Adaptive Service Provision in Mobile Computing Environments

Ouahiba Fouial, Katia Abi Fadel, Isabelle Demeure

Ecole Nationale Supérieure des Télécommunications, Computer Science and Network Department
46 Rue Barrault, 75634 Cedex 13, Paris, France.
Tel : +33 1 45 81 80 86
email: {fouial, kabifade, demeure}@enst.fr

ABSTRACT

Adaptability is one of the challenges of today's mobile distributed systems. In this paper, we identify the issues relative to adaptability in a service provisioning context. We introduce an adaptive service provision platform for mobile computing environments capable of supporting flexible Value Added Service (VAS) provision to mobile users. We describe how this platform can support service adaptability to user profile and preferences, to terminal and network capabilities and, to user location.

I. INTRODUCTION

The challenge of today's mobile computing environments is to give the users access to any information at any time, from any place, in any form. In this paper, we focus on adaptive service provision in mobile computing environments.

A flexible adaptive service provision platform is expected to provide part or all of the following features:

- be adapted to non permanently connected devices, and to the support of roaming,
- be adapted to limited capability devices,
- support service look-up, discovery and provision,
- support trading in order to locate and access the service best suited at any time,
- support service downloading and configuration of services on the terminal,
- support user profiling and preferences,
- support QoS management.

The remainder of this paper is organized as follows. In Section 2, we define the concept of adaptability. Section 3 takes a closer look at this concept, considering how service adaptability should be carried out and where adaptability should be placed in the overall architecture for service provision. Following this, in Section 4 we propose an architecture for adaptive service provision. In Section 5, we present an adaptive service discovery and provision session. In Section 6, we focus on the End-User Terminal (EUT) component of the platform. An implementation of this component is then briefly discussed in Section 7; this implementation ensures service adaptability to user profile and preferences, service adaptability to terminal capabilities and, service adaptability to operating context (service adaptability to network capabilities is not considered in this paper). A prototype of this implementation and some developed scenarii are presented in section 8. Finally, Section 9 presents some concluding remarks and future work.

II. ADAPTABILITY DEFINITIONS

Before proceeding further, let us define the terms adaptation, adaptivity and adaptability.

Several definitions of adaptability were given in [1]. We adopt the following one :
"A*daptation* means change in the system to accommodate change in its environment. More specifically, adaptation of a software system *(S)* is caused by change *(d_E)* from an old environment *(E)* to a new environment *(E')*, and results in a new system *(S')* that ideally meets the needs of its new environment *(E')*. Formally, adaptation can be viewed as a function:

$$E \ x \ E' \ x \ S \rightarrow S', \text{ where } meet\ (S', need\ (E'))$$

A system is adaptable if an adaptation function exists."

Adaptability is subsequently defined as the ease with which a system or parts of the system may be adapted to the changing requirements.

Finally, systems that adapt to users automatically based on their assumptions about them are called *adaptive* or *adaptable*.

In this paper, we concentrate on adaptive service provision in mobile computing environments.

III. ADAPTIVE SERVICE PROVISION

Adaptability in service provision environments covers the following aspects: service adaptability to user profile and preferences, service adaptability to terminal and network capabilities and, service adaptability to user location. We review each of these aspects in turn.

A. Service adaptability to user profile and preferences

The importance of service adaptability to user profile and preferences has boosted the activities of many standardization work groups. In particular ETSI-3GPP[2,3] introduced the Virtual Home Environment (VHE) [4].

The goal of VHE is to present the user with a common "look and feel" interface and service experience regardless of location, network and terminal type. The concept of VHE is such that users are consistently presented with the same personalized features, user interface customization and services in whatever network and whatever terminal (within the capabilities of the terminal and network), wherever the user may be located.

The concept of user profile and preferences is a key part of VHE. The function of the profiles is to define the service environment for a user in terms of his/her general communication preferences, user terminal interface preferences and any other parameters that are important to that user.

The parameters of a user profile are specified by the standard. Each user profile consists of two kinds of information: user interface related information and service related information.

User profile may be stored in the mobile terminal (the SIM card or the mobile equipment memory), and/or the core network depending on the type of the profile. In the event of loss/damage of mobile terminal (SIM or ME), profiles must be fully recoverable and be used to reconfigure a new mobile station.

