Adaptive Middleware Platform for Next Generation Mobile Networks

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Abstract: - Mobile 3G/4G cellular networks, along with Wireless LAN and satellite global positioning and communications networks provide a framework to support global coverage and instant communications, even in the most inacces-sible areas of the planet. In this highly heterogeneous communications and services environment, we propose a lightweight Adaptive Distributed Middle-ware Platform (ADMP), which aims to enable seamless service provisioning to mobile users and professionals anywhere, anytime and in any context. ADMP is expected to "liberate" applications from space and time limitations, networks, platforms and device dependences, minimise time-to market con-straints and eliminate major hurdles that hinder the deployment of new mobile services and applications.

Key-Words: - Adaptivity, Middleware, Service Creation, Location Awareness, QoS, Mobility

1 Introduction

In the near future, advances and innovations in the microelectronics, telecommunications and audio-visual industries will enable individuals to wear, carry, own or use a number of network devices varying from PDAs to innovative wearable gadgets (e.g. watches with blood pressure sensors, sunglasses with camera, earphones and monitor) able to gain access to ubiquitous services. In parallel, multi-technology, ambient networks in houses, cars, corporate environments or public areas are deployed or are under deployment. Fixed and wireless MANs, Wireless LANs (WLAN), 2G+/3G and beyond cellular networks, along with satellite global positioning, navigation and communications networks provide a framework to support global coverage and instant communications, even in the most inaccessible areas of the planet.

Though there are many powerful open middleware solutions for service provisioning, supported by large consortia and promoted in major fora and standardization bodies, it is highly improbable that there will be, in a near future, a single dominant middleware platform, which would be good enough for all networks, devices and purposes. In this paper, we propose a lightweight Adaptive Distributed Middleware Platform (ADMP) able to enable seamless service provisioning to mobile users and professionals anywhere, anytime and in any context by interoperating with existing platforms. The proposed platform introduces a layer of meta-polymorphic intelligence, between the network infrastructures, existing platforms, and mobile applications, so as to offer a unified, ambient-aware, adaptive, and personalized service-provisioning environment. In order to maximize interoperability and wider acceptance, ADMP is based on open interfaces and integrated with and/or expanding already available solutions, standardized or under standardization i.e. 3G Open Service Access (OSA), Virtual Home Environment (VHE), Parlay/ParlayX, Customized Applications for Mobile network Enhanced Logic (CAMEL), Mobile Application Part (MAP).

The paper is organized as follows. In section 2, we describe the main requirements from a distributed middleware platform for mobile communications, while in section 3 we describe the platform architecture. In section 4, we describe the realization of some major features of this architecture. Conclusions are recapitulated in section 5.

2. Middleware Platform Requirements

In order to provide seamless services to mobile users and professionals anywhere, anytime and in any context, the proposed platform should fulfill or tackle the following requirements:

2.1 Platform Interoperability

One of the major trends towards 4G [1] is the great heterogeneity of the deployed networks. Given the technological divergence of private and public networks, the issues of service portability and interoperability have become of prime importance not only for service providers and network operators, but also for service and application developers. Currently, there are many efforts, under development or standardization, to provide a middleware solution for open network interfaces, but most of them practically focus only on 2G+ and 3G cellular networks. The most important efforts are:

- CAMEL a GSM recommendation to support Intelligent Network (IN) and terminal position-related services for roaming users [2].
- JAIN is a set of Java-based network APIs that aim to bring service portability and secure network access to telephony and data networks.
- Parlay is a technology independent API, designed for mobile, fixed and next-generation IP networks [3]. Parlay is based on open standards such as CORBA, Java, UML, and provides applications APIs for: mobility, location management, call control, messaging, content based charging and policy management.
- Parlay-X specification (April 2003) details a set of simple web-services to be used as building blocks for telecom applications.
- PAM Forum focuses on advanced mobile applications that allow the communication between humans based on their current connectivity to the network (presence) and their current activities. In April 2003, PAM merged into the Parlay Group.
- OMA aims to ensure seamless mobile services across different wireless networks, mainly concentrating on cellular networks. In May 2003 the Parlay Group and the OMA signed a co-operation agreement for the two groups to work together.
- OSA, defines an architecture that enables applications to make use of network functionality through an open and standardised API specified in OMG IDL.

