A VHE architecture for advanced value-added service provision in 3rd generation mobile communication networks

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***Abstract*-In the emerging era of 3rd generation mobile communication networks, it is expected that operator differentiation in the market will highly depend on the advanced provision of value-added services, including the successful implementation of the Virtual Home Environment (VHE) concept. In this paper[1], after discussing some issues critical to VHE realization, we introduce a distributed application platform architecture, capable of supporting flexible value-added service provision to mobile users of 3rd generation networks, as well as address issues crucial for business deployment such as charging, billing and accounting. Moreover, we describe how this architecture can support the seamless, customized service access to roaming users, inline with the VHE requirements.**

***Keywords:* VHE, value-added services, UMTS, roaming, charging, accounting.**

I. INTRODUCTION

In the forthcoming world of 3rd generation mobile communications, the Virtual Home Environment (VHE) concept is emerging, aiming to offer personal service environment portability across network boundaries and between terminals [1]. This essentially means that the mobile user should be able to seamlessly access value-added services (VASs) with the same "look and feel", while roaming and from a variety of terminals with highly diverse capabilities (e.g., mobile phones, PDAs, laptop computers). Moreover, in the multitude of available services, she should be able to locate the ones that best match her needs. In the open market that will be created further requirements are going to emerge for other business players. 3rd party service vendors, also termed value-added service providers (VASPs), shall wish to implement their services in a way that will make the latter portable to practically all of the terminals and networks universally available, thus increasing their potential profit. Finally, operators as well as VASPs need to accurately monitor service usage, so that they can appropriately bill their customers and fairly distribute the associated revenues between them.

The following technical requirements are imposed by the above user- and business needs:

- Standardised execution environments for various classes of mobile terminals.
- Specification of a universal format for representing terminal capability data, and of mechanisms for terminal capability negotiation[2].
- Maintenance of user profiles, containing the VAS provision-related preferences of each user.
- Efficient methods for service discovery and access across network boundaries.
- Collection of service usage data, calculation of the appropriate charges and incorporation of the latter in a single home bill for each user (charging and billing).
- Distribution of the revenues among the home operator, serving operator and VAS provider (accounting).

The rest of the paper is organized as follows: the following section discusses and proposes solutions for various critical issues in service portability, namely terminal execution environments, terminal capability negotiation, user profiling, service discovery, charging and billing, as well as roaming agreements and accounting. Subsequently, we present a proposed architecture for a VAS provision support framework and describe how the latter can support seamless and personalized VAS access by roaming mobile users, inline with the requirements of the VHE. Finally, the last section presents our conclusions.

II. ISSUES IN SERVICE ROAMING

A. *Terminal execution environments*

The existence of standard terminal execution environments is to the benefit of all parties involved in VAS provision to mobile users. VAS developers will be able to sell their products to a worldwide market, thus having unlimited revenue potential. Operators will

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[2] The term "terminal capability negotiation" is used here, since it appears in the 3GPP standards. However, the procedure referred to is rather a one-way (terminal to VAS provision entity) terminal capability announcement.

have a wide choice of 3rd party service vendors, whose VASs can be offered to the mobile subscribers, without having to worry about implementation details and potential incompatibilities with user terminals. Terminal manufacturers will be able to invest in other device features to differentiate themselves in the market, being confident that their products support the services available in the market. Finally, users will be offered a huge variety of services from any terminal they choose to buy or happen to use in the case of roaming.

Standardized terminal execution environments should be able to host third-party applications independent of the underlying hardware and operating system. Thus, interpreted languages should be specified for the implementation of services for these environments. The 3GPP are in the process of specifying two standard execution environments for mobile terminals: USAT (USIM application toolkit) [2] and MExE (Mobile station Execution Environment) [3][4].

