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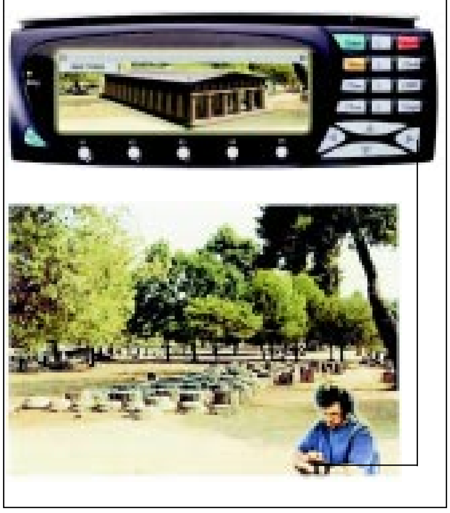
LoVEUS†: Software Architecture

The architecture is an artifact in the design that represents decisions on how requirements are to be fulfilled. As a manifestation of early design decisions, the architecture represents those decisions that are hard to change and hence deserve careful consideration. As a consequence, according to the current phase of the LoVEUS (*L*ocation-*A*ware *V*isually *E*nhanced *U*biquitous *S*ervices) project and the availability of appropriate mobile terminals, a possible architecture and basic implementation issues of the LoVEUS system are elaborated in this paper.

Figure 1 Visually enhanced content at premium sites



Introduction

The convergence of evolving mobile technologies (2.5G and 3G) and the Internet will enable completely new services to be developed. Based on the bandwidth and new core services being made available through next-generation mobile networks and the corresponding user's mobile terminals, the LoVEUS system will allow the provisioning of location- and orientation-sensitive multimedia information.

The aim of the LoVEUS project is to provide European citizens with ubiquitous services for *personalised, tourism-oriented multimedia information related to the location and orientation* within cultural sites or urban settings, occasionally enriched with relevant advertisements. Herein a strong focus will be set on information visualisation aspects. The development of a *user-friendly next-generation mobile terminal* that integrates mobile phone, personal digital assistant (PDA) and wearable computer technologies and features into one, enhanced by the presence of a Global Positioning System (GPS) receiver and a digital compass builds another important target. Finally the provision, through this basic infrastructure, of a *new paradigm for promoting tourism, cultural heritage* as well as commercial services, exploiting and expanding the ideas of location-aware services will be enabled.

For the time being three basic value-added services have been recognised as promising for the LoVEUS system:

- visually enhanced content at premium sites,
- active map with city navigation, and
- panoramic view.

The first one is outlined in detail for further clarification of the LoVEUS system.

Figure 1 shows the *visually enhanced content at premium sites*, which targets the cultural heritage and tourist guide functionality. This will allow the European traveller for example to view the reconstruction of an important monument he/she is looking at. In this way the monument's 'readability'—that is, the degree to which a monument can be comprehended or understood in terms of its original architecture, form and function—can be dramatically enhanced. The information received on the user's terminal will be personalised, matching his/her individual preferences in terms of content focus (for example, sports), format (for example, audio, video) and language (for example, Greek, English)[2].

The LoVEUS system will establish the necessary hardware, software and network infrastructure for location- and orientation-aware services introducing numerous new features for service providers, infrastructure providers and client terminals. In this paper, a multi-tier based architecture is discussed putting special emphasis on the LoVEUS application server and mobile terminal.

