New architecture for a centralized next generation profile register in future mobile telecommunication networks

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Abstract

The evolution of the mobile telecommunication networks resulted in logically and physically distributed subscriber profiles, specialised interfaces and network-specific protocols. Access to complete subscriber information and integration of service-oriented technologies are challenges of a centralized Next Generation Profile Register (NGPR). This paper addresses the future integration needs of a NGPR and presents the actual status of the research work and results.

Keywords

UMTS, GSM, Home Location Register (HLR), Home Subscriber Server (HSS), Next Generation Profile Register (NGPR), Service-Oriented Architecture (SOA), Subscriber Profile, Generic User Profile (GUP)

1. Introduction

The Universal Mobile Telecommunication System (UMTS) Release 5 (Banet et al, 2004) (Kaaranen et al, 2001) (refer to Figure 1) is a 3rd generation mobile network and consists of three domains; the Circuit Switched (CS) domain, the Packet Switched (PS) domain, and the IP Multimedia Subsystem (IMS) (ETSI TS 123 228, 2004). These co-existing diverse domains are based on different technologies and communication protocols.

The most popular network, the 2nd generation mobile network GSM (CS), uses the application layer protocol Mobile Application Part (MAP) (3GPP TS 09.02, 1998), defined in the Signalling System Nr. 7 (SS7) (ITU-T Q.700, 1993), for signalling. UMTS (PS/IMS) supports SIP (Rosenberg et al, 2002) and SDP (Handley et al, 1998) for signalling and call control. In general the domains can be divided in IP (PS/IMS) and non-IP networks (CS).

GSM deploys Base Station Controller (BSC) and Mobile Switching Center (MSC) to interwork between the radio interface GERAN and the Public Land Mobile Network (PLMN) / Public Switched Telephone Network (PSTN). The Home Location Register (HLR) is the main GSM subscriber database. The Visitor Location Register (VLR) is referenced by the HLR and contains a copy of the HLR subscriber profile.

In UMTS the HLR is extended by multimedia data from the IP Multimedia Subsystem (IMS) and is named Home Subscriber Server (HSS). In contrast to the former GSM (Rel. 98), the IMS separates explicitly between transport, control, service capability, and application/services layer. Transport is handled by the PS domain and control by the IMS. The PS domain consists of the Serving GPRS Support Node, Gateway GPRS Support Node. IMS includes Call State Control Functions (CSCF), the Media Gateway, and the Media Gateway Control Function (MGCF). Call control is separated from the services by the SIP-based ISC interface. ISC guarantees unified access to different types of application servers and services. UMTS defines also a personalized subscriber profile, service portability and service mobility.

Additional internal network services for the intelligent networks are provided by the optional Service Control Point (SCP). The Equipment Identity Register (EIR) addresses and categorizes stolen devices by the International Mobile Equipment Identity (IMEI) of the mobile phone.
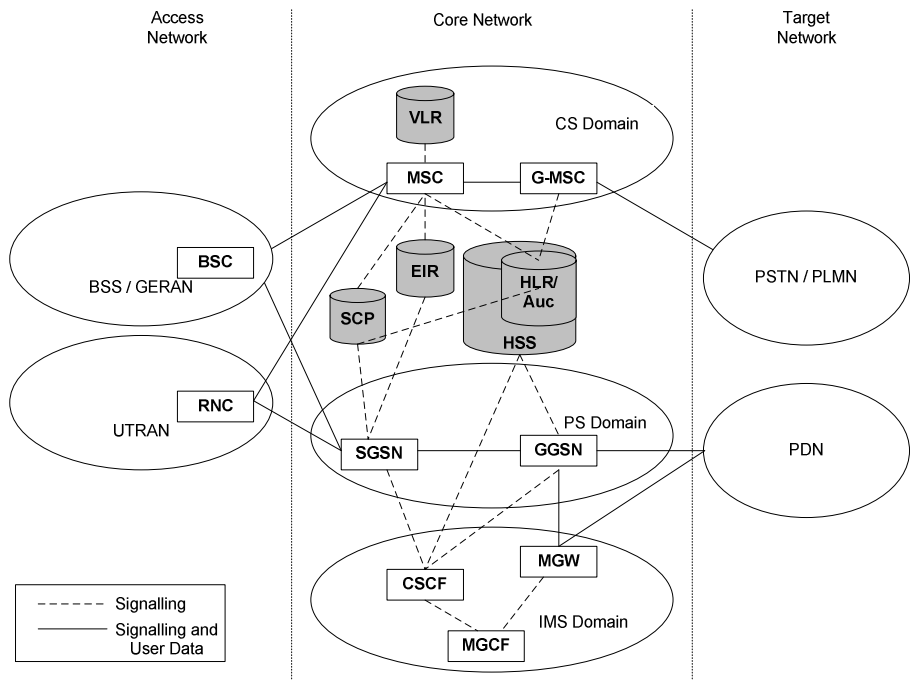