B. Service adaptability to terminal capabilities

Knowledge of terminal capabilities is essential for adaptive service provisioning so that the user is presented only with the services that can be supported by the device he/she is currently using for network access. Therefore, the terminal capabilities should be communicated to the service provisioning entity via a *capability negotiation* process.

The capability negotiation represents the mechanism by which the mobile terminal and the service provisioning entity interact to inform each other of the specific mechanisms, capabilities and support which each is able to support within the scope of a service provisioning interaction. The capability negotiation normally takes place prior to any content transfer between the two entities and any service provision to the user.

Various efforts have been undertaken by standardization work groups to define a universal format for terminal capability description, as well as a mechanism for capability data negotiation with the service provisioning platform.

The MExE (Mobile Station Application Execution Environment) [5] specification standardizes capability negotiation through the Composite Capability/ Preferences Profiles (CC/PP) specifications [6] that is based on the HTTP protocol. A CC/PP description is intended to provide information necessary to adapt the content and the content delivery mechanisms to best fit the capabilities and preferences of the user and its agents.

C. Service adaptability to operating context (location awareness and localization)

The importance of user localization is a primary factor for service personalization.

Knowing where a person or object is at any time presents a powerful new dimension to the range of information services that can be offered.

Location-dependent services determine the geographic position of mobile subscribers and provide them with relational information and services via the Internet and/or wireless networks [7].

To be aware of the user location, the application needs a source of location information that, can be provided, for example, by a Global Positioning System (GPS) card [8]

D. Service adaptability to network resources

The service provision platform could be faced with wide variations and rapid changes in network conditions and local resource availability during service provision.

The mobile user may move between different mobile environments or change the configuration of his/her mobile device. Consequently, the performance of service downloading and service execution in the mobile device may vary significantly [9].

In order to operate in such dynamic environments, the platform must support service adaptability to the changes in mobile environments both at the mobile terminal and in the core network.

IV. AN ARCHITECTURE FOR ADAPTIVE SERVICE PROVISION

The adaptive service provision architecture presented in this section was developed in the context of the IST MOBIVAS project [10]. It consists in three basic entities: the mobile terminal, the Network Operator (NO), and the VAS Providers (VASPs) which offer their services by connecting their network infrastructure to the operator's network (Figure 1).

The user maintains a subscription with the network operator and has access to services offered by the operator and its contracted VASPs.

A new software module named the VAS Manager (VASM) is added to existing access and core network architectures.

The VASM is mainly responsible for the management of the provided service list. It should present the users with a complete and updated list of all available services. In addition, it should cope with the co-

ordination of functions required for the seamless and consistent VAS provision to the mobile users.
The VASM provides the user with the ability to discover and select any of the applicable services that are adaptable: to the terminal capabilities, to the user profile and preferences, to the operating context in particular user's location, and finally to varying network resources (e.g. network bandwidth).

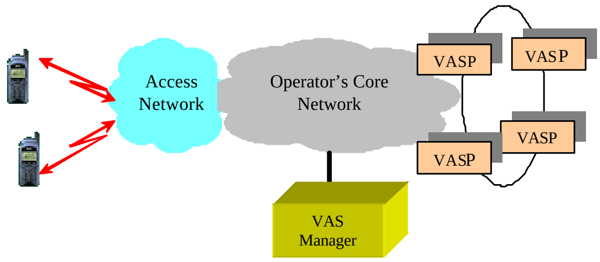

Figure 1 – An architecture for service provision

V. ADAPTIVE SERVICE DISCOVERY AND PROVISION

Taking into consideration the potentially huge range of services available to the mobile users, the demand for an efficient and easy mechanism for VAS discovery and provision, adapted to the terminal capabilities, user preferences and user location, is rapidly rising. The proposed platform addresses this challenging issue.

Through a personalized user interface, the VASM provides subscribers with the ability to discover the registered services and select the one they wish to download and use. This is accomplished through the service discovery interface that is downloaded to the terminal and provides the user with the ability to :

- view lists of the registered services classified by categories,
- access the user's favorite services,
- perform a key-word based search for VAS.

