A SELF-ADAPTIVE SERVICE PROVISIONING FRAMEWORK FOR 3G+/4G MOBILE APPLICATIONS

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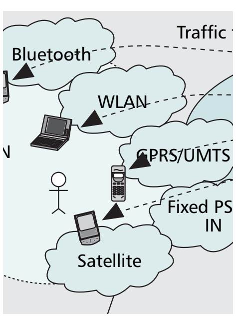

In face of the increasing acceptance of the notion of next generation networks, there is the need for the realization of next generation service delivery platforms, which allow for the seamless and adaptive provision of multimedia information and communication services to mobile users.

ABSTRACT

In light of the increasing acceptance of the notion of Next Generation Networks (NGN), which will result from the convergence of the fixed and mobile telecommunications, Internet, and entertainment sectors, there is a need for the realization of next-generation service delivery platforms to allow seamless and adaptive provisioning of multimedia information and communication services to mobile users. This means that in such an NGN environment different end systems, access networks, and service platforms have to be integrated. For this highly heterogeneous communications and services environment, we propose a self-adaptive service provisioning middleware framework (ASPF), which, by interoperating with existing wireless and wireline service delivery platforms, aims to enable seamless omnipresent service provisioning to mobile users anywhere, anytime, and in any context. The ASPF is intended to "liberate" applications from space and time limitations, networks, platforms, and device dependences, minimize time-to-market constraints, and eliminate major hurdles that hinder the rapid deployment of new mobile services and applications. Key to this goal is interworking/integration with current SDPs, such as IN/CAMEL, OSA/Parlay, and the emerging IMS.

INTRODUCTION

The continuing evolution of microelectronics, telecommunications, audio-visual techniques, and information services is delivering the technology to fulfill the vision of omnipresent services. Today, many technologies are available that can be combined to exploit the business potential of applications that work anywhere and anytime in a seamless and intuitive way. In the near future, individuals will be able to wear, carry, own, or use a number of network devices, varying from notebooks and PDAs to wearable gadgets (e.g., watches with blood pressure sensors; sunglasses with cameras, earphones, and monitor), all with the ability to access ubiquitous services. In parallel, multitechnology ambient networks in houses, cars, corporate environments, and public areas will be widely deployed. Fixed and wireless metropolitan area networks (MANs)/WiMax, wireless LANs (WLANs), Global System for Mobile Communications/General Packet Radio Service (GSM/GPRS), third-generation (3G) and beyond cellular networks, along with satellite global positioning, navigation, and communications networks provide, together with their associated service delivery platforms (SDPs), an environment to support global service coverage and instant communications, even in the most inaccessible areas of the planet.

Although there are many powerful open middleware solutions for service creation and provisioning, supported by large consortia and promoted in major fora and standardization bodies, it is highly improbable that there will emerge, in the near future, a single dominant middleware platform sufficient for all networks, devices, and purposes. In this article we propose a self-adaptive service provisioning middleware framework (ASPF) to facilitate seamless service provisioning to mobile users and professionals anywhere, anytime, and in any context. The proposed framework interoperates with existing service delivery platforms by introducing a layer of meta-polymorphic intelligence between the network infrastructure, existing platforms, and mobile applications. This allows it to offer a unified, ambient-aware, adaptive, and personalized service provisioning environment. In order to maximize interoperability and wide adoption, the ASPF is based on open interfaces and is either

 1536-1284/04/$20.00 © 2004 IEEE

integrated with or expands already available SDP solutions, whether standardized or under standardization. Such standards include legacy platforms, based on the Mobile Application Protocol (MAP), intelligent network (IN), and 3G Partnership Project (3GPP) customized applications for mobile network enhanced logic (CAMEL) standards, current platforms based on the 3GPP virtual home environment (VHE) specifications and the related open application programming interface (API) platforms, such as 3GPP open service access (OSA), Parlay, and Parlay X, as well as emerging all-IP provisioning environments, such as the 3GPP IP multimedia system (IMS).

This article provides an overview of the ASPF and is organized as follows. We define the major requirements for a distributed middleware framework for mobile communications, and then describe the platform architecture. We describe the realization of some major features of this architecture. Conclusions are then drawn.

Framework Requirements

To meet the end-to-end dimensioning of the overall system and provide turnkey services to mobile users and professionals anywhere, anytime, in a seamless manner and at an affordable price, the service provisioning framework must meet requirements that lead to efficient (re-)usage of available resources (networks, technologies, capital expenditures, services, etc.). The proposed ASPF considers at least the following key domains.