Figure 1 - UMTS Release 5, High Level

Beside the telecommunications real time systems, the Operations Support System (OSS) administrates subscribers as customers and manages the network. The OSS and its interfaces are not standardised and integrate the main subscriber databases in a proprietary way (refer to Figure 2).
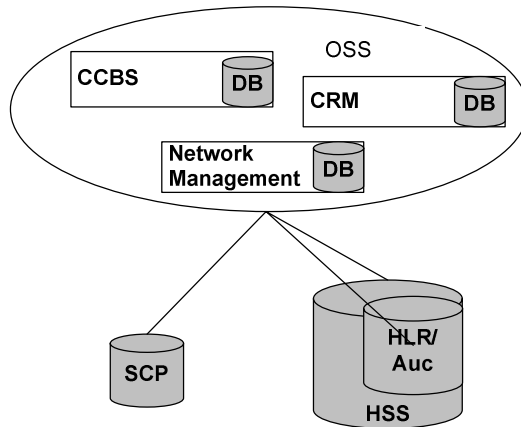
Figure 2 - Operations Support System (OSS)

These subsystems of a mobile network are for example the Customer Clearing and Billing System (CCBS), Customer Relationship Management (CRM) and the network management.

Wireless LAN (WLAN) is one of the most popular wireless networks. Several mobile telecommunication operators realize specialised networks to support WLAN at locations of public interest. Interworking between WLAN and UMTS is a feature of UMTS Rel. 6 (ETSI TS 123 234, 2005), but until now domains are separated and roaming/handover is not yet supported. Also other upcoming radio interfaces like Bluetooth or WiMAX are not integrated and build their own domain. Subscriber profiles and services are network-dependent and can not be reused in a generic way.

2. Integration need of the subscriber databases in telecommunication networks

2.1. Introduction

The diverse co-existing telecommunications networks deploy several network-dependent database instances. A database look-up of a single mobile subscriber (ETSI TS 123 008, 2005) and the dedicated subscribed services is a challenging task.

Distributed main subscriber profile and subscriber data
Main subscriber profiles (e.g. HLR/VLR and HSS) are distributed over the different databases of the diverse mobile network. The main GSM subscriber profiles are stored in a distributed environment, where each HLR contains a predefined block of subscribers. Signalling requests investigate the HLRs by routing tables. For example, subscribers from external networks use the Mobile Station ISDN (MSISDN) number to allocate and call a subscriber attached in the home network. Leading provider use two digits of the Subscriber Number (SN) of the MSISDN to mediate between the HLRs (refer to Figure 3). For UMTS, the Subscription Locator Function (SLF) manages distributed HSS systems.
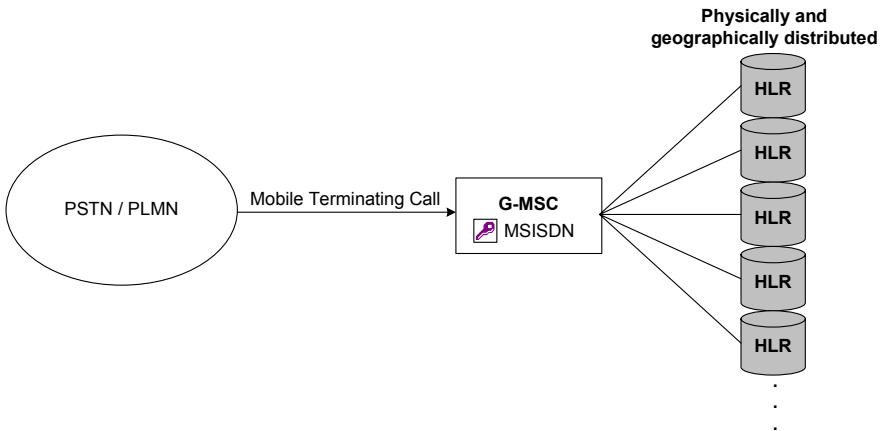
Figure 3 - HLR mediation

