.w3c.org/XML.

[9] RDF: Resource Description Framework home page, http://www.w3.org/RDF/.

[10] CC/PP working group home page, http://www.w3.org/ Mobile/CC/PP/.

[11] T. Harbaum et al., "Layer 4+ switching with QoS support for RTP and HTTP", Globecom 1999.

[12] E. Gazis et al., "A flexible charging and billing approach for the emerging UMTS network operator role", ASTC Applied Telecommunications Symposium (ATS) 2001.

[13] M.Koutsopoulou et al., "Subscription Management and Charging for value Added Services in UMTS Networks", IEEE Semiannual Vehicular Technology Conference VTC2001, May 2001, Rhodes, Greece.