Platform Interoperability

One of the major trends toward the fourth generation (4G) is the great heterogeneity of the deployed networks [1]. Given both investors' requirements for capital expenditure intensity and the technological divergence of private and public networks, the issues of service portability and interoperability have become of primary importance. This is true not only for service providers and network operators, but also for service and application developers. Therefore, many efforts are under development or standardization seeking to provide a service delivery middleware solution for open network interfaces; however, most focus mainly on 2G+ and 3G cellular networks. The most important efforts to be taken into account today are [2]:

3GPP CAMEL, a GSM recommendation to support IN and advanced operator-specific services for roaming users [3]. CAMEL platforms, so-called CAMEL support envrionments (CSEs), are deployed around the world in many GSM networks for enabling mainly prepaid roaming.

JAIN (Java APIs for integrated networks) defines a set of Java-based network APIs: interfaces to SS7 signaling (TCAP, ISUP, MAP, INAP, OA&M), as well as all-IP signaling protocols (H.323, MGCP, and SIP) and a carrier grade service execution environment called the JAIN service logic execution environment (SLEE). JAIN aims for service portability and secure network access to telephony and data networks, and speedup of the service creation and deployment process.

3GPP OSA is one of the most important efforts in the mobile telecom world. It defines an architecture to support the VHE vision, enabling operators and third party applications to make use of network functionality through a standardized and extensible API. The OSA API, specified jointly with the Parlay group in IDL, Java, and WSDL, provides an abstract view of the core network functionality, such as (multimedia) call control, data session handling, messaging, user location, charging, account management, presence, and policy management. In addition, the API supports capability and application management through a so-called framework API [4]. The API is provided by an OSA gateway to the applications residing on dedicated application servers.

The **Parlay** API, defined by the Parlay Group, has been designed for mobile, fixed, and next-generation IP networks, and therefore slightly extends the scope of OSA [5]. The API capabilities are identical to those of the OSA API. Thus, there is often the notion of an "OSA/Parlay gateway."

The **Parlay-X** specifications extend the OSA/Parlay specifications by providing a higher level of abstraction based on Web services technology. The main motivation is to enable the emerging Web services programming community to make easy-to-use network capabilities. Special Parlay application servers act as emerging Parlay X gateways.

The Presence and Availability Management (**PAM**) Forum focuses on advanced mobile applications, in particular on concepts of communicating with people based on their current connectivity to the network (presence) and current activities (availability). In April 2003 the PAM Forum merged into the Parlay Group, as the OSA/Parlay API included a PAM interface.

Open Mobile Alliance (**OMA**), formed in 2002, today represents the ultimate mobile industry forum that aims to ensure, via open standards, seamless mobile services across different wireless networks and terminals. To date it has mainly concentrated on cellular networks (2G/2.5G/3G), which already have a large number of customers. In May 2003 the Parlay Group and the OMA signed a cooperation agreement that will allow the two groups to work together.

3GPP IMS (IP multimedia system) defines an overlay all-IP service architecture for real-time multimedia service provision on top of packet networks that is currently under deployment in 3G mobile systems. The IMS is based on the key signaling and administration protocols from the Internet Engineering Task Force (IETF), the Session Initiation Protocol (SIP) and Diameter. SIP application servers, based on servlet technology, as well as OSA/Parlay and CAMEL can be used for flexible IMS service provisioning.

The definition of interworking solutions between these above service middleware platforms is already in progress; for example, OSA/Parlay specifications take into account legacy and emerging IP networks and propose mappings to MAP, CAMEL Application Protocol (CAP), and IMS/SIP. However, interworking between components of the same service running on different middleware platforms is still

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Although automatic machine-to-machine based services will play a significant role in the forthcoming communication era, humans will still be the major consumers of new communications and entertainment multimedia services.