The solution for location and orientation tracking concentrates on the availability of location technologies that are device-based. Alternative technologies that may be provided by the network will be considered as they become available. The mobile network operator participating in the

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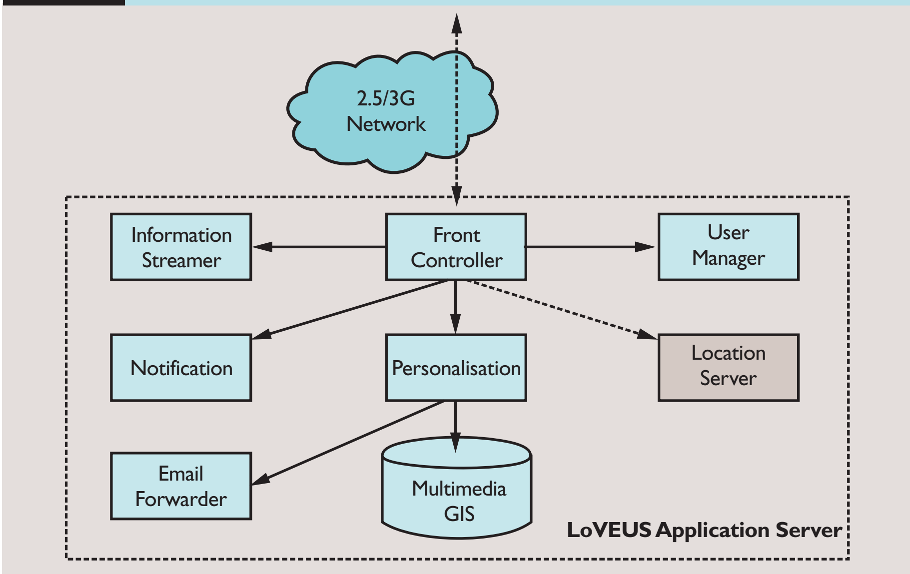
* In Figure 1 the user has his back turned to the scene for better visualisation of the next-generation terminal and the earphones; in actual settings the user would be looking towards the presented scene.

Figure 2 LoVEUS application server



consortium will enable the cell-ID and the TA parameter to be uploaded to the location server. The possible location will be then limited to a circular sector ring of less than 550 m. Other methods used for positioning (EOTD, AGPS, etc.) require extra equipment and are out of the project's scope. The terminal/network-assisted technology is well suited in the case of poor unassisted GPS satellite visibility; for example, in urban canyons. The communication protocol between the location server of LoVEUS and the mobile terminal will take into consideration these alternatives and introduce the necessary encoding and information exchange.

The supporting tools enabling the content to be prepared (tourism and advertisement content are treated the same during this task) and inserted in the system will of course be considered in the realm of the project, but are out of scope in this paper.

In the next sections, the paper descibes the application server architecture at a general level and goes on to discuss the most promising architecture on the client side. The paper concludes with a discussion of basic implementation issues.

LoVEUS Application Server

In the following, based on the user requirements, a draft picture of the LoVEUS functional architecture is provided, along with a description of the component functionality.

As shown in Figure 2 the server will consist of a set of components with the *front controller* being the part of the server which is responsible for the whole communication and application control. The front controller receives the client requests and in the beginning performs the access control via the user management component. Assuming that the user has been granted access to the desired request, the front controller maps the request to a set of business logic operations. It then extracts the required data from the request and amends it to the appropriate operations it will call in processing the client request. After calling all necessary operations and components the front controller waits for their responses. When the called components have finished their work and responded their results to the front controller, the front controller constructs the response for the requesting client and sends it back to the client. The construction of the client response is basically dependent on the client state, the client type and the user profile. According to the chosen business model the front controller generates output necessary for the correct charging of the end-user's account for the delivered service.

The *user manager* component is responsible for:

- user registration (add new user/update/retrieve/remove);
- user profile management (add new user profile/update/retrieve/remove);
- user device management (add new device/update/retrieve/remove);
- group registration (submit/update/retrieve);
- group profile management (submit/update/retrieve); and
- examine user authentication and authorisation (access control).

All of the tasks except for the access control are done by the user itself. Possible ways to do this are through a mobile terminal (for example, wireless application protocol (WAP), WWW), PC (for example, WWW), phone (for example, service operator). The most important information in adding a new user are the user's contact information, the bank account/credit card information, the cultural and heritage information preferences and the advertisement information preferences. This has to be done by every user prior to the use of the service as it is a payable and personalised service.