Different database storage entities for one subscriber
Beside the main subscriber profile stored in the HLR or HSS, other profiles are co-existing (e.g. in the SCP, WLAN, CCBS, CRM, and network management databases). SCP or databases within the OSS normally use the same keys to extend the subscriber profile with data from intelligent networks, business applications, or billing functionality (refer to Figure 2). Also different radio interfaces like WLAN, Bluetooth and others handle separated subscriber profiles. These profiles should be integrated in the existing OSS and mobile business applications to support a unified customer and billing system.

In order to provide general access for database instances and distributed subscriber profiles, the concept of a central subscriber database has been investigated (Lopez Aladros et al, 2003) (Rupp et al, 2004.1 and 2004.2). Sufficient performance can be achieved by modern fibre channel or gigabit LANs and storage area networks. Traffic tests verify the centralized concept for the VLRs and HLRs (Nantavechsanti, 2005).

Complete subscriber profiles facilitate the interworking between several application servers. Business applications and also third party applications can directly access the complete profile information of a mobile subscriber. In UMTS, application servers can be based on open interfaces (ETSI TS 123 198, 2005) and may access the HSS by the Sh interface (ETSI TS 123 228, 2004).

Specific Interfaces
The 3rd generation partnership project (3GPP) standardises interfaces and protocols, but implementations are generally vendor-dependent because of vendor-specific standard extensions. This requires software modification to support specialised network nodes. Therefore, a flexible service concept should facilitate the interworking between vendor-dependent network nodes.

These requirements as well as the standardisation issues have to be addressed when designing a Next Generation Profile Register (NGPR). A NGPR should be based on open interfaces, interoperable services and a common subscriber profile.

2.2. FlexiNET

The EU-Project Flexinet (FlexiNET, 2005) is coordinated by Alcatel and addresses the centralized data storage concept. FlexiNET cross-connects UMTS and WLAN mobile networks via network gateways (refer to Figure 4). FlexiNET uses SOAP services to interoperate between the access networks, the application servers and the centralized data gateway node (DGWN). This concept enables interoperability for closed networks and deploys a common application interface and data interface for the WLAN and UMTS network. These wireless networks are integrated by the FlexiNET UMTS Access Node (FUAN) and the FlexiNET WLAN Access Node (FWAN). The network access points provide gateway functionality and support cross-connect control as well as switching/routing control. FUAN complements existing UMTS access nodes and provides adequate interfaces to switch between the traditional network and FlexiNET. Also FWAN interworks between the WLAN infrastructure and FlexiNET nodes to access common services and generic subscriber data. The DGWN provides subscriber and application data by data centric services for the access networks. The interworking bus with legacy switch platforms is used to connect traditional network nodes with FlexiNET nodes. This mechanism uses standard signalling interfaces to switch between the networks and accesses co-existing subscriber data of the UMTS/WLAN core network.

The research work presented in section 3. is done in the context of FlexiNET. My research work offers alternatives and extensions for the flexible network architecture.