USAT is a toolset for developing applications residing in USIM cards. A USAT application may incorporate menus for specific VASs into the standard menus of the mobile terminal, thus making services easily accessible to unsophisticated users. Moreover, highly secure transactions are feasible, since all application logic and data that can be downloaded and used is wired in the USIM, a smart card issued and constantly controlled by the home operator. However, USAT applications lack the multimedia features required in the 3rd generation epoch. It can be considered as a solid, limited capability solution for certain types of applications demanding secure transfer of low volumes of data to the mobile terminal.

MExE, a 3GPP technical specification, provides a standardized environment for secure application execution in a mobile station (MS). MExE categorizes mobile devices by giving them different, so-called, MExE classmarks so that MSs can be targeted at a range of implementations for MExE. For the time being two MExE classmarks are defined:

1. *MExE classmark 1* - based on WAP. It requires limited input and output facilities on the client side and is designed to provide quick and cheap information access even on narrow and slow data connections.
2. *MExE classmark 2* - based on Personal-Java with telephony specific extensions, which requires more processing, storage, display and network resources and supports more powerful applications and flexible man machine interfaces. MExE Classmark 2 also includes support for MExE classmark 1 applications.

Currently, within 3GPP there is an on going effort for the definition of the MExE classmark 3. According to plans, it will be based on Java KVM, a lightweight Java virtual machine implementation and the Connected, Limited Device Configuration (CLDC) specification [5].

B. *Terminal capability negotiation*

Knowledge of terminal capabilities is essential for VAS discovery and provision, so that the user is offered only with the services that can be supported by the device she currently using for network access. Moreover, those services may need to be adapted to the terminal capabilities. Thus, the latter should be communicated by each terminal to the VAS provisioning entity that is currently serving it.

Seamless service access across different networks with various terminals requires the availability of a universal format for capability description, as well as a mechanism for capability data negotiation.

The MExE specification standardizes capability negotiation. The MExE approach is based on the W3C CC/PP specification [6] for the announcement mechanism and the WAP UAProf standard [7] for the format of capability data. The Resource Description Framework (RDF) [8] is used to enable the interoperable encoding of profile metadata in XML and the extensibility of the data representation schema. The capability data is embedded in HTTP/1.1 headers and sent to the VAS provisioning entity. This implies that communication between terminal and VAS provisioning server is performed using HTTP/1.1 or an HTTP/1.1 derived protocol (e.g., WSP of the WAP protocol stack). In MExE the VAS provisioning entity is called MExE server. MExE servers are essentially entities that enable MExE terminals to discover and access MExE services. In addition to that they should be able to obtain the terminal capabilities and provide the terminal with the right application version. MExE servers would typically be hosted in network nodes inside the operator's domain or in the premises of VASPs. However, MExE servers can reside in any location accessible from a MExE terminal, even in another MExE terminal. Apparently, subscribers of a mobile operator could have access to a large number of MExE servers.

C. *User Profile*

User profiles are a central concept for consistent VAS provision to roaming users, in line with the VHE concept [1] introduced by the Third Generation Partnership Project (3GPP) [9]. A user profile can be defined as a combination of different preferences specific to a user [1]. Users may define one or more user profiles according to their needs (e.g., home, business, leisure profiles).

Important issues related to the efficient application of user profiles for consistent VAS provision to mobile users are the following:

- *Content of user profile.* This is currently specified by the 3GPP standardization [1]. Each user profile consists of two kinds of information:
  - user interface related information;

- services related information.

A user interface profile may include information such as:

- menu settings, e.g. menu items shown, menu structure, the placement of icons;
- terminal settings, e.g. ringing tone and volume, font type and size, screen and text color, language, content types and sizes accepted.

A user services profile may include information such as:

- a list of favorite user services, as well as personal configuration information for each of the above services, if applicable.
- service status (whether the service is active/de-activated).