The *personalisation* component performs the profile-based personalisation in aggregating content according to the user's preferences and in preparing this content prior to its transmission appropriate for the requesting mobile terminal.

The *Multimedia GIS* (geographic information system) is the component where all the content will be stored. This enhanced GIS will associate GIS data to multimedia objects (tourist and advertisement information) enabling the streaming of multimedia content, especially MPEG-4 BIFS (binary format for scenes) and synchronised audio streams through the use of a component called the *information streamer*. The information streamer will consist of commercial off-the shelf components, which will be adapted if necessary for the use in these scenarios.

While the user is moving around he/she will be notified about the existence of 'interesting' information by the *notification* component. Information will be characterised as 'interesting' when the user's actual position is in an area (location) where information is available which he/she marked in his/her personal profile as interesting. These can be either cultural information like a recommended guided tour through an area of the city or advertisement information like a very good restaurant in this area.

One of the user requirements is the possibility for the end-user to get the information (for example, a picture of the reconstruction of a visited monument) sent to his/her personal email account. The *email forwarder* component is envisaged to fulfill this task in addition to the preparation of the content according to the user's personal profile (for example, format and resolution of the picture).

The use of a GPS receiver on the client side makes the *location server* component optional. In the case where a location server is used (means the use of a network-based positioning technology) the component will be responsible for the provision of the user position and the user tracking.

LoVEUS Mobile Terminal

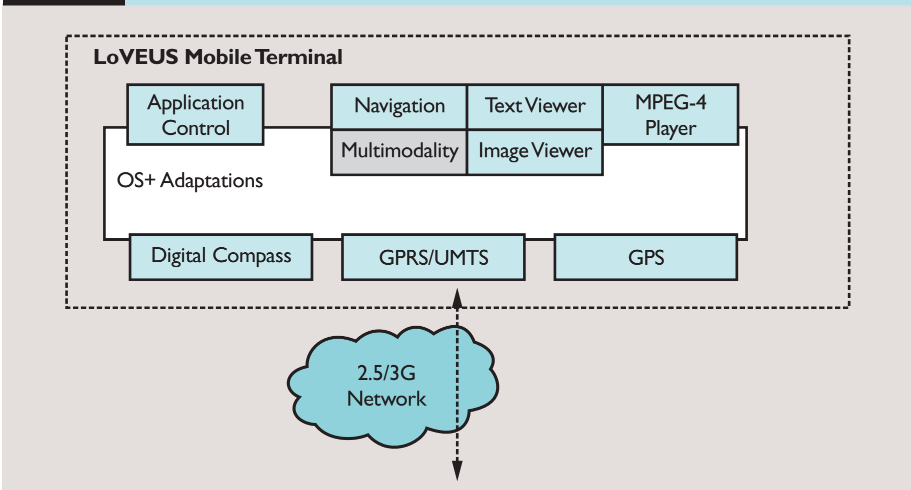
The mobile terminal will investigate the merging of wearable computer technology with next-generation mobile phones (2.5G and 3G) and PDA-like functionality into one device, providing the user with independence from 'switching' between devices for carrying out similar activities. It will incorporate a digital compass, introducing the notion of orientation, and a GPS module for the exact positioning of the end-user. Also crucial is the operating system granting access to all parts of the terminal, especially to the colour display and the ports.

Figure 3 shows the functional decomposition of the mobile terminal. Additionally to the controlling function the *application control* component will handle the complete communication issues (for example, information exchange with the server) through the use of the GPRS/UMTS hardware and software. The *navigation* component will be responsible for the correct positioning of the user and the navigation/routing based on a digital map view. This means that when a user is walking around in the city and requests for his/her actual position he will see a map of his/her environment with an icon indicating his/her position and direction on this map. The navigation/routing/tracking functionality will be used to help the user find the next point of interest (PoI) he/she wishes to visit or when using the guided tour functionality, which guides the user from one PoI to another according to a predefined order. Whenever a piece of map is required the navigation component will ask the server for the construction of this map according to the user's profile, his current position, direction and his application context.