Interworking between middleware platforms is already in progress, e.g. OSA provides mapping recommendations to CAMEL-based mobile networks, a Parlay Gateway has been specified etc. Recently, 3GPP, ETSI and Parlay Group have created a Joint API Working Group targeting the specification of OSA/Parlay APIs, while the close co-operation with JAIN assures the realization of this API in Java. However, interworking between components of the same service, running on different middleware platforms is still immature and significant efforts are required in order to define and develop service-access interfaces and efficient interworking functions.

2.2 Service Personalization

Service personalization will also be very important. In 3G networks, the Virtual Home Environment (VHE) provides service personalization. According to ITU/ IMT2000 "VHE is a capability whereby a User is offered the same service experience in a visited network as in his Home system" [4] while according to 3GPP, "the VHE ensures that users are consistently presented with the same personalised features,…, whatever terminal, wherever the user may be located" [5]. However, appropriate interfaces' extensions have to be defined in order to provide service personalisation not only in cellular networks, but also in satellite links, wireless LAN and picocell networks.

2.3 Location Awareness

Location awareness is equally important for future mobile applications and service. However, access to network elements, like CSCF or HLR, is only possible within the network operator domain, by using mobile network specific concepts (CAMEL, MAP). Consequently, there is no standardized way for third party applications to use these functionalities. Also OSA provides an interface that can be used to request the location of a user in the form of less (i.e. identification of the radio cell), or more accurate (i.e. geographical position) reports. On the other hand there are also GPS based location solutions [6]. The most important are the Enhanced Observed Time Difference (E-OTD) and the Assisted GPS (A-GPS). An obvious problem with the existing services is that knowing somebody's general location is in many cases unhelpful, as in order to meet him/her, one has to give a call to find out exactly where he/she is.

2.4 Quality of Service

In the developing open service marketplace service providers will differentiate themselves not only on the functionality of the (atomic) services they offer, but also through the levels of configurability and QoS assurance that they can provide. Optimal QoS assurance for individual services in a heterogeneous and highly dynamic environment is by itself a challenging research topic. Consideration of composite services adds a significant degree of additional complexity to this problem, since the optimal allocation of network resources in a given scenario must be coordinated between the constituent atomic services in order to maximize the utility of the composite service to the user. User/terminal mobility between different administrative domains complicates the issue further. OSA/Parlay provides mapping of the service QoS parameters onto network-specific QoS parameters. However, other required functionality like dynamic QoS management, dynamic QoS negotiation or re-negotiation if traffic falls below the lowest guaranteed QoS traffic class, coherent bandwidth allocation and priority management are not supported.

3. Middleware Platform Architecture

A unified platform should target all types of access networks, varying from picocells and WLANs to satellite links. Various middleware solutions are available over these networks, while the increasing diversity of devices – terminals, network elements, and application servers – imply that in the near future, there will not be a single dominant middleware platform, which would be good enough for all devices and purposes. Thus we assume that various platforms (e.g. JAIN, OSA, Parlay, CAMEL), platform gateways (OAS/Parlay) and APIs will be available over these networks.

The proposed Middleware Platform Architecture is shown in Fig. 1. In order to achieve interoperability with the most open way, we adopt the Object Management Group (OMG) Model Driven Architecture (MDA). The MDA process, goes far beyond the CORBA based interoperability at the level of standard component interfaces, and places formal system models at the core of the interoperability problem. What is most significant about this approach is that the system definition exists independently of any implementation model and has formal mappings to many possible platform infrastructures (e.g., Java, XML, SOAP). Following