- *Interoperable encoding of user profile information.* Such a common vocabulary for describing user profile information has not yet been specified by the 3GPP. The format of the user profile data should be universally recognizable, so that it can be used in the case of roaming. XML [10], a meta-language introduced by W3C, is a prime candidate for that purpose. It is highly appropriate for the exchange of information between entities without prior knowledge of the data structure. Moreover, it is emerging as an industry standard, supported by all major software and database vendors.

- *Location where it could be stored.* The user profile could be distributed in various parts of the terminal and network. For the sake of performance, a major part of the user profile could be stored in the mobile equipment, so that in case of roaming it is accessed by the visited network without contacting the user's home operator. The Universal Subscribed Identity Module (USIM) card [11] is a more appropriate place for the user profile than the terminal, so that the user can access VASs from various terminals worldwide just by carrying with her her USIM. However, the user profile should be fully recoverable by the home network in case of terminal equipment or USIM damage or loss. A mobile operator could store the user profiles of its customers in an enhanced HLR or a dedicated proprietary network node, that could be, for example, accessible over the Internet. The former solution has the advantage of enabling the reuse of already available expensive network equipment (like the Home Location Register, HLR) for the challenging task of keeping a database of potentially millions of records, while the latter provides more flexibility in implementation and simplifies access to the user profile database.

If the user profile is distributed in various locations, each version of the user profile could, besides actual user preferences data, contain links (URIs) to the remaining parts of the profile stored elsewhere. For example, an USIM-located user profile might include only terminal preference data, as well as the URI of the home operator location hosting the user service preference information. User profile distribution introduces an additional requirement for synchronization between different profile parts.

D. Service Discovery

The mobile user of the forthcoming 3rd generation era will demand the availability of VAS discovery mechanisms that will enable her to easily, quickly and efficiently locate the services, that best suit her needs. Typically a service discovery user interface should at a minimum give the following options to the user:

- *Keyword-based VAS search.*
- *Listings of VASs classified in categories.*
- *Listing of the user's "favorite" services.*

Before a user selects a service, she should be informed about the service features, such as a short description and indicative tariffing information.

Service discovery in the context of mobile communications is a challenging problem for various reasons. The end user requires the efficient, in terms of time and network traffic, execution of the task, so that the results are presented to her quickly and with low cost. The expected huge range of services available makes the task of filtering and selecting the most appropriate for the user highly demanding. Moreover, due to the limited bandwidth and low reliability of the wireless link, the entire operation should be completed with a low number of network messages, thus minimizing the resulting network traffic.

All the above requirements should be satisfied without compromising the interoperability of the operation between different operators. Two candidate approaches for achieving that are could be achieved by employing:

A standardized Application Programming Interface (API) that should be available to the VAS discovery client running in the terminal.

A web-based approach, according to which, a standard reserved DNS name (e.g., "vasm", "vasm.operator_name.com") will contain the VAS selection user interface of the operator currently serving the mobile user.

The latter solution presents to our opinion a more realistic choice, as the VAS selection client embedded in the web page, could employ various technologies for communication with the VASM and service discovery (HTTP/CGI, Web server extensions, Java RMI, CORBA, mobile agents [12], etc.). This way we have an open solution, without the specification of e.g., a standard API. Thus, the various operators have complete freedom to differentiate themselves in the market by implementing the service discovery and selection operation in the most efficient way possible, without compromising interoperability with other operators.

E. Charging and Billing

Charging is the function whereby call information is formatted in order to make it possible to determine usage for which the user/subscriber may be billed. Billing is the function whereby the records generated by the charging function are transformed into bills requiring payment [13][14].

Users transferring data over existing circuit-switched networks pay for connected duration, irrespective of whether any data is transferred. However, in 3rd generation networks, more sophisticated pricing and billing is imperative. The operators should promote a "fair usage" charging model for the new data services, in addition they would like to flexibly price these new services so that customers can be enticed to try them out. Therefore, the charges for VAS usage should depend on several factors like the volume of data transferred, the duration, the time of day, the user's location and the service being accessed.

