Profiling for Mobility Context Management and Transport Service Provision in 4G Networks§

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Abstract : **Currently, mobile service provision is facing important advancements towards more flexible business models and fresh Internet-like services with the internetworking of several complementary access technologies using the Internet Protocol (IP) as a mean of integration. The result of such integration, also known as "4th Generation Networks", will require the provision of a "persistent transport service" of for users' session flows and transactions. In this paper we present the conceptual high level description of a context-based management distributed service and profiling system in order to provide this persistent transport for mobile user's data applications in a heterogeneous environment of IP-based network.**

1. Introduction

Currently, mobile service provision is facing important advancements towards more flexible business models and fresh Internet-like services with the introduction of new 2.5G/3G of mobile communication systems. Additionally, several complementary access technologies are evolving, for instance, broadband WLAN systems and broadcast systems are becoming available; systems like Bluetooth are being developed for ad hoc and short-range connectivity. The interconnection of all these access networks (ANs) using the Internet Protocol (IP) has been envisioned as the mean by which the user will be in some sense "always best connected". It is expected that the IP technology will be the basic mean for transport in the core (backbone) and ANs including personal area, ad hoc ANs and ANs in motion.

The results of such evolution, also known as "4th Generation Networks", are related to more flexible service provision characterized by dynamic user registration, flexible charging/accounting models; advanced profile management of users, networks and terminals; context aware systems and others [1]. It is a general point of view that 4G networks will provide continuous and "always best served" to "always best connected" users anywhere, anytime with anybody which means the provision of a persistent transport service for users' session flows and transactions.

This envisioned future imposes basic requirements in mobile user's terminal such as cross-layer and TCP/IP-based design; QoS, multi-homing and mobility support; adaptation and re-configuration at different level of the protocol stack, intelligent discovery and access network selection, ad hoc connectivity and roaming to other different networks [2]. In this paper we present the conceptual high level description of a context-based management distributed service and profiling system in order to provide a persistent transport for mobile user's applications in a heterogeneous environment of IP-based network.

The paper is organized as following: in section 2 we describe the model and concepts that we have introduced to abstract the problem of supporting a persistent transport service in 4G scenarios; in 3, a high level description of a MT design suitable for 4G networks is presented; section 4 introduces s our perspective of the use of mobility context information management system in 4G and an ontology-based solution to enhance current approaches of profile creation for context information representation; in 5, the high level description of the management system is presented; section 6 concludes the paper with different alternatives for the of a mobility context management service for a persistent transport provision in future scenarios.

2. Mobile Customer and Persistent Transport Service Provision in 4G Networks

In future 4G networks, it will be possible to access services and to use distributed applications independently of the time and the user location. When moving, a user will access different wireless services via his/her MT. We define "wireless services" (WiSs) as a set of functions and infrastructures related to applications and communications facilities offered to consumers by providers, and providing consumers with requested resources according to a service agreement.

WiSs will be provided by a wide range of players. In order to avoid complex classification of these players, we differentiate them by the main facilities that they offer. These belong to the class of "infrastructure

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service providers" which serve data transportation (e.g., AN service) or to the class of "application service providers" that correspond to the application layer and upper levels higher layers, Fig.1.b.

A mobile user will access to WiSs depending on its activities and preferences and its MT capabilities. In order to make an abstraction of the relationship between the mobile user and its MT when accessing to WiSs, we introduce the concept of "Mobile Customer" (MC), Fig. 1.a. A MC is a specific terminal configuration and application settings according to the current user's role.

During the day, the user will develop "roles", i.e., different activities and relationships with other individuals (e.g., business, private, leisure roles); in each role, the user might react differently. For instance, a business employer will require to get information as soon as possible regardless of the price. The user's roles are represented by its respective "profiles" of WiSs usage. These include preferences, interests, descriptions and aid in filtering information when executing applications and accessing WiSs.

The access to WiSs will also be determined by the type of MT used. MTs could offer different levels of portability, from laptops to virtual devices composed of different specialized devices. Other features can characterise a MT (human interface, cost, CPU, etc) that will influence its possible use. The degree to which it can interconnect with networks and other devices will be a key value.