The type of this service discovery interface depends on the terminal capabilities and user preferences announced to the VASM by the terminal upon the service discovery request. Each request for service discovery indicates to the VASM the capabilities of the requesting terminal, along with the identity of the network location that the terminal has currently reached. The requested VAS listings are presented to the users after filtering the VAS Data Base according to the terminal capabilities, the user selections and the user preferences specified in the user profile. The prime form of a look-up service menu listing basically includes the VASs that match the selections of the user.
Gradually and following the selections of the user, the content of this listing is further refined.

The final form of the look-up menu includes the various available versions of the selected service that the requesting terminal can execute. Each version is associated with a short description and indicative tariffing information.
Following the service discovery phase, the user is able to select the desired VAS and to initialize the VAS downloading phase with the corresponding VASP.
When the VASP receives a downloading request, he packages the service and generates security parameters. These parameters are transmitted to the user who stores them locally. The service is then downloaded to the mobile terminal and the user can execute it according to rules defined by the VASP.

Figure 2 summarizes the different steps to be performed to ensure an adaptive service discovery and provision.

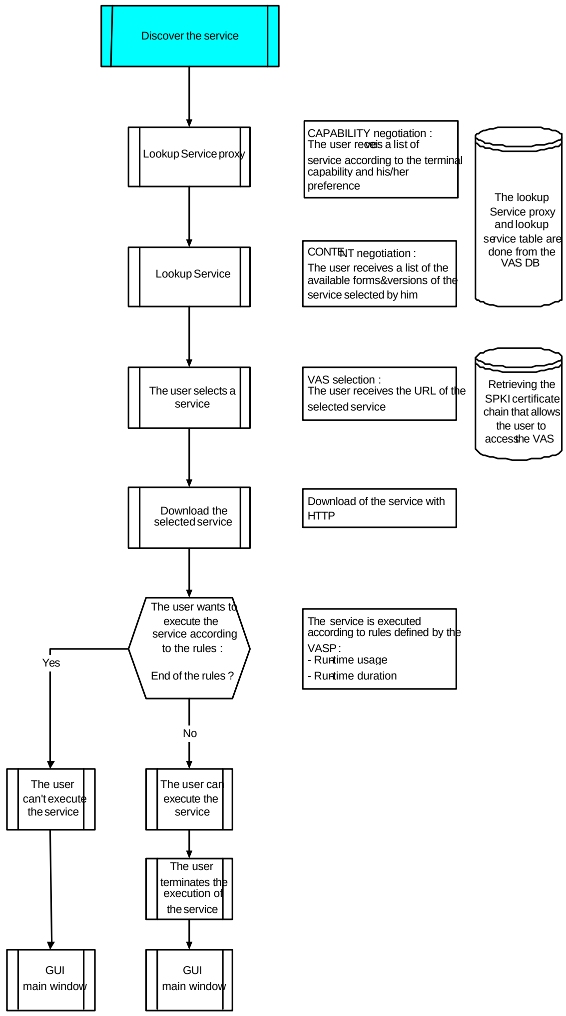

Figure 2 – Adaptive Service Discovery and Provision

VI. ARCHITECTURE OF THE EUT PLATFORM

In the following sections, we focus on the terminal component of the architecture presented in Section 4. This component is named the End-User Terminal (EUT) Platform.

Figure 3 depicts the layered components of the End-User Terminal Platform. The Application Support Programming Interface contains the necessary APIs for the service execution in the mobile terminal. The Service Management Component supports the modules which control and manage the service provision procedures from the user network connection to the service execution in the terminal part. The Network Adaptation Component deals with low level issues relative to the QoS provision and the protocol downloading.

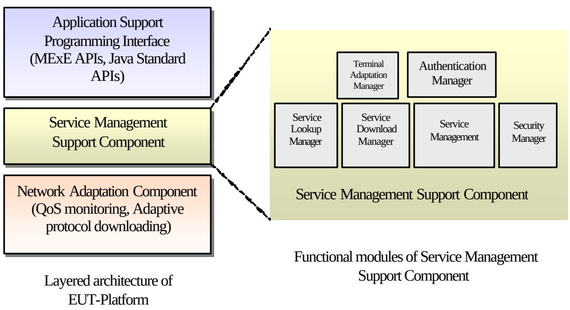

Figure 3 -EUT Platform Layered Architecture

- *Network Adaptation Component (NAC)*

This component deals with issues concerning the QoS monitoring and the adaptive protocol downloading. The NAC provides the Service Management Support Component with an interface that enables service adaptation to the network capabilities and resources.