Therefore, the introduction of 3rd generation services presents a significant challenge for the charging and billing aspects of service provision. In the following we present a detailed listing of the requirements of the involved business players [15].

User requirements:

- *Single itemized bill*. The user wishes to receive a single, itemized bill for all services (basic telecommunication services, as well as VAS), regardless of who offers these services (operator or VAS provider), and of how these services are accessed (via the home operator or by a foreign network in case of roaming).
- *Indicative charging information for each VAS*. Before the user selects to use a service, she should be aware of how much VAS access will cost her.
- *Understandable tariff structure*. The tariffing schemes employed should be presented to the user in a form understandable by her, so that she is aware of the costs that may result from her choices (e.g., accessing a specific VAS with the best possible quality of service).

Operator requirements:

- *Integrated system for charging and billing*. An automated and secure charging and billing system residing within the administrative domain of the operator.
- *Application of various billing models.* The charges for VAS usage should depend on several factors like volume of data transferred, the duration, the time of day, the user's location, the service being accessed and the quality of service of VAS provision.
- *Minimal load on the network due to charging and billing process*. The charging and billing processes should not impose excessive load on the network.
- *Fairness*. Charges should fairly reflect network resources usage. Users should be discouraged from aimlessly reserving superfluous network resources, by being billed for that.
- *Flexibility*. Given that there are many business players that influence VAS charges, the tariffs and the pricing models should be designed and developed independently, so that the tariffing policies can change with the minimal impact to the system.
- *Real-time billing*. During the time of a call or the usage of service the network operator should be able to monitor whether the usage is within the credit limit assigned to a particular user or not. This means that the billing process should be completed almost in real time.

VAS provider requirements:

- *Dynamic modification of pricing policies*. The service provider should be able to dynamically modify the pricing of its VAS (service part of the bill). In addition to that, the ability to introduce new pricing models should be considered as a major requirement, since new types of services are constantly. However, any change in the pricing of a certain VAS should not violate the corresponding business level agreement between operator and VASP.
- *Fair revenue sharing*. There is a need to find a suitable model that distributes the revenues between the home operator and VAS providers. The separation of the charges in transport and service charge could be helpful towards this goal.
- *Competitiveness*. Costs should be appropriate for the application. Certain applications have an inherent value associated with them. The cost of IP telephony usage should be equal or less than the circuit switched telephony or even users will not pay much more for video-on-demand that they currently pay to rent a movie from the local video shop.

F. Roaming Agreements and Accounting

Accounting is the process of revenue sharing amongst operators in case of roaming and between operators and VAS providers for VAS usage. In order for an operator to provide network access to roaming users, a prior agreement should exist with the corresponding home operators. The serving network is free to make whatever interconnections and commercial agreements it chooses with other 3rd parties [16]. In case of roaming, the serving network shall collect and process the charging data generated in its network elements. The record of each individual transaction shall be reported to the home environment at short time intervals in order to provide itemised bills, and to avoid any disputes between the involved parties.

A common format should exist for the representation of the charging data between operators, for interoperability purposes. The existing standard, used in the circuit-switched only GSM systems is the Transferred Account Procedures (TAP records), specified by the GSM Transfer Account Data Interchange Group (TADIG) [17]. This format requires enhancements in order to be appropriate for packet-switched traffic pricing. These include specification of new record attributes: data volume counts, time stamps, IP address, Access Point Number (APN) [15] used by the user, QoS requested and negotiated. The accounting process between operator and VAS provider is analogous. The operator should credit the VAS provider for the usage of its services in a fair manner according to the commercial agreement between them.

III. AN ARCHITECTURE FOR VAS PROVISION

The VAS provision architecture presented in this section is similar to the one that will be developed in the frame of the IST project MOBIVAS [18]. 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.