When trying to make use of WiSs, an instance of a "Mobile Customer" (determined by the user, its role, and its applications and terminal configuration) will be set during the "association" with ANs. MCs will try to gain access to WiSs in places where different ANs and application providers are available. For example, a MC inside a shopping mall can access specific shopping services provided by a business through its isolated hot spot WLAN while s/he could also simultaneously access general application services through a wider WLAN which could be interconnected with a core IP network.

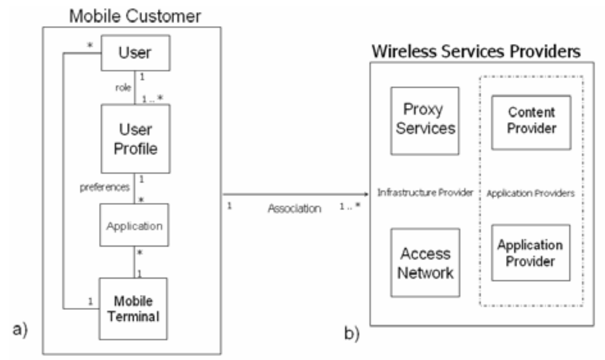

Figure 1. Persistent Service Provision amid WiS providers and MC.

The association allows the configuration of the MC whit the required IP parameters to be reachable through this AN. The configuration is possible by several means: DHCP, IPv6 address configuration and Mobile IP. Mobile IP allows to the MC to be associated with a specific AN (a home AN) even out of its domain. It makes possible the preservation of active sessions of non mobility-aware applications when the MC changes its wireless point of attachment in the AN (horizontal handover) or handoffs to other AN (vertical handover).

Mobility-aware applications may switch their data flows over different associations by means of multi-homing and mechanisms for mobility support at higher level (such as SIP extensions) when new ANs are available with more resources or the previous association is lost by wireless link drops. Therefore, the MT should be able to manage different simultaneous associations in order to ensure the "persistence" of their applications flows during horizontal and vertical handovers. MCs are not unchanging entities.

Additionally to IP parameters, a MC must re-configure and adapt its protocol stack and components to be able to support the requested transport service for an applications flow under variable network conditions, i.e., to provide a "persistent transport service" of its sessions. Among the configurable components and layers are the current QoS Service Provider, network interfaces, routing protocols, physical resources (e.g., CPU and memory) and others.

3. Terminal Architecture Proposal for Persistent Transport Service Provision.

In order to interoperate with 4G access network providing a persistent transport service, there are some fundamental requirements that the mobile terminal has to fulfill such as a TCP/IP-based design, QoS and mobility support, adaptation and re-configuration at different level of the protocol stack, multi-homing, intelligent discovery and access network selection, ad hoc connectivity and roaming to other different networks. Taking these requirements into account, we have defined a high level description of a TCP/IP-based mobile terminal architecture (Fig. 2). Our proposal is based on a previous generic reference model, BRENTA, defined during our participation in BRAIN/MIND projects [3]. In general, the architecture is divided in two main planes: the user data or "network plane" and the QoS or resource "control plane". The first deals with user data handling, and the latter deals with the network plane management, including the coordination of local, network, and peer's resource management in order to achieve required QoS levels.

In the user data plane, different kind of applications from Internet legacy applications (Web, mail, etc) to adaptive and QoS-aware applications relay in a generic interface, the "Common QoS Interface" (CQoSI) [4], to request Hard (IntServ-like) and Soft (DiffServ-like) QoS support independently of the underlying QoS technologies. The CQoSI is based on generic primitives and parameters (expressed as a range of bounded values instead of fixed valued parameters).

A middleware, the "QoS Processor", translates these parameters to network level QoS parameters according to the available QoS Service Provider (QoSSP).

The main objective of the QoS Processor is to provide an adaptable and re-configurable transport service to active sessions during the MC displacement.