- *Service Management Support Component (SMSC)*

The different components of the Service Management Support Layer are:

1. Terminal Adaptation Manager

The Terminal Adaptation Manager is responsible for adapting the provided services to the user profiles and terminal capabilities. Two types of profiles are defined : User Profile (includes User Interface Profile and User Services Profile) and Terminal Profile.

2. Authentication Manager

This module is responsible for the User Registration and the User Authentication (User Login). The User Registration is performed only once when the user signs up a contract with the platform. The User Login is performed every time a user starts a new session.

3. Service Lookup Manager

This module is responsible for service lookup table formulation and service selection. It compiles several lists of available VAS according to the requirements of the terminal/network capabilities, user location, user preferences and user profiles. Then, it presents the filtered lists to the user.

4. Service Download Manager

This module is responsible for the secure download of the requested service as well as its invocation on the terminal. This component requests the download of a service proxy selected by the user.

5. Service Management

This module is responsible for execution and control of the downloaded service. It starts the service once downloaded to the terminal and controls its execution.

6. Security Manager

Security in the mobile terminal is involved in the download process.

VII. ADAPTABILITY MANAGEMENT

Adaptability in our service provision platform is ensured during the two following phases: RTE provision phase and service provision phase.

A. Initial Platform RTE (Run Time Environment) Provisioning

The use of adaptive service provision platform is initiated and controlled by the user. The terminal must first be equipped with a version of the RTE platform which depends on the terminal capabilities. This download operation is performed through a capability negotiation procedure between the terminal and the Platform Server. Once the terminal runs the downloaded RTE platform corresponding to its capabilities, the user can access the platform facilities.

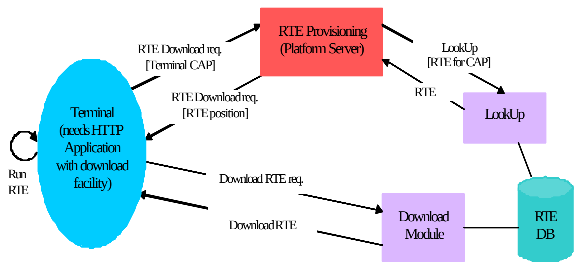

Figure 4 –Adaptability in RTE Provisioning

B. Service Discovery and Service Provision

The EUT platform guarantees that the users are consistently presented with the same personalized features, user interface customisation and services whatever the terminal (within the capabilities of the terminal).
Profiles used in our EUT platform consist of a number of different parameters collections. The EUT offers interfaces for creation, update, retrieval and deletions entries. The following collections are provided: user profile, terminal configuration profile and interface profile.

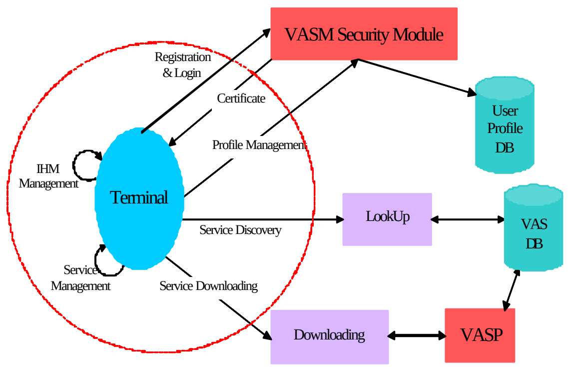

Figure 5 –Adaptability in Service Discovery and Service Provision

In our platform, the user is provided only with services that are adapted to his/her terminal capabilities, his/her personal preferences and his/her location.

VIII. PROPOSED PLATFORM PROTOTYPE IMPLEMENTATION

The prototype implementation of this platform covers the terminal part in order to demonstrate the possibility of software downloading and service adaptability between the user terminal and the other components of the platform.

A. Software Architecture

The programming language used for the overall platform is Java version 1.2.2. The operating system used is the RedHat Linux 7.1 with kernel 2.4.
The communication between the platform components is based on the standard, highly interoperable HTTP and XML technologies.

We use two types of hardware devices in order to demonstrate adaptation to terminal capabilities:

- A *high end terminal* based on a laptop
- A *low end SPIF terminal* [11] developed in our lab based on a Motorola MPC860 Power PC.