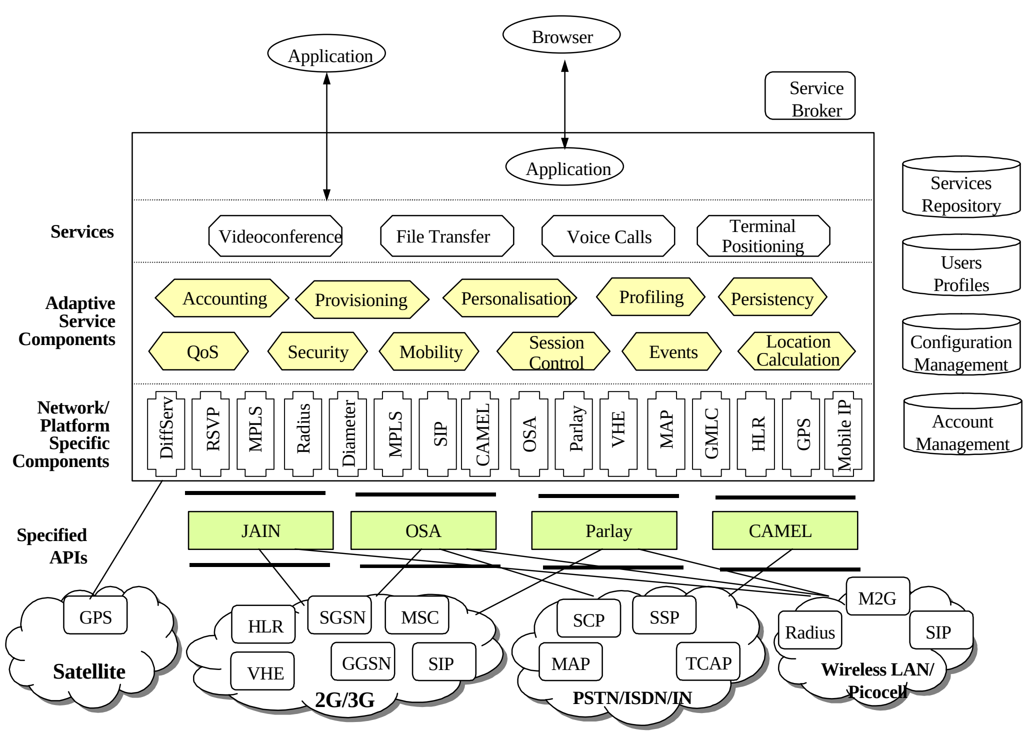

Fig. 1. Proposed Middleware Architecture

the MDA approach, Services are described using formal models, initially expressed in a platform-independent modeling language, such as Unified Modeling Language (UML). Services that can be identified are: File Transfer, Voice Calls, Multiparty Videoconference and Terminal Positioning. Applications that utilize these services, will also inherit their adaptivity features.

The adaptability of the services is based on the proposed Adaptive Service Components (ASCs). The ASCs are polymorphic components, specialized for each functionality or feature, able to adapt to external triggers. For example, whenever the network layer reservations are violated, the relevant ASCs will be triggered to adapt themselves to the available network resources, based on rules, scenarios and service level agreements (SLAs). In order to achieve this polymorphism, ASCs will follow the disciplines of the OMG MDA's Metamodeling. The metamodeling strategy is ultimately achieved via shared metadata, while understanding metadata consists of the automated development, publishing, management, and interpretation of models. The technology provides dynamic system behavior based on run-time interpretation of such models. Based on this technology, ASCs will be highly interoperable, easily extended at run-time, and completely dynamic in terms of their overall behavioral specifications (i.e., their range of behavior will not be bound by hard-coded logic). As it is shown in Fig.1, various ASC have been identified including: Location Calculation, Session Control, Mobility, QoS, Security, Profiling, Personalization, Provisioning.

The platform-independent ASC are subsequently translated to Network/Platform Specific Components (NPSC) by mapping the ASC model to some implementation language or platform (e.g., Java) using formal rules. Development and integration may be facilitated through common platform services and programming models. For example, J2EE enables implementation and deployment of component-based, distributed applications, while the Java community is developing pure Java programming models in the form of J2EE standard APIs. Examples of NPSC may include components to interface OSA, Parlay, VHE, GMLC, HLR, GPS, SIP, MPLS, DiffServ, RSVP. In many cases, when the platform offers an open API (e.g. OSA, Parlay), the NPSC will just wrap the functionality, while in other cases (e.g. SIP, GPS) full-fledged NPSCs should be implemented.

Finally, active Services/Agents, like Service Broker, Services Repository and User Profiles warehouse support automatic services provisioning and self-configuration based on user's preferences. Where applicable, these active components will be based on the XML Metadata Interchange (XMI) and Common Warehouse Metamodel (CWM) OMG standards.