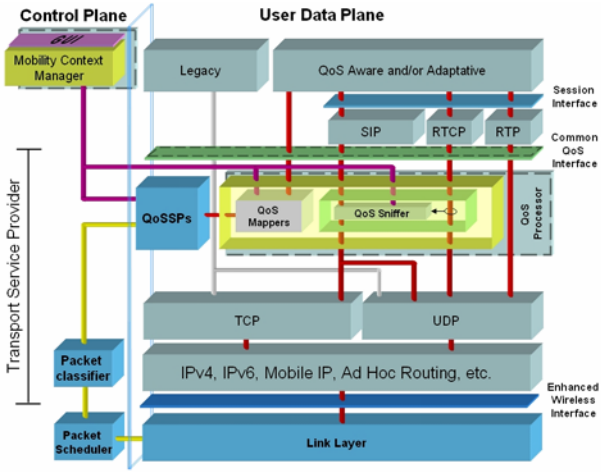

Figure 2. Proposed TCP/IP-based terminal for 4G networks.

The QoS Processor also interacts with the "Mobility Context Manager Service" (explained below), providing information about incoming and outgoing sessions requests by SIP User Agents and the state of active flows monitoring their parameters periodically (e.g., inspecting RTP reports by the QoS sniffer module). The "Transport Service Provider" encompasses transport protocols (UDP or TCP), QoSSPs and networking functionalities. The QoSSP implements, maintains, and handles specific QoS signalling (RSVP, INSIGNIA, NSIS-based protocol, etc). The Transport Service Provider is also in charge of the association with access network which offer Internet connection services based on IP parameters (IP addresses, default routers, etc), IP mobility and routing support for different types of IP-based networks. An "Enhanced Network to Link layer interface" provides to the upper layers a standard link layer interface for different underlying link technology and enhances the interaction between these layers.

4. Context and Profile Definition

In future heterogeneous environments of Wireless and Mobile Networks it will be possible to find situations where the MT shall be able to take its own decisions related to its adaptation and configuration without the control from its home and visited access network taking into consideration the current context, user's roles, ongoing application execution and access network features [4].

The MT should be aware also of the user activities patterns in order to offer the best services to mobile users in a coordinated manner with the main entities implicated in the environment around the MC, such as the Access Network, Application and Content Providers. These patterns are governed by user's roles which state his (her) preferences when developing different activities. Such preferences and user context information are usually declared in a profile, i.e., a set of data exhibiting the significant features of a particular entity.

4.1. Management of Context Information for Persistent Transport Provision

The management of the knowledge of user context aspects such as the user identity, its activity and the respective location and time is one of the main issues of "Context-aware Systems". A system is context-aware if it uses a context to provide relevant information and/or service to the user. Context is defined as "any information that can be used to characterize the situation of an entity" [5]; an entity could be any element like a person, place or object.

The use of context-aware system has been traditionally focused to the adaptation of services and applications according to user context. Projects like Cooltown, Context Toolkit and M3 are well known examples of context-aware architectures for this purpose [6]. In the area of mobile communication services, the Open Mobile Alliance (OMA, previously WAP Forum) and 3GPP had defined architectures for network services and content adaptations in the Content Provider taking in consideration the capabilities of the terminal device and the user preferences[7][8].

More recently, the exchange of context information has been proposed for the proactive configuration of IP-based access network elements in order to improve the handover process of the MT. In the IETF, the Seamoby WG has proposed a Context Transfer Protocol that exchange context information such as security, policy, QoS, header compression, and AAA information to preserve the session flow in intra-domain handover [9].

Taking into the consideration that the MT can be attached to unmanaged ad hoc networks and isolated access networks, that the MT can get information of features of surrounding AN through its radio interfaces, that the MT manages information related to user preferences, device capabilities and active session, we believe that the MT is in a better position to make a decision about access network selection that the network operators. Even more, we consider that context-aware system concepts can also be exploited for the orchestration of MT configuration and adaptation when providing the "persistent transport service" (PST) to application flows.

Although, when the MT lacks of enough memory and power processing, it will be useful to obtain support from network infrastructure for PST provision.

4.2. Context information representation approaches

One of the main issues related to context management systems, is the representation of context information, i.e., the way in which context information is stored and transported. Some markup languages and information models have been developed and proposed as basis for context information representation:

- *XML* is a meta-language for describing markup languages that provides a facility to define tags and the structural relationships between them. Since there is no predefined tag set, i.e., a standard information model, there cannot be any preconceived semantics.