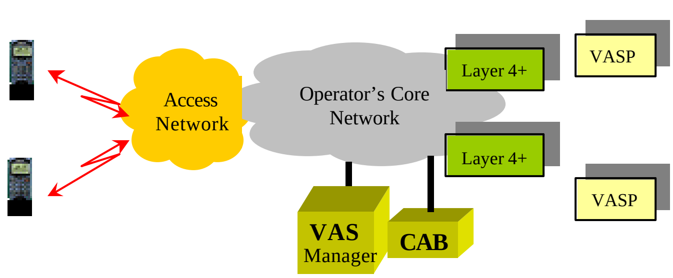

Fig. 1. Architecture of proposed VAS provision platform.

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) [19].

The VASM is responsible for the management of value-added services (VAS) and of a database containing VAS-related data (VAS DB). The VASM is controlling access of subscribers to value-added services and the operation of the VAS database. The VASM will be typically hosted in an IP network node outside the core UMTS network of the operator. Services should be registered in the VAS DB before they can be made available to mobile users. This service registration could be 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 should provide the subscriber with the ability to discover the available services and choose the ones she desires to use. The web-browsing model should be used for service discovery, as proposed in a previous section. The user should be able to select her desired service through a user interface, typically analogous to an Internet portal, provided by the VASM. This user interface can have a universally assigned DNS label, e.g., "vasm" or "vasm.operator_FQ_domain_name", where with the value "operator_FQ_domain_name" we mean the fully qualified domain DNS name of the operator. By accessing this URL from an appropriate pre-installed HTTP/1.1 or WAP enabled client application, the mobile user will be able to contact the VASM of the network currently serving her (whether it is her home or a visiting network). The VASM should reply with a web page containing a VAS selection client.

Service listings are presented to the user after filtering according to the current terminal capabilities and the preferences specified in the user profile. The terminal capabilities can be obtained by the VASM from the terminal using the relevant mechanism specified in MExE (CC/PP protocol). The terminal capabilities need not be sent to each different VAS, since the VASM is aware of the terminal capabilities and it is its task to provide the terminal with a suitable version of each service requested by the user. Thus, applications non-fully compliant to the MExE specifications, as far as the terminal capability negotiation is concerned, can be provided to MExE enabled terminals.

At least a part of the user profile could be kept in mobile equipment storage or in the USIM and provided to the VASM in the way as the terminal capabilities. This part of the user profile should contain links to any user preference elements that are stored only in the network. Thus, a VASM can retrieve the entire user profile using information included in the VAS discovery request sent by the terminal.

Layer 4 switching [19] uses transport layer information, e.g. TCP or UDP port numbers, to forward packets. This also allows collecting additional information about source and/or destination of a data frame. Not only the destination machine, but also the type of program transmitting and receiving the data units via well-known ports can in many cases be determined by the layer 4 information.

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 (the L4+ routing device) 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 procedure. Our approach is to break the cost of a VAS-usage related chargeable event into two parts [20]. 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 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).

We assume the existence of various tariff classes as well as different pricing models in the CAB system. In order the network operators to attract more subscribers, they offer more than one tariff classes and respective pricing models aiming to fulfil the different needs of each user. In addition, it is possibly that the tariffs and the pricing models (according to which the service charges are calculated) are different from VAS to VAS. So the pricing policies could vary for the same operator from customer to customer and from VAS to VAS.

The charging process for a specific VAS session is initiated after the execution of a service in the terminal has begun.

IV. ROAMING SCENARIO

This section presents a scenario of seamless VAS provision to roaming mobile subscribers, supported by a platform conforming to the architecture described in the previous section.

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, we separately examine two cases:

- The proposed VAS provision platform is not supported by the serving operator.
- The proposed VAS provision platform is supported by the serving operator.

In both cases we assume that when the user switches on her mobile phone outside the coverage area of its home operator, an appropriate serving network is found using standard signaling interactions. A business level agreement should exist between the home and serving operators for providing data services to roaming users. 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 core UMTS network and L4+ systems. The latter is necessary for the collection of charging information, as described in the following sections.

