Chapter 1
Introduction

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1.1 Overall View

One important aspect of ubiquitous environments is to provide users with the possibility to freely move about and continue the interaction with the available applications through a variety of interactive devices (including cell phones, PDAs, desktop computers, digital television sets, and intelligent watches). Indeed, in such environments one big potential source of frustration is that people have to start their session over again from the beginning at each interaction device change. Migratory interactive services can overcome this limitation and support continuous task performances. This implies that interactive applications be able to follow users and adapt to the changing context of use while preserving their state. This book reports results based on the work carried out in the OPEN project (http://www.ict-open.eu/), which provides integrated solutions able to address three aspects: device change, state persistence and content adaptation. This is obtained through a middleware able to consider and integrate various aspects: adapt and preserve the state of the software application parts dedicated to interacting with end users; support mechanisms for application logic reconfiguration; and define suitably flexible mechanisms from the underlying network layers. The resulting middleware is able to interoperate with existing technologies. Thus, OPEN aims to offer an intelligent infrastructure able to: deliver seamless and transparent support to users in carrying out their tasks when changing available devices, even in multi-user interactive applications; provide and coordinate more reliable and dynamically changing/reconfiguring services; offer personalized user interaction by exploiting different interaction modalities and network technology by means of an infrastructure providing the necessary context information regarding the available devices, connectivity, users and related transformations for content adaptation.

The OPEN project has defined middleware solutions developed in the context of example applications from various different domains (business applications and

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gaming), to demonstrate the feasibility of the approach, the limited effort required to application developers, and its ability to enable new application services. There are many applications that can benefit from migratory interactive services. In general, applications that require time to be completed (such as games, business applications) or applications that have some rigid deadline and thus need to be completed wherever the user is (e.g.: online auctions). Other applications that can benefit from this flexible reconfiguration support are those that have to provide users with continuous support during the whole day through different devices (for example, in the assisted living domain).

1.2 Motivations

Despite the multitude of different types of terminals available in the market, our lives have not yet become a multi-device experience since one source of constant frustration is that people cannot continue to perform their tasks when they move about and change their interaction device. This is due to the lack of migratory services

Fig. 1.1 Example of multi-device environment mediated by the migration infrastructure

technology for the migration of applications in different usage scenarios. This book promises to fill this gap by providing a general and open migratory service platform solution based on a sound and innovative scientific approach developed by a multi-disciplinary consortium combining the expertise of three technological world leaders (SAP, NEC, Vodafone), three well known research organizations (CNR-ISTI, University of Aalborg, and Clausthal University) and one SME (Arcadia).

One important aspect of pervasive environments is to provide users with the ability to freely move about and continue the interaction with the applications in use through a variety of interactive devices with different interaction resources (e.g. cell phones, PDAs, desktop computers, digital television sets, intelligent watches, an example is in Fig. 1.1) and communication channels with different characteristics and performance (i.e. WiFi, Bluetooth, sensor networks, UMTS, …). In this regard, there has been a recent increase in interest in migratory interactive services. They provide users with the ability to change the interaction device and still continue their tasks through an interface adapted to the new platform. Migration can involve various types of devices. In some cases, migration can be used to improve the user's experience by switching to a better suited devices (bigger screen, more graphical power, …) or to a more efficient communication channel/a communication channel that can guarantee better QoS (shorter delays, higher bandwidth).

1.3 Objectives

In order to address the complex issues related to migration there is a need for a service platform able to consider and integrate various aspects: adapt and preserve the state of the software application parts dedicated to interacting with end users; support mechanisms for application logic reconfiguration; and define suitably flexible mechanisms from the underlying network layers. The resulting service platform should be able to interoperate with existing technologies. In general, a service is a computer-based entity that provides well-defined functionality, together with the policies that should control their usage. We also address services whose main goal is to support users, and thus include both the user interface software and the internal application logics. Services can communicate with each other. This activity might consist of bare data passing or more coordinated activities. Therefore, services have to be supported by an underlying infrastructure that allows them to coordinate with each other.

Migratory interactive applications require that the user interface adapts itself to the resources and the existing services of the new device/environment; this can also imply dynamic (re)configuration of the overall application, which in turn involves establishing the required/requested connections between the available components/services, which are user interface components, as well as non-user interface components providing application services.

Migratory Interactive Services also imply an intelligent context-aware infrastructure able to capture the state of the user interface and application logic on the

source device, transmit it to the target device (transformed if necessary) and then generate an appropriate user interface to the target device as well. The devices used for interaction can support various modalities (graphical, vocal, gesture, …), which can even be exploited in various combinations depending on the context of use. We also address partial/distributing migration, which is the ability to move from interacting with an application through a single device, to interaction through several coordinated devices using various modalities. This allows users to comfortably control, for example, videos displayed on a wall-sized screen through a vocal interface, or project a presentation stored in a personal device such as a PDA to a desktop-controlled maxi video screen in a conference hall while annotating the output through an intelligent whiteboard and maintaining control on the personal device. Migration of an interactive service to a set of devices detected and classified on the basis of the tasks supported by their resources can require complex processing.

Migration can result in new capabilities for the whole pervasive application. Therefore, the application logic may also adapt by dynamically composing or decomposing the changing set of available application services resulting in dynamic adaptation of the applications in use at the functional level. This implies establishing the required/requested connections between the available components/services, which are user interface components as well as non-user interface components providing application services. Moreover, services that are no longer required in the newly established application have to be detached from the system. This attaching/detaching process at runtime is called dynamic reconfiguration. Such dynamic reconfiguration requires a description of the services offered in such a way as to enable the integration of new components at runtime, even if they were not anticipated at application development time. Often the services required and offered by the two components are not identical, though they would be compatible. Therefore, there is a need for assessing the match between required and offered services in order to enable dynamic reconfiguration of the application. In some cases there may be multiple possibilities regarding one requested service. The choice can also be based on Quality of Service properties such as the available bandwidth or the delay that user is willing to wait. This adaptation requires a sufficient description of the QoS properties at the application layer in order to enable the infrastructure to reason about it during the run-time re-configuration.