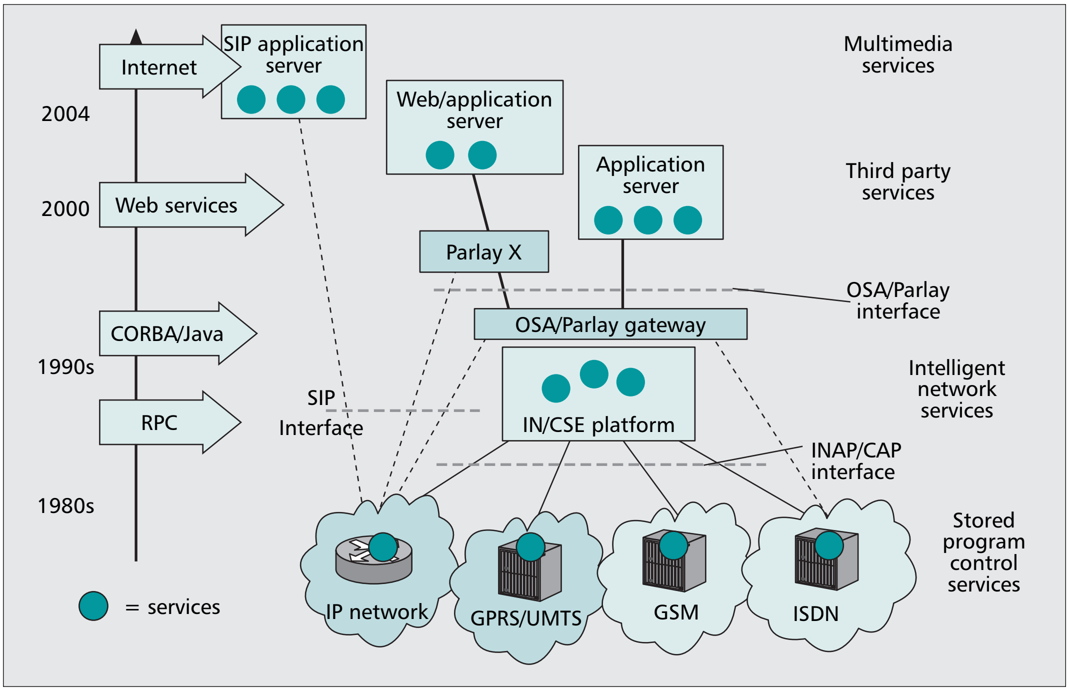

Figure 1. *Evolution and relationships between different service delivery platforms.*

immature; significant efforts are required in order to define and develop service access interfaces and efficient interworking functions. Figure 1 shows the evolution and relationships between different service delivery platforms.

Service Personalization

Although automatic machine-to-machine-based services will play a significant role in the forthcoming communication era, humans will still be the major consumers of new communications and entertainment multimedia services. It is therefore a major requirement to ensure that usability of the technology and related services is adapted to the target audience [6].

In 3G networks, the VHE provides service personalization. According to the International Telecommunication Union (ITU)/IMT2000, "VHE is a capability whereby a User is offered the same service experience in a visited network as in his Home system" [7], while according to 3GPP, "the VHE ensures that users are consistently presented with the same personalized features, whatever terminal, wherever the user may be located" [8]. However, appropriate interface extensions have to be defined in order to provide service personalization not only in cellular networks, but also in satellite links, wireless LANs, and picocell networks.

Location Awareness

Location awareness is equally important for future mobile applications and services. In current 3G networks, access to functionality such as CSCF or home location register (HLR) providing location information is typically only possible within the network operator domain, and even then only using mobile-network-specific protocols and interfaces. However, OSA does provide 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. There are also GPS-based location solutions [9], the most prevalent being Enhanced Observed Time Difference (E-OTD) and Assisted GPS (A-GPS).

It can be argued that provision of raw location information in isolation only provides a very limited scope for the tailoring of services to a user's current circumstances. Often such information is not sufficiently accurate to allow pinpointing a user's location; more important, location information would need to be supplemented by additional context information such as presence or availability to be of real use. There is a need to provide a means of collating and coordinating context information, including location, generated by different devices a user possesses/uses in order to provide to services a truer indication of how they can best adapt their behavior to satisfy a user's current needs.

Quality of Service

In the developing open service marketplace service providers will differentiate themselves not only on the functionality of the services they offer, but also through the levels of configurability and quality of service (QoS) assurance they can provide. Optimal QoS assurance for individual services in a heterogeneous and highly dynamic environment is in itself a challenging research topic. Consideration of composite services (where two or more services are executed in a coordinated manner to satisfy a particular user task specification) adds a significant degree of 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 meet users' expectations. User/terminal mobili-