In the second case, the user is offered personalized access to VASs available from the home as well as the visited operator. This necessitates an agreement between the two operator's to provide the serving platform privileged access to data in the home network (e.g., user profile data) as well as for the settlement of revenue sharing among the two operators and inclusion of VAS access charges to the subscriber's home operator bill.

For reasons of presentation clarity, the VAS provision process is divided into two parts:

- VAS discovery and access.
- Charging, billing and accounting.

Detailed action sequences are presented in detail for every task in both cases.

A. *The proposed VAS provision platform is not supported by the serving operator.*

1) *VAS discovery and access:*

1. The user requests from the VASM the service discovery client. This can be accomplished by typing the VASM DNS label of the form "vasm.operator_FQ_domain_name " in an appropriate web browser, which would typically send an HTTP request to a web server hosting the VASM. The terminal capabilities are included in the request header in XML format. This information is cached by the VASM and used for processing subsequent requests. . The request may also include the part (if any) of the user profile hosted in the USIM or the

mobile equipment. Note that due to operator security concerns, the VASM may not be accessible from the public Internet. In that case terminal IP connectivity to the VASM can be provided over the inter-PLMN backbone network.

2. Based on the terminal capabilities, the VASM selects for this particular client the most suitable service discovery client version. The latter is downloaded to the terminal.

3. The user through the service discovery user interface can issue to the VASM several types of requests. These requests can be roughly divided into two categories:

   - VAS discovery requests. By issuing them the user asks for VAS listings, formed according to various criteria (e.g., services belonging to a specific category, or that are included in the user's favorites list).

   - VAS selection requests. By issuing them the user requests access to a VAS of her choice. Moreover, if there are multiple versions of a particular VAS matching the capabilities of the current terminal, the user is able to choose between the one best suited to its needs (e.g., the cheapest).

4. If the case of service selection, the VASM replies with the network address (e.g., URL) of the VAS, so that the latter can be downloaded to the terminal.

5. The VAS client part is downloaded to the terminal and typically interacts with a VAS server residing in an external IP network (e.g., the Internet). All the traffic resulting from this interaction should transit the L4+ systems of the home operator so that all the necessary data for user billing reach the home CAB system. Thus, this interaction is performed over the home network and the inter-PLMN backbone.

2) *Charging, billing and accounting:*

1. The visited network elements generate charging records that concern the allocation and usage of its network. These records are sent to the Billing system of the visiting network, which calculates the corresponding charges (transport charges). Then, this charge should be encoded in a common format (e.g., enhanced TAP 3) and forwarded to the Billing component of the home CAB.

2. The Billing component of the home CAB after receiving such records incorporates the transport charge in the user's bill.

3. The L4+ systems of the home operator monitor VAS usage traffic and create VASDRs that are sent to Charging component of the home CAB. The Charging component processes these records and propagates the results to the Billing component.

4. The Billing component of the home CAB calculates the service charge according to the respective tariffs and bills the user.

5. The Accounting component of 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.

B. The proposed VAS provision platform is supported by the serving operator.

1) *VAS discovery and access:*

1. The user requests the service discovery client either from the home or the visited VASM. This can be accomplished in a way similar to the previous case, that is by typing the VASM DNS label in an appropriate web browser, which would typically send an HTTP request to a web server hosting the VASM. If the label given by the user is "vasm.operator_FQ_domain_name", the request is sent to the home VASM and VAS provision proceeds as described in section IIIA. If the label has the value of the single word "vasm", the user connects with the visited VASM. The terminal capabilities are included in the request header in XML format. This information is cached by the VASM and used for processing subsequent requests. The user International Mobile Subscriber Identity (IMSI) [21] should be sent as a parameter of the request, so that the serving VASM determines that the terminal is registered with another home operator. The request may also include the part (if any) of the user profile hosted in the USIM or the mobile equipment.