Distributed applications, e.g. client-server based, involve remote communications between the components. In this case, the mechanisms for migratory services also need to be closely inter-linked with adequate functionalities to provide seamless connectivity and service to the remote components. This can be achieved by either making the application mobility aware (e.g. the application server will recognize that the ‘new’ client IP address is supposed to replace the previous one in the ongoing session), or by using adequate mobility support mechanisms, either transparently at the network layer through a Mobile Internet Protocol (MIP), or at intermediate layers such as transport layer, or Session Initiation Protocol (SIP) layer, when present.

Handover triggers require close coupling to the user interface adaptation in several cases, e.g., when the quality of the network connection changes substantially

(e.g. video is no longer possible due to degrading throughput) or the network connection has changed from one access technology to another (e.g. from UMTS to WLAN). We will focus on scenarios associated with interactive migratory services because of their inherent complexity and potential impact on future services.

Thus, the main objectives of this book are to describe solutions able to:

- Offer seamless and transparent support to users in carrying out their tasks when changing devices as well as changing available services;
- Offer more natural and personalized interaction obtained by exploiting different interaction techniques supporting the mobile user;
- Exploit the wide availability of network technology to offer more reliable services in the context of migration with dynamically changing devices and services;
- Propose a novel infrastructure in order to increase possible services and application scenarios in several contexts (services for citizen, business, games, new interactive and collaborative method in work or educational applications, and so on).

1.4 Technical and Architectural Aspects

The migration concept can be implemented in various ways and exploiting various technologies. In a few words migration means adaptation to the context of use while preserving the state of the user session. In this section we introduce the possible types of user interface migrations, the possible underlying networking scenarios, and then some architectural aspects.

Migration of an interactive application does not necessarily involve moving the entire user interface from one device to another one. A number of user interface migration types can be identified:

- *Total migration* basically allows the user to change from one device to another one to interact with the application. In this case, the system is in charge of ensuring interaction continuity and supporting user interface adaptation to the different platforms.
- *Partial migration* is the ability to migrate to the destination device only a portion of the interactive application, while the remaining portion remains in the source device.
- In the *distributing migration*, the interactive application is totally distributed over two or more devices after migration. This is different from distributed user interfaces, for which the user interfaces are originally generated as distributed among various interaction resources connected to the same device.
- The *aggregating migration* performs the inverse process: the interactive application of multiple source devices are grouped in the user interface of a single target device.
- The *multiple migration* occurs when both the source and the target of the migration process are multiple devices.

The **Networking scenarios** in which these migratory services are provided influence the possible solutions. Basic cases are listed in the following:

- *Cellular-type*, infrastructure based networks, in which network controlled (or network supported) migration is possible.
- *Full ad-hoc/wireless multi-hop networks*, e.g. resulting from direct Personal-Area-Network (PAN) to PAN communication. Migration solutions in this scenario cannot rely on the permanent presence of proxy servers, for example, and the dynamics in the network topologies as created by the device mobility will require distributed and robust solutions.
- *Mixed ad-hoc/infrastructure scenarios*, such as for instance, created by Personal Networks or by cellular networks with ad-hoc coverage extensions. This could be the case in home automation application scenarios.

This type of issues can be addressed only through a multi-layer architecture composed of different infrastructure layers. At the lowest level there is the network infrastructure, a connectivity software in charge of managing issues raised by the coexistence of heterogeneous networks, and therefore in charge of allowing them to communicate with each other while ensuring high levels of robustness, reliability and adequate performance, even by opportunistically re-configuring themselves.

On a higher level there is the service infrastructure, which is essential for migrating services since it manages the dynamic discovery, provision, distribution, combination and reconfiguration of services required, state continuity, and generates usable interfaces for various input/output devices, so as to address the needs of individual users.

A large part of the application industry will benefit from migratory services. On the supply side, today applications are designed with the platform/terminal where they will be used in mind. Allowing users to utilize such applications on a different platform/terminal is in general a very costly process. Migratory services will instead enable easy application portability. On the demand side, many applications involve tasks and services that are completed over a certain period of time (such as games, making reservations, online news, etc.) so users may change their interaction device in the meantime, or are constrained by rigid deadlines (such as business applications, online auctions, financial applications etc.) for which they must be accessed wherever the user is. Migratory services will enable a continuous and an unconstrained user experience for these classes of applications.

1.5 Structure of the Book

The book is structured into a number of chapters that provide a comprehensive and coherent view on the topics introduced.

We start with Chap. 2 with a description of the State of the art from various viewpoints, then Chap. 3 reports a discussion on where it is useful to migrate, and

what is specific to that environment and adaptation opportunities from a Mobile Operator perspective.

Next, we have the chapters dedicated to the migration platform design. An introduction to the OPEN Migration Platform (MSP) architecture and the possible solutions is provided in Chap. 4. User interface migration based on the Use of Logical Descriptions is discussed in Chap. 5 while Service Migration Network Support is considered in Chap. 6. Then we have the Application Logic Reconfiguration based on application and component descriptions in Chap. 7.

In terms of the application view of migration, we have Chap. 8 on design and development of a migratory application based on MSP, and Chap. 9 on migratory services in an emergency scenario. Chapter 10 is then dedicated to showing how to integrate support for User Interface and Application Logic Migration, using the PacMan game as case study.

Lastly in Chap. 11, we discuss the usability evaluation and the programmability assessment of migration, followed by an indication of potential exploitation and some conclusions.