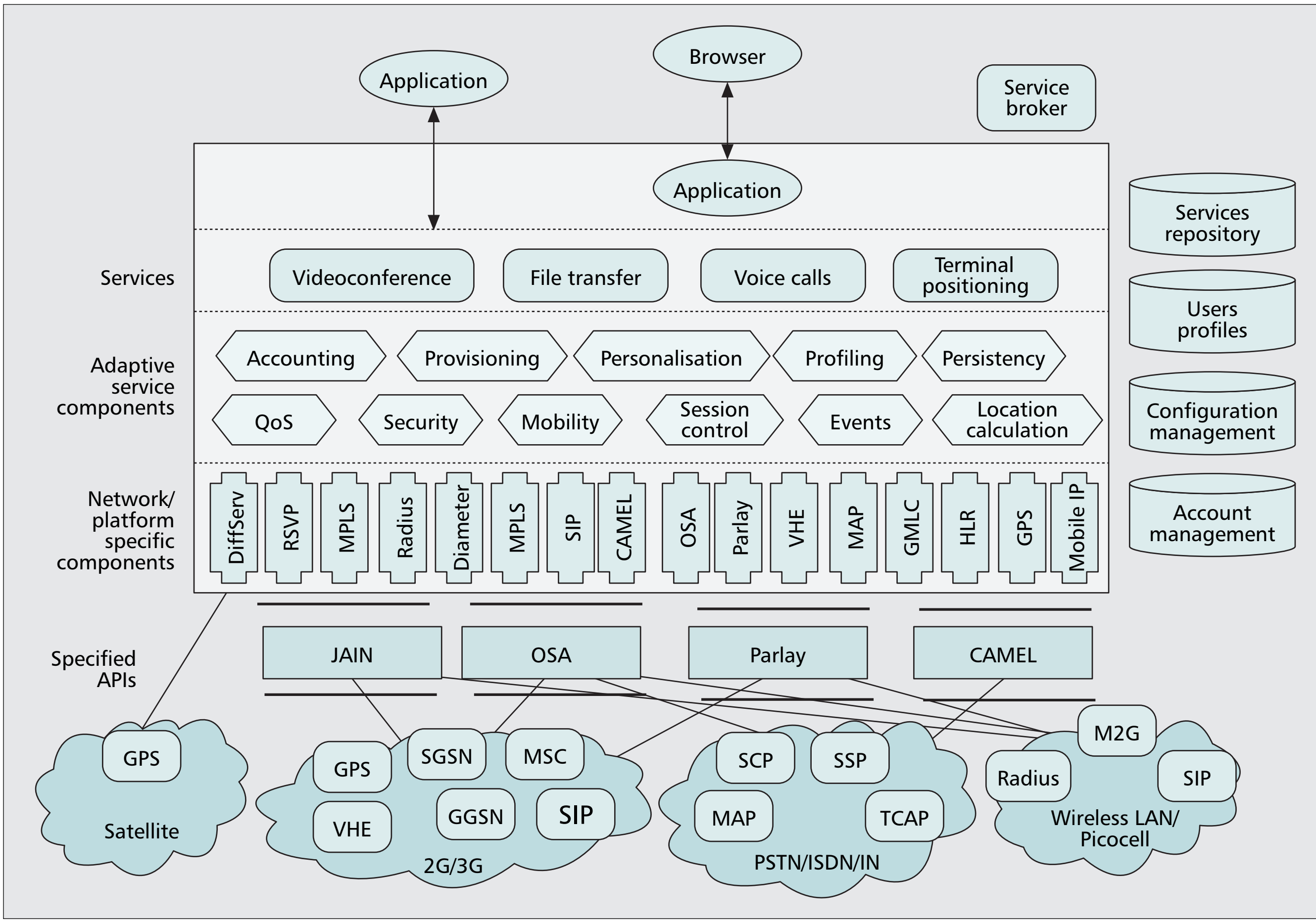

Figure 2. *The proposed self-adaptive middleware architecture.*

ty between different administrative domains complicates the issue further. Existing systems are a long way from providing solutions to these complex issues. For example, while OSA/Parlay provides mapping of the service QoS parameters onto network-specific QoS parameters, other required functionality like dynamic QoS management, dynamic QoS negotiation or renegotiation if traffic falls below the lowest guaranteed QoS traffic class, coherent bandwidth allocation, and priority management are not supported.

Self-Adaptive 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. We believe that the increasing diversity of devices — terminals, network elements, and application servers — leads to the conclusion that, at least in the near future, there will not be a single dominant middleware platform sufficient for all devices and purposes. As a starting point, therefore, we assume that various platforms (e.g., JAIN, OSA, Parlay, CAMEL), platform gateways (OSA/Parlay), and APIs will be available over these networks.

The proposed middleware platform architecture is shown in Fig. 2. In order to achieve interoperability in the most open manner, we adopt the Object Management Group (OMG) Model Driven Architecture (MDA) [10]. MDA goes far beyond common object request broker architecture (CORBA)-based interoperability at the level of standard component interfaces by placing formal system models at the core of the interoperability problem. What is most significant about this approach is that the system definition exists independent of any implementation model. and formal mappings to many possible implementation technologies (e.g. Java, XML, SOAP) are provided. Following the MDA approach, services are described using formal models, initially expressed in a platform-independent modeling language, such as Unified Modeling Language (UML). Through MDA tools, these can be instantly mapped onto specific platform technologies, such as CAMEL or OSA/Parlay. In the context of the ASPF, services that can be identified would provide capabilities such as file transfer, voice calls, multiparty videoconferencing, and terminal positioning.