2. The visited VASM gives the user the option to select if she wants to access the home or visited network services. In the former case the user request for the service discovery client is redirected to the home VASM and VAS provision proceeds as described in section IIIA (Fig. 2). The following steps concern the latter case (Fig. 3).

3. Based on the terminal capabilities the visited VASM selects for this particular client the most suitable service discovery client version. The latter is downloaded to the terminal.

4. The user through the service discovery user interface can issue to the VASM several types of requests. These requests can be roughly divided into two categories:

   - VAS discovery requests. By issuing them the user

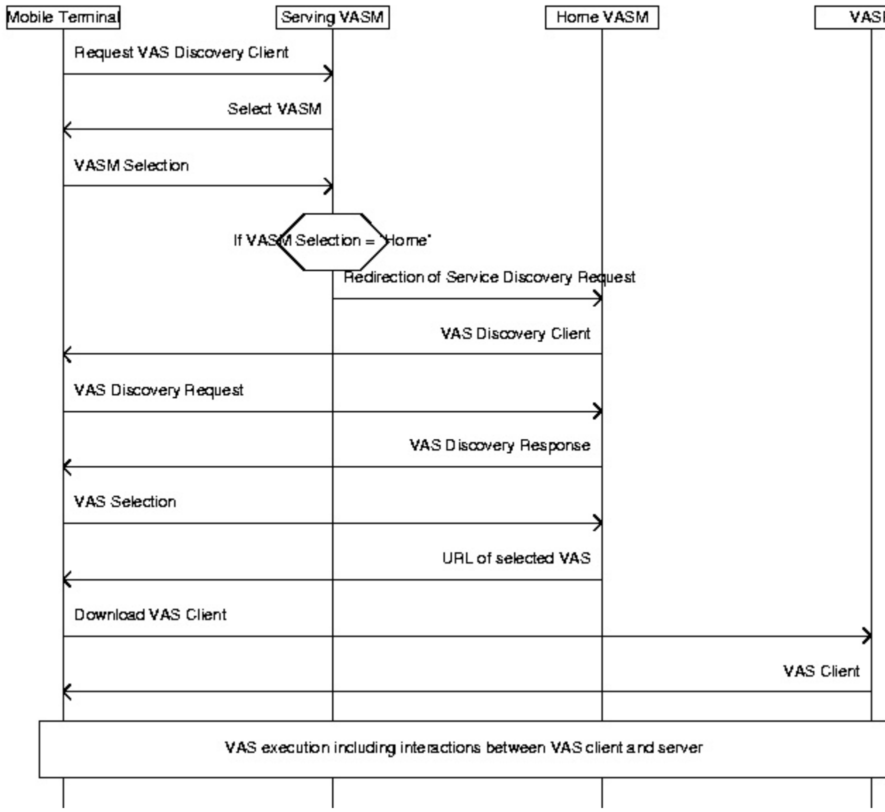

Fig. 2. VAS provision by the home network.

request to obtain VAS listings, formed according to various criteria (e.g., services belonging to a specific category, or that are included in the user's favorites list).

- VAS selection requests. By issuing them the user requests access to a VAS of her choice. Moreover, if there are multiple versions of a particular VAS matching the capabilities of the current terminal, the user is able to choose between the one best suited to its needs (e.g., the cheapest).

5. If the response to any request requires access to the part of user profile stored in the home network, the serving VASM is able to retrieve it from the home network encoded in an universally common XML vocabulary.
6. If the case of service selection, the VASM replies with the network address (e.g., URL) of the VAS, so that the latter can be downloaded to the terminal.
7. The VAS client part is downloaded to the terminal and typically interacts with a VAS server residing in an external IP network (e.g., the Internet). All the traffic resulting from this interaction transits the L4+ systems of the visited operator so that all the necessary data for user billing reach the visited CAB system. The latter propagates billing information to the home CAB system as described in the next section.