- The *Resource Description Framework* (RDF) has been developed to provide unambiguous methods of expressing simple semantics [10]. RDF is used for describing and interchanging metadata following a basic information model in which any resource ("subject") is related to a literal value or other resources ("objects") by means of a description property ("predicate").
- *RDF Schema* (RDF-S) is used to improve RDF semantics [11]. It is useful for the statement of classes, hierarchy of classes and properties, and to indicate which classes and properties are expected to be used together for declaring "vocabularies" (i.e., the sets of property-types defined by a particular community).
- The *Composite Capability/Preference Profiles* (CC/PP) [12] uses RDF for limited representation of context information (Fig. 3.a). It defines a "two-level" hierarchy of components and attribute/value pairs for describing a profile of device capabilities and user preferences that can be used to guide the adaptation of content presented to that device. CC/PP specification does not mandate a particular set of components or attributes, choosing instead to defer that definition to other standards bodies, for instance, the User Agent Profile (UAProf) [7] proposed by OMA. CC/PP suffers several drawbacks when describing context information: it is only based in RDF, loosing the flexibility provided by RDF-S when defining relationships between classes; in addition, it only describes a limited set of components that could be extended to describe richer context information such as network interfaces, QoS, location, etc; there are also a large number of complex relationships and constraints that need to be captured by a profile representing context information that is not possible with RDF or even RDF-S.

RDF and CC/PP information model are serialized in XML.

- *General User Profile* (GUP) [8] is currently defined by the 3GPP. GUP is a collection of user related data which affects the way in which an individual user experiences services. It is serialized in XML schema. It has a more complex but flexible structure (Fig. 3.b). The GUP contains one or more Profile Component Group (PCG) composed by one o more Profile Components (PC). The former contains the Data Payload which is structured likewise in Data Element (DE) and Data Element Groups (DEG). Besides the identification of profile instances, each instance of PC is also identified to be shared among instances of user profiles.

After the reviewing of different languages and information models we consider that 3GPP GUP model information is suitable for representing our "mobile customer" concept, because its structure provides a better organization for introducing complex relationships between elements than the RDF CC/PP approach. However, it lacks of the benefits provided by other languages focused on semantics, such as the *Web Ontology Language* (OWL, not an acronym) [13].

OWL is the ontology language proposed by the W3C. Briefly, Ontology is the formal definition of a set of concepts that describe a domain, their taxonomy, interrelation and the rules that govern these concepts.

OWL expands RDF-S information model adding more vocabulary along with a formal semantics for describing properties and classes, relations between classes (e.g. disjointness), cardinality (e.g. "exactly one"), equality, richer typing of properties, characteristics of properties (e.g. symmetry), and enumerated classes.

Among other features, OWL is a standard ontology language used in several different areas; it facilitates greater human and machine interpretability than that supported by XML, RDF and RDF-S; it provides the ability to declaratively express the relationships between entities enhancing data interoperability, and there are several free tools available to develop, edit, visualize and process ontologies based in OWL.

Based on this language, *OWL-S* [14] specifies an ontology of "services" that makes possible functionalities with a high degree of automation to discover, invoke, compose, and monitor Web resources offering particular services and having particular properties. OWL-S provides three essential types of knowledge about services: the "Service Profile", that advertises the service and presents what it does; the "Service Model", that describes how it works by means of a process model, and the "Service Grounding" which details how to interact with the service. After considering the benefits that OWL can offer for the context information representation by means of profiles, we have used it to define different kind of profiles (for users, MTs, access network, etc.) following the GUP structure and leveraging OWL features. Even more, we have used OWL-S as a part of the design of a manager of mobility context information that assists the MT in both the access network selection and the persistent transport service configuration

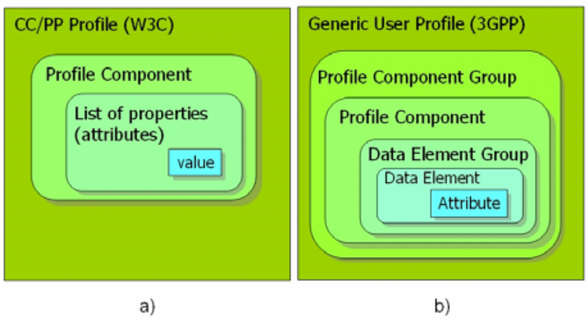

Figure 3. Comparison between W3C CC/PP and 3GPP GUP.