The adaptability of the services is based on adaptive service components (ASCs). ASCs are polymorphic self-adaptive components that are specialized for a particular functionality or feature and are able to adapt to external triggers. For example, whenever network layer reservations are violated, the relevant ASCs will be trig-

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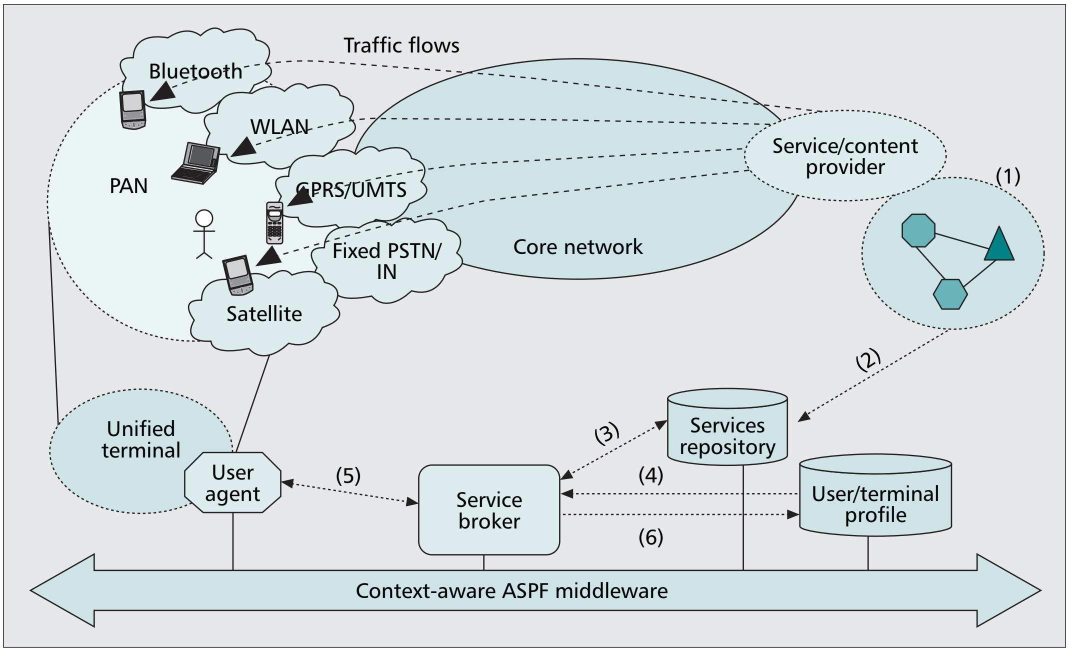

Figure 3. *Service provisioning interactions.*

gered 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 OMG MDA's metamodeling [11]. 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 runtime interpretation of such models. Based on this technology, ASCs will be highly interoperable, easily extended at runtime, 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 shown in Fig. 2, various ASPF ASCs have been identified, including location calculation, session control, mobility, QoS, security, profiling, personalization, and provisioning.

The platform-independent ASCs are subsequently translated to network/platform-specific components (NPSCs) by mapping the ASC models 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, and the Java community is developing pure Java programming models in the form of J2EE standard APIs. Examples of NPSCs may include components to interface OSA, Parlay, VHE, GMLC, HLR, GPS, SIP, multiprotocol label switching (MPLS), differentiated services (DiffServ), and Resource Reservation Protocol (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 must be implemented.

Finally, active *services/agents* like service broker, services repository, and user profiles support automatic services provisioning and self-configuration based on user preferences. Where applicable, these active components will be based on the XML metadata interchange (XMI) and common warehouse metamodel (CWM) OMG standards.

System Realization

Over this architecture, we describe the realization of major features: context awareness and service personalization, QoS adaptation, and location awareness.

Service Self-Advertisement and Self-Configuration

Clearly a large number of composite services can be built from a given set of atomic services and components, but only a subset of these will be useful from an individual end user's perspective. The utility of a given composite service is not only highly dependent on a user's personal preferences and the tasks he/she wishes to perform, but also on the context in which the user will access the service. The ASPF scheme will provide a means of dynamic incorporation of context information, in particular information on current network conditions into the service selection and composition process. This will contribute significantly to the realization of services that can automatically adapt and reconfigure themselves to handle changes in network conditions resulting, for example, from the user switching to a different device or roaming between different access networks. Moreover, new services will be able to advertise themselves, and software components can be automatically installed on the user terminal according to user preferences.