4. Major features realization

Over this architecture, we describe the realization of major features, namely: Context Awareness & Service Personalization, QoS Adaptation and Location Awareness.

4.1 Context Awareness & Service Personalization

We define context-awareness as the varying behaviour of an application according to the current service context, influenced by user's preferences, terminal characteristics, communication links properties, network capabilities, spatio-temporal (time and space) information, service state, history etc. For example, a user may use a PDA to participate in a multimedia conference via the GPRS or UMTS network. The user would hear the audio stream, receive reduced resolution video and have active ftp sessions in the background. When a more

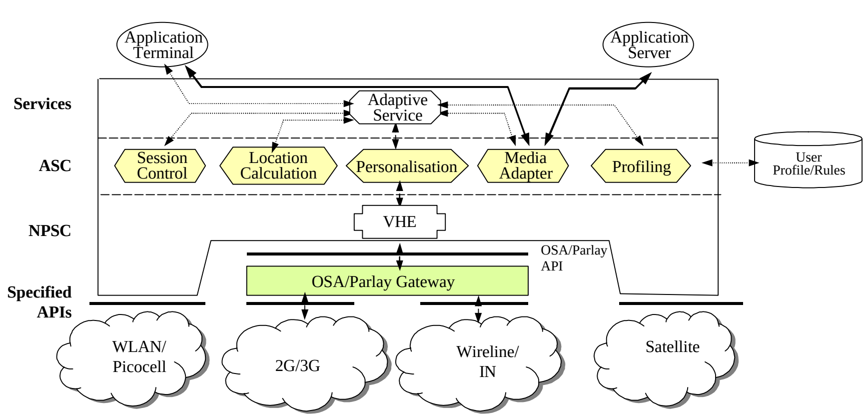

Fig. 2. Context Awareness & Personalization Architecture

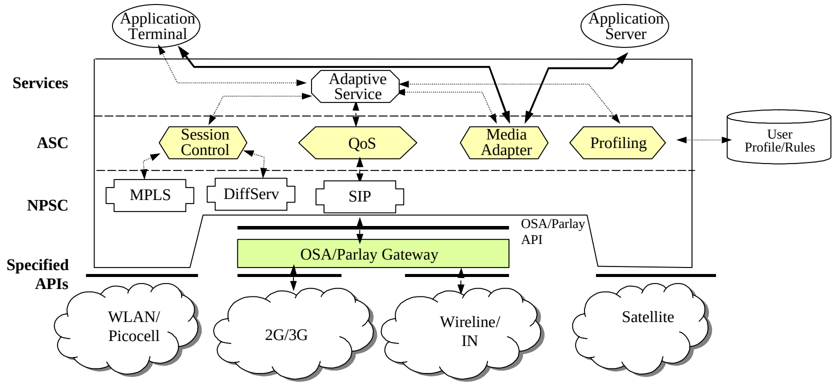

Fig. 3. QoS Adaptation Architecture

suitable network is detected (e.g. WLAN), the relevant ASC will be informed, and if the user has the necessary permissions and has enabled such an option (personalization), all or a subset of its active communication sessions will be transferred, resulting in better audio quality, better video resolution and faster file communication.

The proposed approach in context awareness and personalization is shown in Fig.2. The Personalization ASC co-operates with the Session Control, Location Calculation, Media Adapter and Profiling ASCs to enable the required functionality. The Session Control will manipulate the connections via a SIP NPSC, and may also include interworking with legacy session signaling mechanisms for both fixed and wireless systems. The Location Calculation ASC as described later calculates the exact terminal position, and the Profiling ASC interfaces with the User Profile/Rules warehouse. The Personalization ASC retrieves network information from the VHE NPSC, in case such information is available, and directly or via the service receives the relevant information in order to control the application's behavior.

The adaptation to the network and terminal capabilities will be done by the Media Adapter ASC and controlled by the Adaptive Service element. Initially on the terminal side the Connection/Session Control ASC will establish a connection. According to the transport network this will be achieved via the OSA/Parlay or other NPSC. The content (data and streams) will flow from the Application Server to the Application Terminal via the Media Adapter ASC over TCP/IP connections. The value added Adaptive Service, will receive relevant Location Calculation and Session Control information through the CORBA based API, retrieve user preferences and Service Level Agreements (SLAs) from the User Profile and control the Media Adapter ASC, which will adapt the content flows to the terminal operation environment. The Media Adapter will support the used network protocol to provide the terminal with the appropriate media stream (e.g. announcements, multimedia/video).