2.3. Generic User Profile (GUP) Architecture and Data Model

The Generic User Profile (GUP) reference architecture (ETSI TS 123 240, 2005) consists of the GUP Server, the Repository Access Functions (RAF), the Rg/Rp interfaces and an application server (refer to Figure 5). GUP adopts mechanisms from Open Services Access (OSA) (ETSI TS 123 198, 2005) and the Liberty Alliance Project (Liberty Alliance Project, 2003).
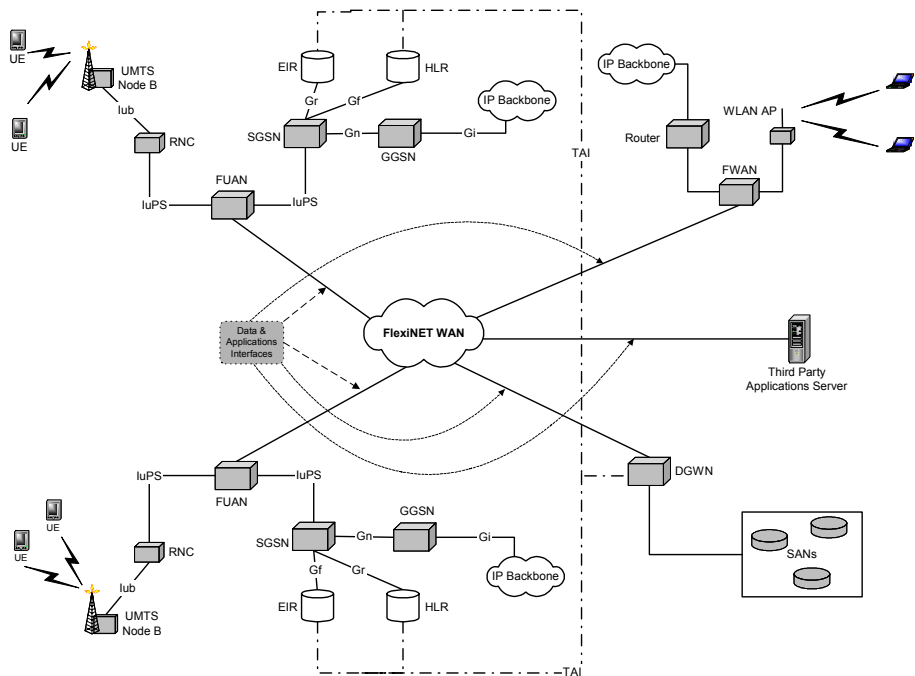
Figure 4 - FlexiNET Network Architecture Overview

RAF deploys a harmonized access interface and performs a protocol and data transformation to the GUP data repositories. GUP data repositories contain the subscriber profile of one database identity. The interface between RAF and the GUP Data repository is not standardised. The Rg application interface is based on SOAP and offers two operation modes. The redirect operation mode is considered for internal access while proxy operation mode should be used for third party access. The Rp interface allows the GUP server and applications to manipulate the subscriber profile. External applications should be only allowed to use the Rg SOAP interface instead of using Rp. The concrete example of the GUP architecture (Figure 6) shows the interaction between applications from mobile devices, home network applications and third party applications with GUP and the concrete database identities (HSS, HLR, VLR, OSS etc.).

The GUP subscriber profile describes a collection of user related data and is based on XML standards (ETSI TS 23 941, 2005). GUP profile is defined by an XML schema and includes several profile components. A concrete profile component includes the data element with the dedicated attribute. A profile component is related to concrete profile data.
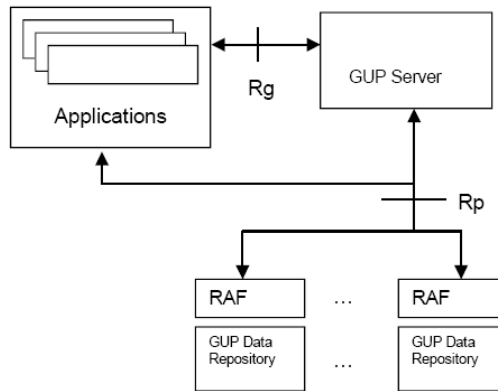
Figure 5 - GUP Reference Architecture (ETSI TS 23 240, 2005)