For the smooth rendering and presentation of the whole application a series of components are required, which physically could be one integrated component. Logically there is the *text viewer* component, which can view textual information in different languages (for example, UNICODE); the *image viewer*, which is able to show at least one image format and allowing scrolling (according to the user requirements, a zoom in/out function is considered a desirable feature); the *MPEG-4 player* enabling the streaming of multimedia content, especially MPEG-4 BIFS and synchronised audio streams. The optional *multimodality* component could enable multi-modal interactions of the user with the application, but is very demanding in the sense of resources and is therefore strongly dependent on the available mobile terminal.

The *digital compass*, the *GPS* and the *GPRS/UMTS* components are provided through a combination of hardware and software and impose a very high hardware integration on the mobile terminal.

Figure 3 LoVEUS mobile terminal



Conclusions

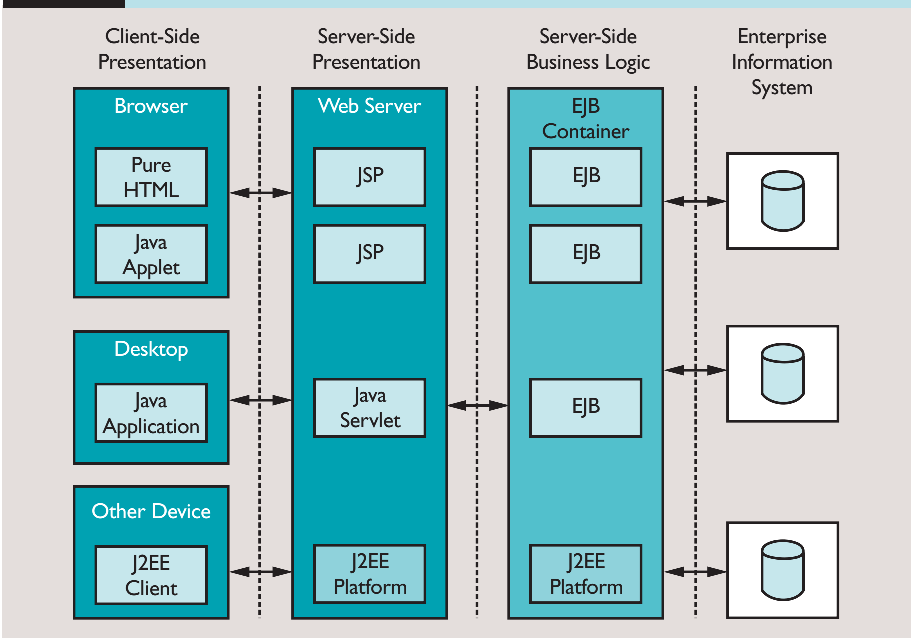
Concerning the overall architecture there are at least two major frameworks (.NET, J2EE) for the definition and provision of such value-added services. The main concerns in choosing the software architecture are portability and the integration of upcoming standards and existing legacy systems.

The Java™ 2 platform, Enterprise Edition (J2EE) architecture and its application model (see Figure 4) enables the server-side integration of legacy systems, the use of different protocols between client and server and the portability of the whole system. Using the J2EE application model the components of the application server could be implemented as Enterprise Java Beans (EJBs) communicating with the client via HTTP/HTTPS.

As we will have to implement the functionality for at least two different mobile terminals (one for the GPRS solution and one for the UMTS solution) portability of the client application is a crucial requirement. A Java™ 2 Platform, Micro Edition (J2ME, see References 2–5) application or applet seems to be suitable, which communicates via the HTTP/HTTPS protocol with the application server. The application control and navigation components would then be implemented as an application or applet and a browser would be used for the presentation of the multimedia content for the PoI. The Java support for rendering MPEG-4 with synchronised audio does, for the time being, not meet the requirements of the application.

