Providing Advanced, Personalised Infomobility Services Using Agent Technology

Pavlos Moraïtis [1,2], Eleftheria Petraki[2], Nikolaos I. Spanoudakis[2]
[1]Dept. of Computer Science, University of Cyprus,
75 Kallipoleos Str., 1678-Nicosia, Cyprus
moraitis@ucy.ac.cy
www.cs.ucy.ac.cy

[2]Singular Software SA,
26th October 43, 54626, Thessaloniki, Greece
{epetraki, nspan}@si.gr

Abstract

This paper describes a real world application, the IMAGE system, proposing e-services for mobile users. We believe that such an application can be interesting for a large public taking into account that current developments in many areas (e.g. mobiles devices, wireless networks industries, GPS, GIS, routing) make possible the proposal of quite complex services for such kind of users. To this end, we precisely present how we integrated electronic services for mobile users (e.g. geo-reference, routing, mapping services) and introduced the personalized service feature, using agent technology in the context of the IST project IMAGE. The overall system architecture and business model are presented along with a particular focus on the Intelligent Module (IM), which is a multi-agent system. The IM is the core component of the IMAGE system. It is composed of several types of agents who realize through interaction, the IM functionalities within the overall IMAGE system.

1. Introduction

Recent developments in the areas of the mobile devices and wireless networks industries, geo-referencing systems and other relevant technologies (e.g. GPS, GIS, routing) motivate works in the areas of intelligently servicing mobile users and the combination of services in order to provide more complex ones [15]. In this context, a user might not only wish to find a route from one place to another (routing service) and see it in a map (mapping service), but also to be able to store the destination for future use. Furthermore, he/she might wish the system to be able to suggest a destination that best matches his/her interests and position. Another user might want to get information on specialized events that occur in his/her geographical area such as concerts or new theatre shows. Finally, the users want accurate, up-to-date information and ability to roam through other countries. All these user demands constitute a brand new area of services: the mobile, global,

personalized, location based services. The new term "Infomobility" services [9] refers to services that allow the mobile citizen to have seamless access to, and interaction with, personalised - location dependent - rich content multimedia information, that are, at the same time, essential parts of the autonomous and self-configuring business structures emerging in electronic businesses.

These are the main challenges for the IMAGE system and mainly its Intelligent Module (IM) presented herein and which was proposed in the context of the IST project IMAGE. This paper aims to show, through the description of a real world application, how such services will be offered and the added value that emerges from agent technology use (see e.g. [18]). Systems that treat similar aspects with IMAGE system are the Kivera [10], Maporama [13], CRUMPET [14] and PTA [8]. However there exist many differences comparing to Kivera, where no agent technology is used, as well as to CRUMPET and PTA that, as in the IMAGE case, also use agent technology.

The rest of the paper is organized as follows. Section 2 presents the problem description and Section 3 the application description. In Section 4 issues related to the application's building are discussed while in Section 5 we discuss about application benefits. Finally, Section 6 discusses related work and conclusions.

2. Problem Description

2.1 Advanced Infomobility Services

Let us now precisely define the new services that we wanted to offer and that are our requirements. The Image system must be able to provide transport solutions and tourist services from a various set of providers, according to the user needs, matched to his/her profile and habits. More specifically, the system must be able to:

- support different "types of users". The user him/herself will choose his/her type and preferences (i.e. tourist, public transport user, driver, etc.) and will receive services that take these parameters into account (e.g. inform the user on various extra locations to visit if he/she is a tourist, suggest a trip according to user preference and habits). Actions will be taken to secure user's sensitive personal information. Moreover the user can choose to edit more than one profiles (i.e. commuter, tourist, business traveler, etc) in order to have different modes of service.
- be able to adapt the service according to user's habitual patterns, by keeping and processing the history of service requests and profiles of the particular user. Predict the user needs if either on purpose or by mistake they are not explicitly mentioned (i.e. if he/she is an E&D and he/she did not state it in the service requested) and evolve with the use. Nevertheless, system initiated actions will always be subjected to user's permission, to avoid user frustration or surprise.

- receive the user request, as analyzed by the user interface, his/her position (through GPS co-ordinates if available) and suggest optimal transportation solutions, tourist events and nearby attractions.
- monitor the users route and automatically provide related events during the journey (i.e. info on traffic jams or emergencies on route), events, consultation and relevant information.

The Image concept provides the ideas and business model for such a system [6]

2.2 Why use agent technology?

The agent-based approach has been selected for developing this system, since the following requirements posed by such an application:

- Timely and geographical distribution of users and services, have to be taken into account.
- Heterogeneity of services, devices and networks are provided by different sources; services can be tailored to users profiles.
- Coordination of elementary services in order to provide the user with a complex, personalized service.