5. Context-Aware System for intelligent access network selection and terminal configuration

In this section we present a high level description of the "Mobility Context Manager Service", a control plane functional component of the mobile terminal architecture proposed in section 3. It develops three functionalities: the generation of mobility context information, the access network selection and the persistent transport service configuration, i.e., the adaptation and/or re-configuration control of the user data plane when supporting new and ongoing sessions.

5.1. Mobility Context Manager Service

The Mobility Context Manager Service is depicted in Fig. 4. The description (the presentation, modeling and grounding) of a distributed implementation of this service is made with OWL-S. The first functionality developed by the service is the generation of mobility context information, i.e., the available ANs and their features in the current MC location. It gathers this information from AN advertisements received in the MC's network interfaces. The raw information is transformed into AN Profiles (ANPs), which feed the Mobility Context Generator component. The last is in charge of the creation of an updated Mobility Context Profile (MCP). All profiles have been defined in OWL.

The MCG retrieve each ANP separately until there is no more profiles in a repeat-while loop. Each ANP is collocated in a provisional list (a container). Finally, the list is processed into a MCP and saved in a repository.

The current MCP is used for the Access Network Selection (ANS) process. The ANS is done based in the MCP and the Mobile Customer Profile (MCuP) both of them stored in their respective repositories. The ANS process gets both profile and first it evaluates the current user role and the list of application preferred settings specified in the MCuP according to the role. Then, the ANS process compares the list of application settings with the features of ANs in the MCP, until it finds a suitable network. If there is no a best AN then the ANS process resolves to select one based on default application settings. Then, the MC establishes the AN association.

The last function of the Mobility Context Manager Service is the Persistent Transport Service Configurator (PTSC). This component is in charge of the mobile terminal configuration when a new association will be established or there is any change in the mobility context that can modify the current PTS behavior. The PTSC receives a message form the ANS process advertising the association and requesting for configuration information. The PTSC replies with a Persistent Transport Service Profile (PTSP), which contains parameters for the configuration of different required components and functionalities of the MT protocol stack.

The PTSC interacts with different management systems and servers in the access network in order to retrieve these configuration parameters.

All the processes were modeled with the composite process visual editor of OWL-S Editor [15] which is used over Protégé, an open-source development environment for ontologies and knowledge-based systems[16]. A "process model", in OWL-S, is a specification of the ways a client may interact with a service.

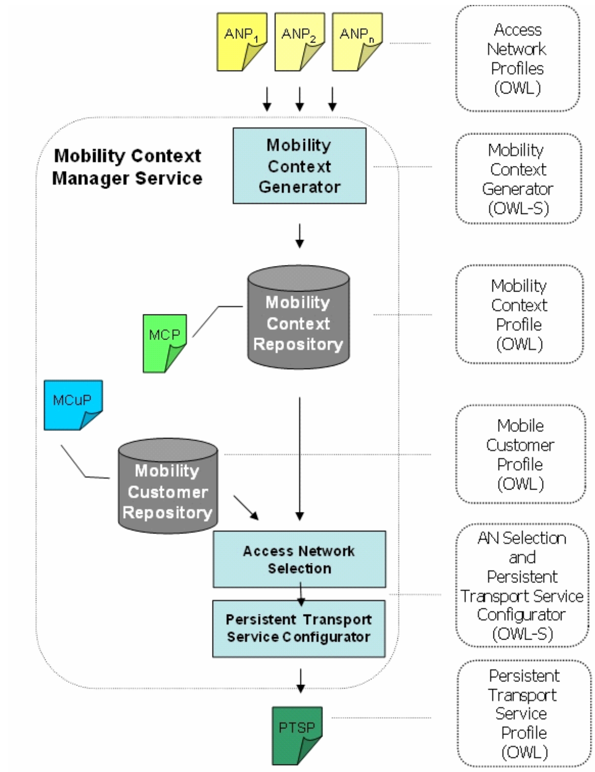

Figure 4. Mobility Context Manager Service.