The profile components include
- Generic user information
- PLMN-specific information
- User Equipment (UE)-specific information
- Billing & charging information
- Available services for subscription
- Actually subscribed services
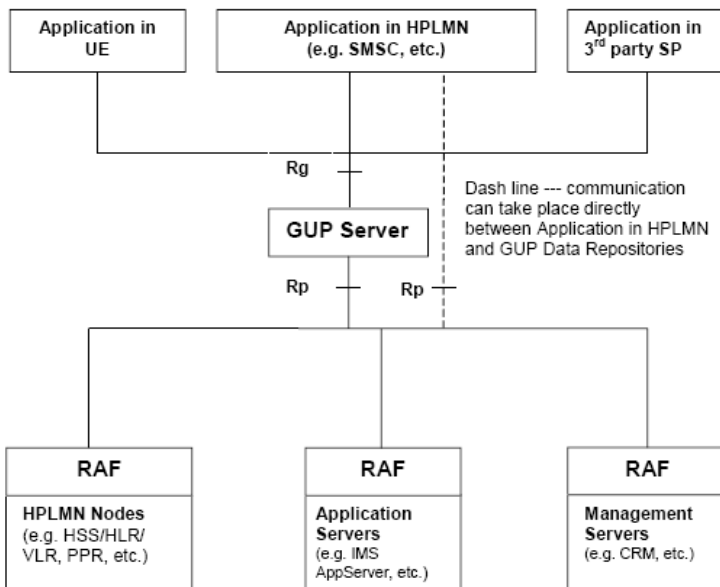- Service-specific parameters and preferences

Figure 6 - GUP Concrete Architecture (ETSI TS 23 240, 2005)

GUP defines a data model and architecture to logically-centralize a subscriber profile in a generic way. GUP addresses the problem of distributed database instances, but still separates the database identities. The GUP subscriber model approach is compliant with the FlexiNET concept and the defined data model could be implemented for the DGWN. The service access interface of the DGWN as well as the GUP Rg interface is based on SOAP.

2.4. XML and SOAP in Future Mobile Networks

The Extensible Markup Language (XML) is independent of operating system platforms, network layers, data storage mechanisms and programming languages. XML describes data on an abstract level and is the basis for service descriptions and the SOAP protocol (Mitra et al, 2003). SOAP is the communication protocol supporting Service Oriented Architectures (SOA) for web services. Web services are programmable, self describing, encapsulated, loosely coupled and support location transparency as well as protocol transparency.

Web services are able to form service building blocks to reuse and compose services (Glass, 2002). This is similar to service building blocks invented for telecommunication networks.

Mobile networks focus on XML in order to build open interfaces. OSA application server standardisation (ETSI TS 129 199 01-14) as well as the GUP server offers a web service interface. Also the user profile transferred on the Cx interface (CSCF – HSS) is described in the XML data format (ETSI TS 23 228, 2005).

In the internet world, SOAP is usually transported over HTTP, but SOAP is independent from transport protocols. In telecommunication world SIP is standardised for the next generation networks. However, SIP may control SOAP message sessions (Deason, 2001 and 2002) to combine the different protocol features for the integration of the telecommunication networks. XML standards for the user plane and signalling have been implemented and are adopted to the IMS domain. VoiceXML and Call Control XML (CCXML) can be integrated by implementing a Media Ressource Function (MRF) for the IMS (Voicegenie, 2005).

XML and SOAP opens the door for the distributed telecommunication and business applications by well defined W3C standards. XML technologies are able to integrate networks, subscriber profiles and services in a network-independent way. The adoption of SOA to the telecommunications world is a new approach integrating diverse networks in a coherent way.

3. Status of the Research Work and Results

3.1. Introduction

The research work aims to design a centralized Next Generation Profile Register (NGPR) for all mobile telecommunication domains (refer to Figure 7). The NGPR should be able to integrate existing XML telecommunication standards (refer to

section 2.4) by adopting a SOA for mobile telecommunication networks. First a suitable, service-oriented gateway-technology has to be investigated in order to interoperate between the SS7-based and IP-based networks (section 3.4).

Another challenging task is the integration of the different subscriber profiles in a generic data model of centralized NGPR. The data model should support existing data structures as well as generic data structures. In contrast to interface and protocol definitions the data model definition of a subscriber profile is not standardised. An approach for a data model supporting generic as well as concrete network-dependent data is presented in section 3.2.