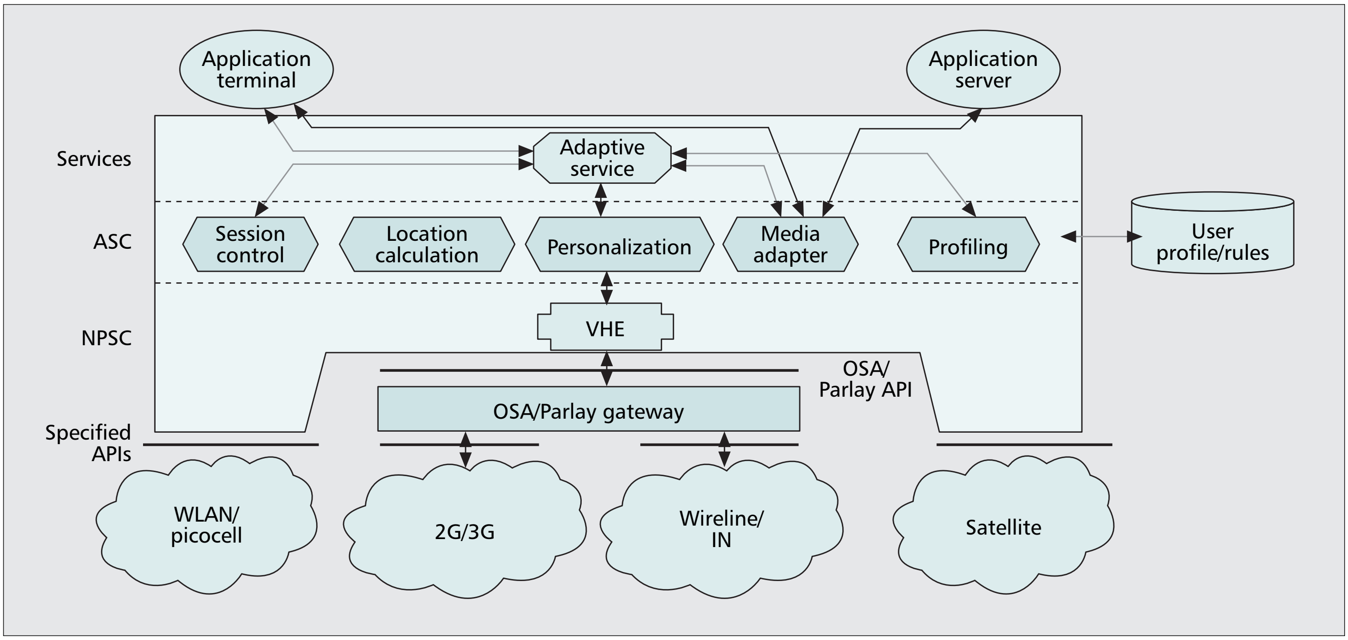

Figure 4. *Context awareness and personalization architecture..*

The service provision interactions are shown in Fig. 3. As a result of service deployment, discovery, and composition (1), service descriptions are published at the *service repository* (2). These descriptions allow identification of services (both atomic and composite) available to complete specific tasks given specific terminal and network conditions. Given descriptions of:

- User and terminal preferences, which are stored at the *user/terminal profile*
- The tasks to be carried out
- The network context in which the user will be accessing the service

the service broker is able to select a preexisting (atomic or composite) service or, if no suitable service exists, to automatically compose a new service that meets the user demands (3), (4). The user is represented by a *user agent*, which negotiates (via the provisioning ASC) with the service broker (5). The user agent provides to the service broker the tasks to be performed in terms of agreed ontological elements, as well as an indication of the user's preferences for the means by which the service is to be delivered. The profiling ASC builds up the user profile over time as the user agent reports to it, via the service broker, the user's service usage patterns and changing preferences (6). Information relating to current network conditions is reported to the service broker by the events ASC and is used as a key constraint in the selection of potential service compositions to carry out the required task. Furthermore, once a service session is ongoing, the ASPF will notify the service broker if changes in network conditions result in the selected service composition no longer being able to satisfy the required QoS levels. The broker will then search for alternative service compositions that can satisfy the required task in a different manner or, if this is not possible, in a manner that closely approximates what the user requires.