5.2. Information model of the Mobility Context Manager Service

We model different context-information by means of profiles. These are used as inputs and output of the described Mobility Context Manager Service.

The Access Network Profile (ANP) describe the features of an AN organized in a set of profile components groups (PCGs). The main features included in ANPs were derived from different reports and papers of several standardization groups, such as WWRF, IETF, IEEE and 3GPP2, which have deliberated on AN selection issues [17][18].

Each PCG describes a feature that could be relevant during the AN selection before the association establishment. These feature are: AN identification, QoS (available bandwidth), cost, security/authentication methods, list of intermediary network providers between the current visited AN and the home network, roaming agreements, middleboxes (NAT, firewalls, SIP servers), etc. After the collection of these profiles, the MCG produces a Mobility Context Profile (MCP) which stores context-information of the surrounding heterogeneous environment of ANs. Each of its PCG is focused in a particular feature such as cost, QoS, etc. and the respective offers of each advertised AN.

The MCP is used along with the Mobile Customer Profile (MCuP) by the Persistent Transport Service (PTS) Configurator to produce a PTS profile that guide the adaptation and re-configuration of the terminal protocol stack. The MCuP is composed of a set of PCGs that store information with respect to the user and its preferences per role (Fig. 5.a), default and preferred software settings (Fig. 5.b), and terminal hardware and software capabilities.

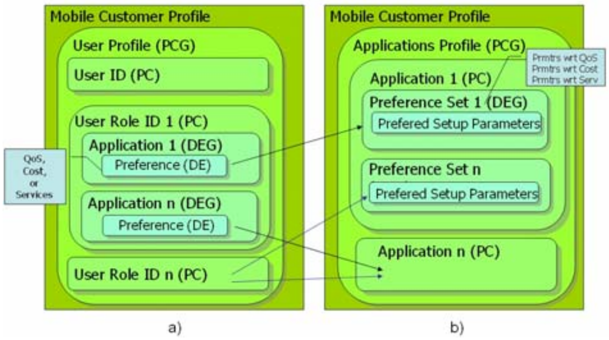

Figure 5. Some PCGs of the MCuP and their relationship.

The MCuP is the union of user, application and terminal sub-profiles. The “User Profile” includes the criteria of preference used by the user in each of its roles when executing a particular application; these criteria could be QoS, Cost, etc., all of them sequentially listed. The “Application PCG” presents the list of parameter values that must be used for the execution of an application according to the criteria established in the user role.

The last profile of our information model is the Persistent Transport Service profile which consist of a series of PCGs that enumerate all the parameters that must be set per protocol layer and terminal functional component for the new (or ongoing) data session. All the profile were edited with the OWL plugin [19], an extension of Protégé with support for the Web Ontology Language (OWL).

6. Possible Deployments of Mobility Context Manager Service

There are several possible variants for the implementation of our proposed Mobility Context Manager Service (MCMS). As we have suggested, in future 4G scenario the MC should develop for its own the ANs discovery and selection, the mobility context generation and the persistent transport service provision. This MC’s autonomy will be possible only if the mobile device will have enough computational resources and a new business model will allow the free association to any ANs. In such scenario, all the components of the MCMS could be developed in the MC.

Current business model requires the user subscription to a home Access Network Provider. The AN Provider establishes the association parameters to allow the access to WiSs by the MC. This association could be established out of the domain of the home AN Provider by means of vertical handover mechanisms and roaming agreements with other AN Providers. In this kind of scenario, the deployment of the MCMS will require the distribution of its components among different entities as the MC, the home and visited AN Providers. For instance, the Mobility Context Generator could be developed in MC while the AN selection could be implemented in the home AN. There an agent could confirm also the advertised parameters in the Mobility Context Profile and apply the respective policies to WiSs the user wishes to execute that are announced in the Mobile Customer Profile. The Persistent Transport Service Profile (PSTP) could be generated with the collaboration of home and visited ANs and submitted to the MC for its configuration.