The data model has to be integrated by a service framework that combines several data-centric services of a single application. The service framework will enable an efficient deployment of services allowing any type of data sets. This framework supports legacy or common/generic services deployed by a well-defined process and registered without the need of a system restart ("plug-in").
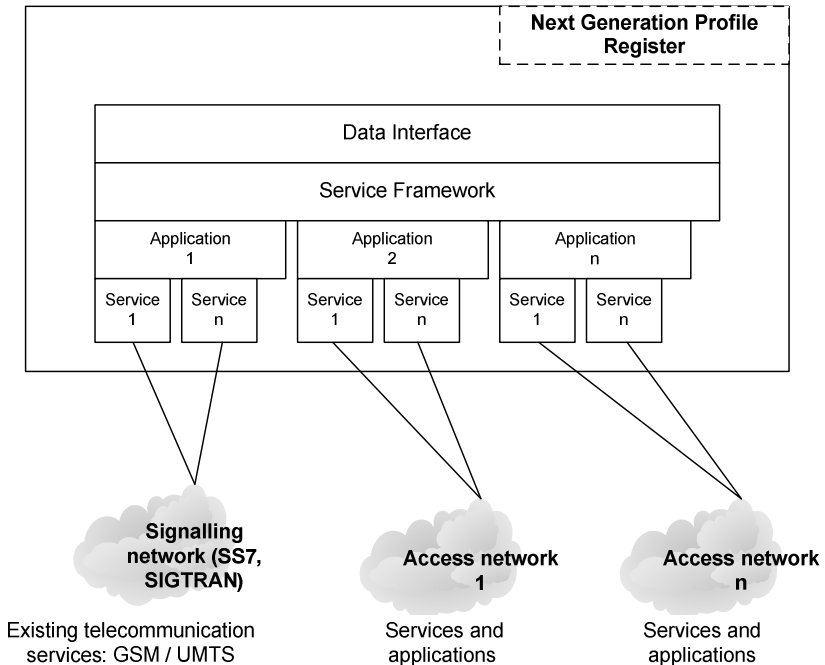

Figure 7- Preliminary Design of a NGPR

The data interface aims to provide various networks common access to the general, integrated profile data. The offered services may also be reused for composing new services, for example, a wireless local area network (WLAN) service may use parts of the offered HLR services for its authentication and authorisation process. These service-oriented concepts are well known, for example, from web services (Fallside et al, 2001) (Glass, 2002) (Mitra et al, 2003).

3.2. Data Model

The data model for a NGPR is proposed to be object-oriented. Object-Oriented Programming (OO-P) defines objects that encapsulate data and operations on the data. Objects allow the re-usability of code and dedicated interface definitions are used for interoperation. Apart from supporting application logic, modern object-oriented concepts additionally support persistent storage capabilities. Object-oriented databases as well as object-relational mapping technologies are able to integrate persistent object data in applications. The need to translate persistent data-objects into relations or other data model structures is eliminated.

The data model should be independent of specific network or service architectures. An example of an object-oriented profile data model has been outlined (Diehl et al, 2005.1). The superset object of the data model identifies the complete set of subscriber-related data combined in the subscriber's profile. This profile consists of different data sets associated with the data storage entities of the various access networks.

For network-independent applications, a subscriber profile is identified by the key of its complete profile. Therefore, run time services dedicated to the applications can access and integrate the complete data sets related to the subscriber. For legacy applications, the existing keys of the corresponding data storage entities may be used. As an illustration, a HLR data model is considered as an example for the NGPR that describes persistent mobile subscriber data such as location, basic telecommunication services, supplementary services etc.

In GSM, two primary keys are defined for database access, the International Mobile Subscriber Identity (IMSI) and the Mobile Station ISDN Number (MSISDN). Conventional GSM services (3GPP TS 09.02, 1998) use the IMSI to access the HLR profile data and the MSISDN as a key for the HLR mobile data. Billing services, for example, may access the whole profile by using the complete profile key (cpKey) of a superset profile (refer to Figure 8). The HLR profile inherits common information about the subscriber that is stored in the superset object.
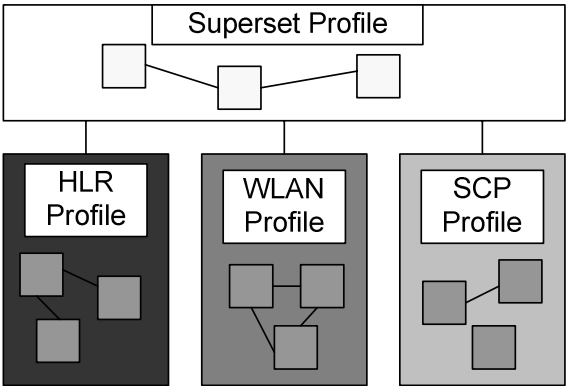

Figure 8 – Example of a Superset Profile

HLR data, for example location or authentication data, can be associated or inherited by other storage entities, which may belong to different access networks. This means that data can be reused between the different data storage entities.