The above requirements invoke characteristics as autonomy, pro-activeness, intelligence and cooperation, which relate to basic motivations that would make someone utilizing agent technology (see e.g. [18]). More precisely agents can have the sufficient intelligence to achieve more (e.g. personalized assistance) or less complex (e.g. travel information retrieval, user location, etc.) tasks in an autonomous way. Such tasks can be achieved either by agents equipped with the appropriate individual capabilities, or by efficient interaction among agents of different types that have complementary capabilities. In the application described in this paper, agents belong to different types (i.e. interface, travel guide, educator, event handler, services, assistant and personalized assistant), and fulfil different tasks associated to the functionalities of the Intelligent Module (IM). In some cases, as we will see later, agents due to their characteristic of pro-activeness will be able to take the initiative to provide users with information related to their profile. The IM is the core module of the IMAGE system that services mobile users through a variety of devices (i.e. mobile phones, PDAs, PCs). The IMAGE project foresees the use of several IMAGE platforms in order to assist mobile users around the world and thus interoperability is a crucial point, which can be also very well achieved through the use of agent technology. This technology can presently provide, in combination with other adopted technologies (e.g. XML [16], DAML-S [4], Web Services [17], etc), appropriate solutions for the interoperability issue among heterogeneous agents.

3. Application Description

3.1 The Image Concept

The IMAGE project aims to create an information system that will respond to the requirements presented above and therefore will service mobile users through a variety of devices (mobile phones, PDAs, PCs). The service will be customisable and adaptive to user habits (personalized service). The service will be location-based and will usually entail showing the user where he/she is, letting him/her view different points of interest (POIs) around him/her such as theatres, banks, museums, etc. and helping him/her plan trips either inside his/her original city or throughout Europe. Specifically, a potential IMAGE customer is able to set an inquiry to the system either requesting a map of the geographical area of his/her location, or requesting the calculation and display of a map representing a journey between two geographical points, an origin and a destination.

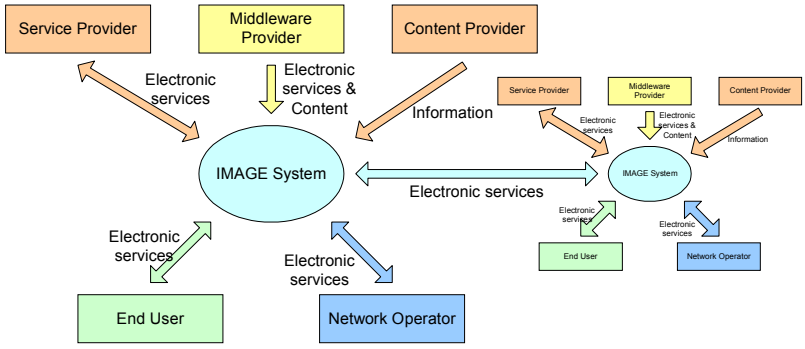

Figure 1 Image business model

These two points can be either defined by the user or calculated by the IMAGE system. Similarly, the types of the points of interest that will be embedded in the map can be either user defined or system defined. Additionally, each city or region will be served by its own IMAGE server and the system will have the ability to interoperate with other servers so that the user can arrange trips and get location based information for other European cities.

The overall Image concept/business model is presented in Figure 1. The Image concept is that the Image system will combine simple, possibly offered by third parties, services and content in order to provide a complex, personalized, global service. The term electronic service (e-service) refers to services that are offered in electronic form and are acquired through the use of electronic devices. Such services can be business-to-customer (through a web page or the mobile phone) or business-to-business (web services). The Image system main function is the interaction with the end users and thus can be operated by business entities that provide services to end-users (i.e. service providers). The relation between the Image system and the other business entities is one to many and involves a number of functions such as the provision of content, services or network infrastructure. The cooperative business entities can be:

- Content providers: entities that provide e-content (e.g. list of hotels for a city). They can have a direct link to the Image system or through a middle-ware provider.

- Service providers: entities that provide e-services to end-users. They can interact directly with the Image system (e.g. e-payment case) or through another middleware provider.
- Middleware providers: entities that provide e-content and e-services. They can operate as an integral part of the Image system or on an agreement basis.
- Network operators: entities that provide the network infrastructure and can operate as application service providers.

The system's main goals are:

- To successfully personalize the service.
- To seamlessly interoperate with other IMAGE systems in order to achieve a global service.
- To acquire services from different and possibly heterogeneous external – third party service providers.