In order to illustrate the distribution of the MCMS components we present a simplified sequence diagram of an alternative future scenario (Fig. 6) in which the MC has the ability to perform the Mobility Context Generation (MCG) and Access Network Selection (ANS) tasks, while the Persistent Transport Service Configuration (PTSC) is provided by an agent in the visited AN. Here, ANs advertise their features which are collected by the MT network interfaces. The MCG composes a mobility context profile that is used during the ANS process. In this step, the ANS process evaluates the user and application needs and compares them with the MCP selecting the best offered AN. Then, the MC associates itself with the chosen AN. The MC localizes the PTSC component service in the URL announced in the AN profile or asking for it to a UDDI registry. The MT sends a message to the PTSC requesting a specific PTS profile. The PTSC interacts with other servers (such as policy manager, QoS managers, AAA servers, etc) to collect all the configuration parameters that will be necessary to access the pretended service over the AN. Finally, MT receives an answer with the requested PTSP which allow it configure itself to access the WiSs.

The PTSC can be aware of events in the access network that can affect the perceived QoS in the offered service. Therefore, related partial information (some profile component groups) can be sent to the MC in order to adapt the current configuration according to the new situation. The performance of the proposed MCMS is out of the scope of the paper, but a fast inspection of the sequence diagram makes possible to deduce that it could overcome the QoS problems related to vertical handovers and roaming events reducing the delay between the interactions of different entities taking this proactive approach.

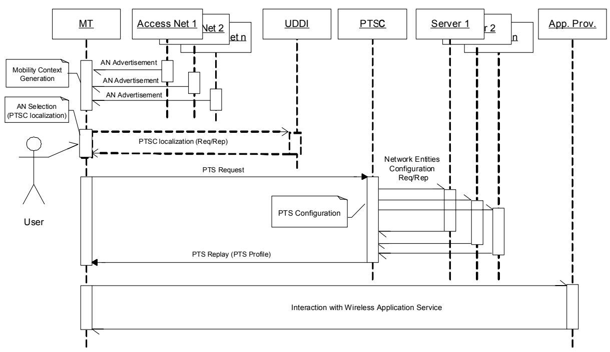

Figure 6. Sequence diagram of the interaction between the components of Mobility Context Manager Service.

In order to provide the required flexibility of the service deployment, we take advantage of semantic web solutions. This technology allows the sharing and processing of data and services by automated tools (software agents) even when these services have been designed totally independently. Offering the mobility context management service (and therefore, the persistent transport service provision) at high (application) level allows us to overcome interoperability problems in heterogeneous systems.

The current implementation of the MCMS has been done following a top-down approach. The high level implementation of the service, i.e. the descriptions of the service components for their discovery, invocation and composition have been developed with the use of the OWL-S Editor [15], an extension of the Protege-2000 development environment for ontologies and knowledge-based systems [16].

7. Conclusions

Future 4G Networks impose fundamental requirements in mobile user's terminal such as cross-layer and TCP/IP-based design; QoS, multi-homing and mobility support; adaptation and re-configuration at different level of the protocol stack, intelligent AN selection, etc. In this paper we have presented a high level description of a TCP/IP-based terminal architecture for 4G networks which cope with these requirements and, specially, we have focused on the high level description of a context-based management distributed service and profiling system that support the mobile terminal for the provision of persistent transport to user's applications in 4G networks. The distributed system, that we have named it "Mobility Context Manager Service" (MCMS), is part of the terminal control plane and it is used for the control of the configuration of the terminal during vertical handover process and roaming. The MCMS is a context-based service composed of three basic components for the collection of information related to the surrounding access networks, the access network selection and the terminal configuration for persistent transport service. These components exchange context-based information of the mobile costumer in form of profiles, and we have proposed the use of ontology languages, such as OWL, to define our information model after the analysis of several approaches. Even more, we have described each service component by means of OWL-S, a schema based on OWL to discover, invoke, compose, and monitor service resources. This currently evolving method will allow a faster and easer deployment of the proposed MCMS in future scenarios where mobile terminal should be more autonomous.

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