Profile data of a subscriber from different access networks is always identified by the subscriber profile key. Therefore, the superset object references one or more specific profiles of the data storage entities of an access network (refer to Figure 8). The specific data storage entity contains the network-specific or database-specific profile data. However, a NGPR data model aims to define as much generic data in the generic superset profile as possible to provide a network-independent model.

A concrete approach for modelling persistent authentication data has also been addressed (Alazeib and Diehl, 2005) using the Ontology Web Language (OWL) (McGuinness and Van Harmelen, 2004). OWL shares and distributes knowledge, represents a rich vocabulary for modelling and focuses on structural properties.

3.3. Services Framework

The service and application model should support a service-oriented architecture. Application and administration services are distinguished. For example, the deployment process can be seen as an administration service offering deploy and undeploy functionalities (Diehl et al, 2005.2). Other administrative services include load services used for inserting new service objects or for copying data from legacy network nodes, etc.

Application services may be further sub-divided into run-time and provisioning services; services in general offer create, update, modify, or delete operations related to user interfaces on the subscriber profile. The HLR services for GSM and UMTS are, for example, part of the HLR application. Other applications may include different access networks or new service platforms. Specific HLR application services include, for example, the legacy signalling operations of the MAP such as UpdateLocation, CancelLocation, SendAuthenticationInfo etc. Concrete HLR application services use a concrete factory design pattern to build the concrete data object (refer to Diehl et al, 2005.2). The concrete factory class always inherits from a super application factory class.

This architecture strictly separates the services together with their building processes from the persistent data. The service logic is encapsulated in the specific service object and only the interface of the service object needs to be advertised to a broker or trader function. "Get" and "set" methods of the concrete data object can be used by the concrete factory for data object interaction. The concrete factory, depending on the operation type, is responsible for building the object. A database handler is used to integrate the built objects in the Profile Model and objects that have been set as persistent can be stored in the database.

The service and application model is protocol independent. For a sample implementation SOAP protocol (Mitra N. et al, 2003) and web services are

considered. SOAP-based web services are a common supported way of realising SOA.

3.4. Service-Oriented Interoperability

Service-oriented interoperability between SS7-based and IP-based networks can be guaranteed by gateway-functionality (Diehl et al 2004). The gateway performs the necessary conversions between MAP messages carried on top of SS7 and MAP messages carried on top of SOAP. In GSM MAP messages are always encapsulated by Transaction Capabilities Application Part (TCAP) (ITU-T Q.771, 1997). In GSM TCAP is encoded by ASN.1/Basic Encoding Rule (ITU-T X.690, 2003) and in UMTS by the ASN.1/Packed Encoding Rule (ITU-T X.691, 2002). In order to support a service-oriented architecture TCAP has to be separated from MAP and embedded into SOAP. ASN.1 /XML Encoding Rule (ITU-T X.693, 2003) and ASN.1 Extended XER (ITU-T X.680, 2003) are able to integrate telecommunications messages into modern Service-Oriented Architectures.

A NGPR should integrate those Encoding Rules to enable service mediation from legacy systems.

4. Conclusion

The concept of a NGPR describes a centralized subscriber database that allows the integration of all subscriber related data in a single subscriber profile. The generic profile of all subscriber related data supports the efficient integration of multiple applications. The profile model is modular and data objects form the building blocks that can be reused in different services and applications. SOA is realized in a network-independent way for the telecommunication networks to support the transparent "access on demand" paradigm. Legacy systems and their data models can be integrated using appropriate gateway adaptation functions.

Research work will be carried out defining the final integrated architecture of the NGPR. Focus of the further work is interoperability, open interfaces, service mediation and the evaluation of the model.

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