Context Awareness and Service Personalization

We define context awareness as the varying behavior of an application according to the current service context, influenced by user preferences, terminal characteristics, communication link properties, network capabilities, spatiotemporal (time and space) information, service state, history, and so on. For example, a user may use a PDA to participate in a multimedia conference via the GPRS or Universal Mobile Telecommunications System (UMTS) network. The user would hear the audio stream, receive reduced resolution video, and have active sessions in the background. When a more 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 to context awareness and personalization is shown in Fig. 4. The personalization ASC cooperates with the session control, location calculation, media adapter, and profiling ASCs to enable the required functionality. 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, described later, calculates the terminal position, and the profiling ASC interfaces with the user profile/rules warehouse. The personalization ASC retrieves network information from the VHE NPSC if 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 ele-

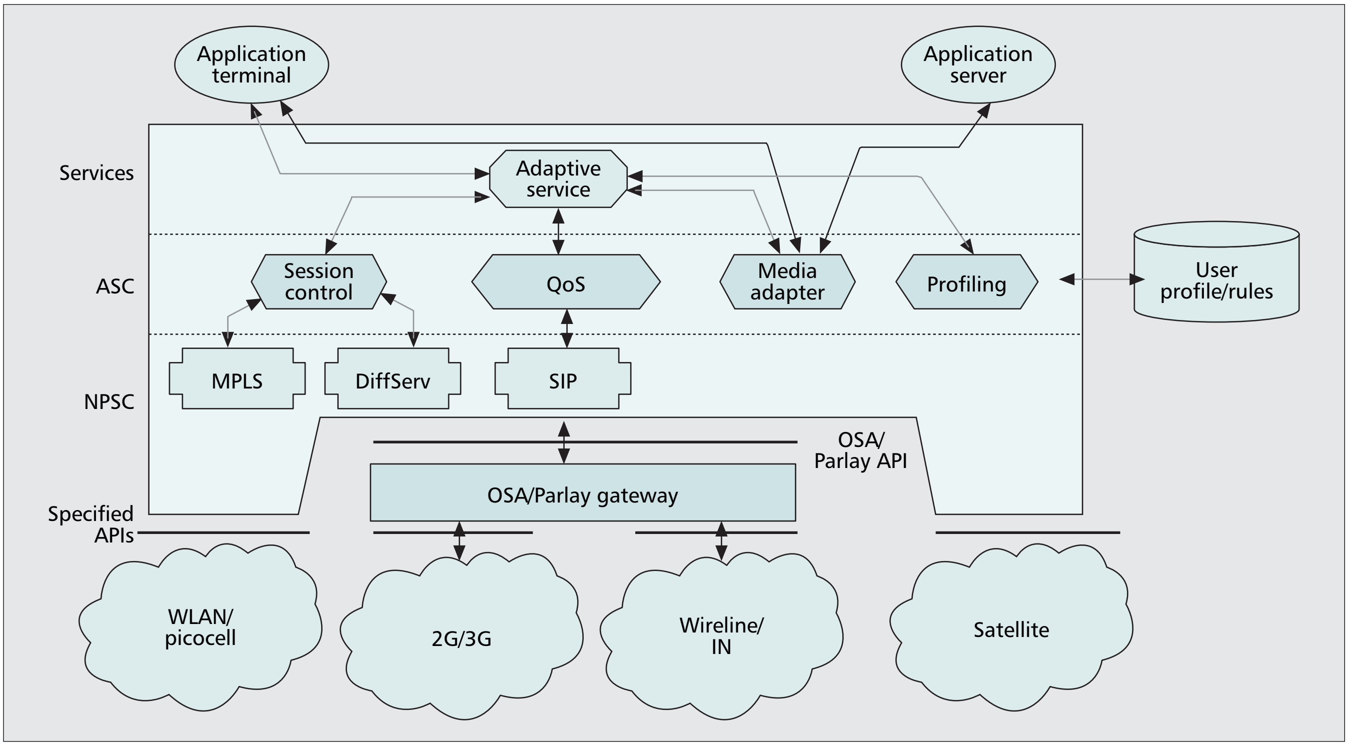

Figure 5. *QoS adaptation architecture.*

ment. 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 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 a mobile agent. The media adapter agent will cooperate 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.

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 ASPF provides context-aware and QoS adaptation functionality.

Figure 5 shows a typical scenario in which a SIP NPSC informs the QoS ASC of changes in the available network resources. Cooperation with the location awareness ASC further enhances the scenario. The QoS ASC reconfigures itself to reflect the new state. The adaptive service now coordinates 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 QoS delivery to the terminal accordingly.

To achieve this functionality, ASPF should address the following issues:

QoS middleware interactions. The coupling between the network-layer QoS and the QoS middleware layer should optimize the results and interactions.

End-to-end QoS signaling. An appropriate QoS signaling mechanism should be engineered so that the network can detect QoS violations and inform the QoS middleware layer. SIP-based solutions should be considered not only for their viability, but also for their easy interoperation with 3G and IP-based networks.

Session signaling and negotiation. Investigation of the utilization of SIP as the session signaling setup, taking into account the interaction between SIP signaling and QoS routing mechanisms, and the investigation of the possibility of changing the session setup signaling protocols to include the QoS negotiation in the setup phase.