A thin-client approach where the client would only send periodically its GPS position and orientation to the server and do the information rendering will not be feasible. Doing all the processing on the server side and being in navigation mode would cause a very high communication traffic over the network between client and

Figure 4 J2EE application model[1]

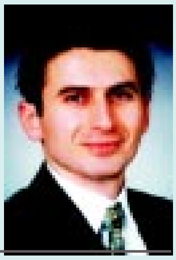


server. This is because of the GPS and compass information that has to be passed every few seconds to the server and the maps that have to be passed from the server to the client. In addition the panoramic view service will be hardly possible to work in real time. As a consequence the costs of the application would be high and a mobile network cell could easily collapse having many end-users using the application simultaneously in a hotspot.

The J2ME consists of two configurations, depending on memory constraints: connected device configuration (CDC) and connected limited device configuration (CLDC). A configuration is a Java virtual machine (JVM) and a minimal set of class libraries and application programming interfaces (APIs) providing a run-time environment for a group of devices with similar properties in terms of memory, size, and processing power. Configurations provide very little functionality; they just prepare the ground on which to add whatever you need. It is the profiles that give functionality. A profile adds several kinds of functionality, such as graphical user interface, better networking support, and so on. Like configurations, profiles may also be device-category specific.

For example, mobile information device profile (MIDP) on top of CLDC is most appropriate for small mobile Internet devices such as mobile phones, smartphones and PDA-like devices, which can spare at least 128 Kbytes of memory. Considering the specific needs of this group of target devices, the configuration is very compact and limited. The virtual machine

Biographies



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Michalis Karagiozidis received his diploma degree (Dipl.-Inf.) in Informatics at the University of Stuttgart in 1998. He specialized in distributed systems and information systems/databases with an emphasis on Internet applications. His thesis was on 'Architecture and use concept for Internet applications in cars' based on Java and XML. From 1998–2001 he was employed at DaimlerChrysler AG Research and Technology establishing a working group 'AutomotiveXML' for the use of XML technologies in car and service platforms. There he participated in and coordinated various projects in the realm of generic human–machine Interfaces, value-added and location-based services. Since January 2002 he has been employed at the Development Programmes Department of INTRACOM S.A. as Technical Manager in the domain of location-based services.

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that is used, K Virtual Machine (KVM), is extremely compact with an actual footprint of 40–80 Kbyte, depending on compilation options and the target platform. Like any other JVM, it enables you to download and execute applications, and like applets, the applications provide a method for presenting dynamic content. Adding a heap size of 128 Kbyte and a few tens of bytes for configuration and class libraries, a typical budget totals 256 Kbyte. This value is even within the memory limitations of phone centric 3G devices.

CDC is targeted at somewhat bigger devices, such as set-top boxes and in-car systems, which have more generous environments in terms of processing power and battery power. CDC targets devices with 32-bit processor and up of 2 Mbyte memory using the standard Java virtual machine or C virtual machine (CVM) and providing many more features of the Java standard edition. As CDC is a superset of the CLDC, CLDC-based applications can run unchanged in a CDC-based environment, having any required CLDC-based profile the applications uses available on the device.

As most appropriate mobile terminals (for example, Compaq's iPAQ), which will be available by the year 2002, support the J2ME/CLDC/MIDP libraries, the implementation of the client as a so-called *MIDlet* would also grand the charm of being able to switch later in time to mobile terminals supporting CDC. As a consequence the application could be easily ported from the GPRS solution to the UMTS-wearable solution by the year 2003 and adding functionality would be straightforward.

Having discussed all this implementation issues, it is important to keep in mind that the functional decomposition given in this paper is not yet considered final. Adjustments, re-arrangements and perhaps even further breakdowns may make sense and could give rise to new implementation issues.

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