The Adaptation Service specification will be based on a flexible engineering scheme, which will enable the Media Adapter to be wrapped as mobile agent. The Media Adapter agent will co-operate with the Application Server to adapt the media streams to the type and characteristics supported by the terminal and to the used network. At the terminal side, a corresponding agent will decode the stream and provide content output at the terminal.

4.2 QoS Adaptation

QoS adaptation issues are addressed by incorporating QoS aware ASCs and NPSCs into the proposed middleware framework. This enables the application programmer to concentrate on implementing the business logic of the application, while the ADMP framework provides context-aware and QoS adaptation functionality.

Fig. 3 shows a typical scenario in which a SIP NPSC informs the QoS ASC of changes in the available network resources. Co-operation with the Location Awareness ASC further enhances the scenario. The QoS ASC reconfigures itself to reflect the new state. The Adaptive Service now co-ordinates with the Profiling ASC to retrieve user preferences and SLA and uses this information to control the Media Adapter ASC to adapt the content flow if necessary. The Adaptive Service will also control the Session Control ASC, which in turn controls a QoS NPSC (this could be MPLS, DiffServ, RSVP, etc.) to adjust the QoS delivery to the terminal accordingly.

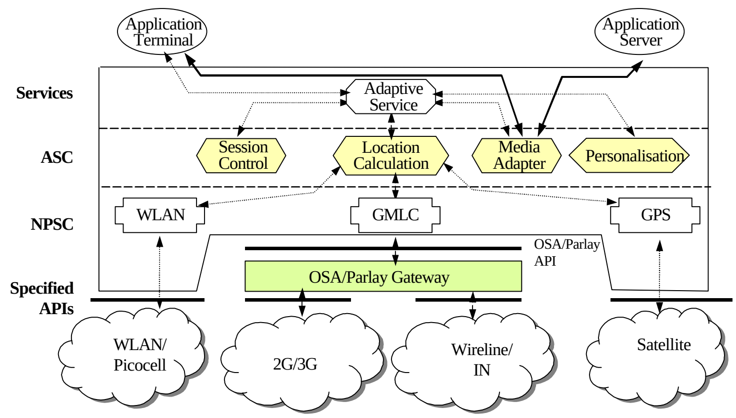

Fig. 4. Location Awareness Service Components

4.3 Location Awareness

The proposed Location Awareness service implementation is completely independent from the actual service utilization environment (network type, terminal type, user preferences). To enable this feature, the Location Calculation ASC offers an abstract API to the applications. An overview of the proposed location calculation and adaptation scenario is given in Fig.4.

Over the 2G+/3G/4G cellular networks, location information and location calculation and control functions are retrieved from the OSA/Parlay Gateway (i.e. Le and Cx interfaces). This information is provided to a GMLC (Gateway Mobile Location Center) NPSC. Additionally, WLAN and GPS NPSCs receive more accurate location information, based on terminal positioning signal measurement functions. The three NPSC provide information as meta-data to the polymorphic Location Calculation ASC, which calculates the exact terminal position. Based on the Location Calculation ASC, the Media Adapter and the Personalisation ASCs are triggered to adapt the service and the media content accordingly.

5. Conclusions

In the forthcoming 4G environment, fixed and wireless MANs, Wireless LANs (WLAN), 2G+/3G and beyond cellular networks, along with satellite global positioning, navigation and communications networks will provide a framework to support global coverage and instant communications, even in the most inaccessible areas of the planet. Though there are today many powerful middleware solutions for service provisioning, it is highly improbable that there will be, in a near future, a single dominant middleware platform, which would be good enough for all networks, devices and purposes. In this paper, we propose a lightweight Adaptive Distributed Middleware Platform (ADMP) able to enable seamless service provisioning to mobile users and professionals anywhere, anytime and in any context by interoperating with existing platforms. The proposed platform introduces a layer of meta-polymorphic intelligence, between the network infrastructures, existing platforms, and mobile applications, so as to offer a unified, ambient-aware, adaptive, and personalized service-provisioning environment.

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