Two services are used to demonstrate the Platform features:

- A streaming multimedia player service named MobiPlay
- A location based service

Two versions of both services were developed:

- A SPIF version with MIDP profile [12]
- A high-end terminal (laptop) version with a full Java AWT[13] graphical interface

These two versions are useful in order to demonstrate the service discovery based on various parameters such as the terminal capabilities, the user profile and the service specific data.

B. Scenarii

Several test scenarii have been defined in order to test the platform and validate the functionalities of the EUT and the corresponding interfaces.

- *Scenario 1:*

Objective: *RTE provisioning and RTE download*
Actors: *one user, two types of terminals*
Test :

- RTE Look-Up (RTE for terminal capabilities)
- RTE download for the high end terminal with full Java AWT GUI
- RTE download for the low end terminal with MIDP GUI Profile
- RTE run in each of the two terminals

This scenario has demonstrated the procedure of RTE provisioning and download. The version of this module is adaptable to the terminal capabilities. Once the terminal runs the downloaded RTE, the user operates inside the platform.

- *Scenario 2:*

Objective: *Profile Management*
Actors : one user, VAS Manager, VASP
Test :

- Login
- Profile access
- Profile modification
- Check if modifications were considered

In this scenario, we have demonstrated that the user can update and modify his/her profiles (user profile, terminal profile and interface profile) and can restore them in the next sessions. In fact, the user can update the configuration of his/her terminal, the terminal interface and his/her user identification data. This scenario has also demonstrate that the user can be consistently presented with the same personalized features, user interface customization and services in whatever terminal (within the capabilities of the terminal).

- *Scenario 3:*

Objective: *Capability & Content negotiation*
Actors: *two users, two type of terminals, VAS Manager, VASP*
Test:

- Login of the user of terminal 1
- MobiPlay Look-Up for terminal 1
- MobiPlay selection & download & execution for terminal 1
- Login of the user of terminal 2
- MobiPlay Look-Up for terminal 2
- MobiPlay selection & download & execution, for terminal 2
- Check if the proposed services really depend on the terminal capabilities

This scenario has demonstrated that the user is provided only by services which are adapted to his/her terminal capabilities and his/her personal preferences. The final form of the Look Up presented to the user includes a list of services that fit the combination enhanced terminal capabilities/user preferences.
In this scenario, two users with two different terminal configurations ask to be provided by the same service. The result shows that the VAS Manager provides to them two different versions depending on the terminal capabilities.

- *Scenario 4:*

Objective: *Heterogeneous terminals*
Actors: *two users, two types of terminals, VAS Manager, VASP*
Test: test all the main functionalities of the EUT platform for the two types of terminals (SPIF and laptop):

- RTE provisioning
- Capability and content negotiation
- Service look-up and service selection
- Software downloading
- Service management
- Profile management

The main goal of this scenario was to demonstrate that the EUT platform can be used by terminals which vary from small terminals with small limited capabilities to powerful terminals. All EUT functionalities were tested for each terminal to demonstrate the easy mechanism of service discovery and provision adapted to the terminal capabilities, user preferences and user location.

IX. CONCLUSION

This paper investigated issues related to adaptive service provisioning in mobile computing environments. A generic platform for VAS provision to mobile users was introduced. We particularly focused on the End-User Terminal (EUT) platform. To this purpose, we described the generic end-user terminal functionalities and we describe how this platform can support service adaptability to user profile and preferences, to terminal/network capabilities and to user location.
The different EUT modules and all interactions with the other platform components have been implemented and successfully validated.
In order to test the adaptivity of our service provision architecture and particularly the EUT platform, two service scenarios were designed. The first service is a location based service. The second service is a streaming multimedia player service. Two versions of each of the two services were developed: one for a restricted capability terminal (SPIF platform) and one for an enhanced capability terminal (laptop) .
In this paper we presented a pragmatic approach which consists of integrating the existing technologies to support adaptive service provision to mobile users.
In the future, we plan to investigate in more depth the issues mentioned in this paper with particular focus in service adaptability to network capabilities and QoS management.
Further research should be directed in the area of adaptability and reflexivity as basis for the investigation of complex adaptive service provision platform for mobile computing environments.

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