2) *Charging, Billing and Accounting:*

1. The visiting network elements generate charging records that concern the allocation and usage of its network resources. These records are sent to the charging component of the visited CAB system.
2. The L4+ systems of the visited network generates VASDRs that sends to the charging component of the visited CAB.
3. The visited CAB system charging component processes these records and sends to the billing component.
4. The billing component of the visited CAB calculates both (transport and service) charges according to the respective tariffs.
5. Then, these charges are encoded in a common format (e.g. enhanced TAP 3) and forwarded to the billing component of the home CAB system, in order to charge the its subscriber.

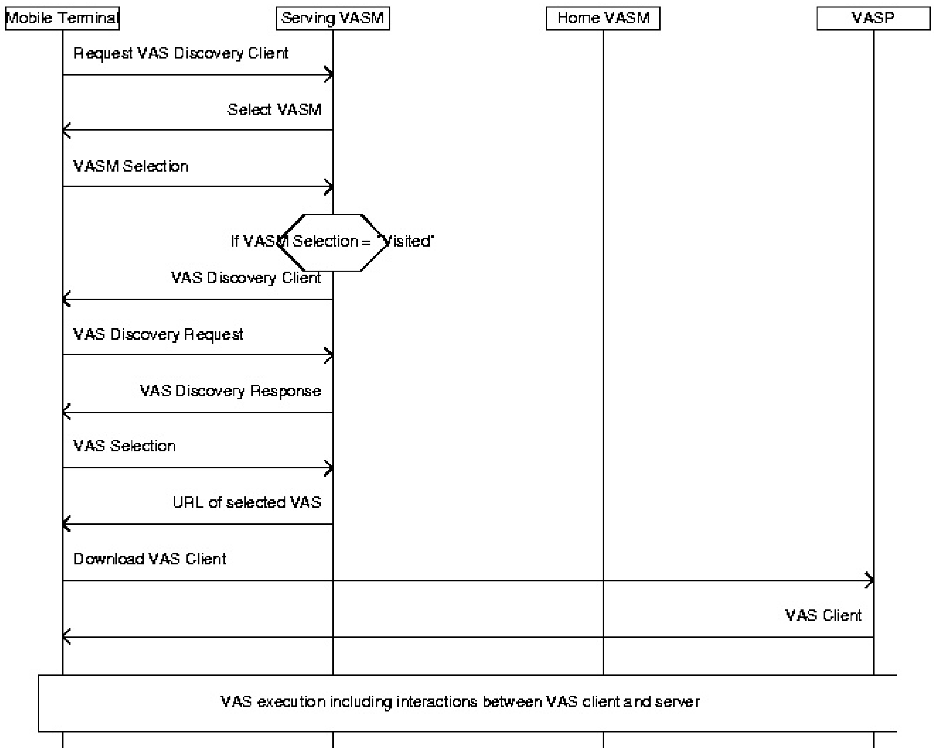

Fig. 3. VAS provision by the visited network

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6. The visited CAB system accounting component calculates the revenue share of the VAS provider.
7. The billing component of the home CAB system incorporates these charges in the user bill.
8. The accounting component of the home CAB system calculates the revenue that is due to the visiting network operator for its resources usage.

V. SUMMARY AND FUTURE WORK

In this paper we provided a discussion of issues critical to the realization of the VHE concept in the context of 3rd generation mobile communication networks. We proposed a platform architecture enabling flexible VAS provision to mobile subscribers and described how this platform can support the realization of customized service access by roaming users, inline with the VHE requirements.

In the future we plan to investigate in more depth the issues mentioned in this paper with particular focus in alternative business models that will probably emerge in the 3rd generation epoch and the resulting new technical requirements. Moreover, a prototypical implementation of the proposed platform will be developed, and extensive experiments will be performed to provide proof of concept for the presented architecture and provide the means for further research on issues such as system performance and scalability.

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