Network layer QoS interoperation. Some research is still required to map the QoS mechanism within ad hoc networks to those approaches used in IP core networks. This interoperation is not only related to the translation of the protocol's messages but also with the billing mechanism, QoS profiles management, and so on.

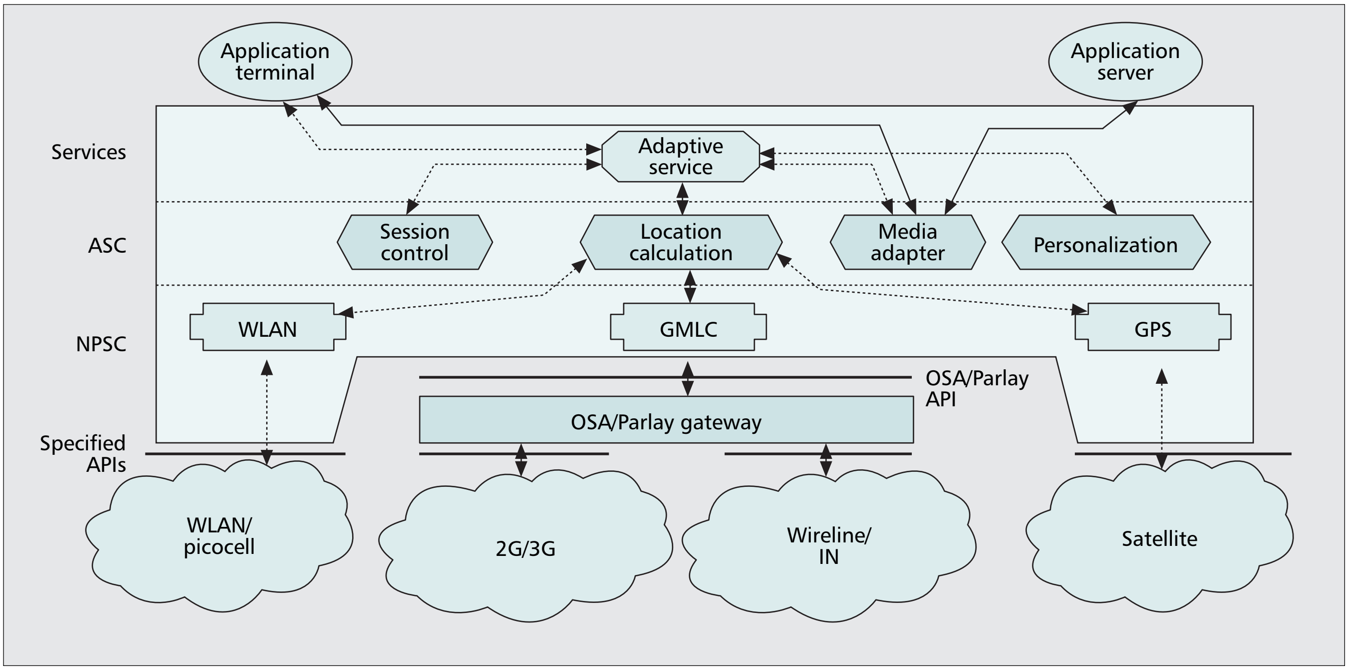

Figure 6. *Location awareness service components.*

Location Awareness

The proposed location awareness service implementation is completely independent of 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. 6.

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 gateway mobile location center (GMLC) NPSC. Additionally, WLAN and GPS NPSCs receive more accurate location information based on terminal positioning signal measurement functions. The three NPSCs 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 personalization ASCs are triggered to adapt the service and media content accordingly.

Conclusions

In light of the ongoing heterogeneity of fixed and mobile access networks, and the anticipated provision of seamless services, there is a need for integrating service delivery platforms and corresponding middleware platforms. Although there are today many powerful middleware solutions for service provisioning, it is highly improbable that in the near future there will be a single dominant middleware platform that would be suitable for all available networks, devices, and application provisioning scenarios. In this article we have proposed a self-adaptive service provisioning middleware framework (ASPF) that enables seamless service provisioning to mobile users and professionals anywhere, anytime, and in any context by interoperating with existing SDPs. The proposed platform introduces a layer of meta-polymorphic intelligence between the network infrastructures, existing platforms, and mobile applications to offer a unified, ambient-aware, adaptive, and personalized service provisioning environment.

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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.

experience includes development and systems engineering of communications software for commercial systems (1996–2000), field test project leadership for GSM handsets (2000–2001), and systems engineering of application platforms (2001–present). Additional to these tasks he is innovation and technology manager (2001–present) and participates in the 5th Framework Program IST project OPIUM: Open Platform for Integration of UMTS Middleware (2001–present).

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