The Image system bases its operation in several modules, namely the intelligent module (IM), the data management module (DM), the geo-reference services module (GS), the e-Payment module (PM) and the user interface module (UI).

Intelligent Module (IM) is the core of the IMAGE system. It manages, processes and monitors the user requests and establishes the interconnection between the various IMAGE internal modules. It is also responsible for the interoperability between the different IMAGE servers, for acquiring geo-reference, mapping, routing and proximity search services either from DM, GS or from external to IMAGE electronic services and middleware providers. To that way it provides the complex, personalized IMAGE services based on individual profile and preferences model. In this paper we focus to the IM conception and implementation, which along with the DM module are the core Image modules (other modules are optional, can be any local service or middleware provider), because IM actually provides the IMAGE services. DM module is mainly responsible for acquiring content from different content providers (with different format or service provision mechanisms) and making it available to the IM in a uniform way.

3.2 Intelligent Module (IM) System's Analysis and Design Issues

The Gaia methodology [21] was employed for system analysis and design. The Gaia methodology is an attempt to define a complete and general methodology that it is specifically tailored to the analysis and design of multi-agent systems (MASs). Gaia is a general methodology that supports both the levels of the individual agent structure and the agent society in the MAS development process. MASs, according to Gaia, are viewed as being composed of a number of autonomous interactive agents that live in an organized society in which each agent plays one or more specific roles. Gaia defines the structure of a MAS in terms of a role model. The model identifies the roles that agents have to play within the MAS and the interaction protocols between the different roles.

Other competent methodologies like MaSE [20] or ZEUS [2] were disqualified because they were not as agile as Gaia and one greatly benefits from them if he uses the respective development tools (AgentTool [5] and ZEUS [1]).

After the design phase, multi agent system developers can choose among a variety of existing platforms in order to simplify the development process. However, these platforms differ significantly in terms of the architecture, standards compliance, availability and support. The various features of a platform must be analysed and evaluated according to a project's needs before the actual use.

The Image project required an open environment, compliant with the standardizing efforts of the Foundation for Intelligent Physical Agents (FIPA). The multi agent platform that would be used should be able to communicate with other FIPA [7] compliant applications. Furthermore, issues that had to be taken into account were maintenance and availability. Under these aspects, the platforms that were selected and examined are JADE and FIPA-OS, that are also used widely by other IST projects (e.g. [14], [3]). They are both open source projects with constant maintenance and support and they are both FIPA compliant. They were analysed in terms of ease of installation and application development, architecture, agent management, communication features and interoperability. Also, a test application was created for each platform in order to verify the platform robustness, resource optimisation and execution time. Finally we decided to use JADE.

In the context of this work a kind of roadmap, based on our experience within this project, of how one can combine the Gaia methodology for agent-oriented analysis and design and JADE for implementation purpose, was proposed [12].

3.3 The IM System's Architecture

During the Gaia design phase the following roles were identified. Briefly the main characteristics of these roles are:

- *Interface*: This role is responsible for interfacing the multi-agent system (MAS) with the user interface (UI) or any other network operator and for providing white and yellow page information to other agents fulfilling also an interface role. Summarizing the interface agent can be considered as a middle agent [19].
- *Travel Guide*: This role provides routing, mapping, proximity search, user location acquisition services to the MAS by invoking relevant web services provided by GS, DM or any external provider.
- *Educator*: This role provides information about points of interest (POIs) to the MAS by invoking relevant web services provided by DM or any external provider.
- *Events Handler*: This role forwards to the user information about current events that may be of interest to him/her by invoking relevant web services provided by DM. These events can be traffic or leisure events such as traffic jams or exhibitions' openings and are sent to the user without his/her prior request.

- *Services*: This role serves as a supervisor of the multi agent system, initializing the system parameters, launching new agents when necessary and monitoring the agents' operation. This role is responsible for system maintenance and disaster recovery.
- *Social*: This role is responsible for dynamically locating new agents that are added to the system and for maintaining an acquaintances structure that contains white and yellow page information about other agent-contacts.
- *Assistant*: This role serves unregistered users (guests) in the two core IMAGE functionalities: display the user position in a map along with the POIs that the user has requested and calculate a route according to the user provided origin and destination. This role interacts with the Travel Guide and Educator roles and combines their input to produce the final result.
- *Personalized Assistant*: This is the most complex role and it serves a registered user, stores and manages his/her profile and personal data and uses the requests' history in order to adapt the services to his/her habitual patterns. Service adaptation is achieved by hour of the day dependent profile management and continuous refinement of user selected POI types whenever the user requests to view specific POI types around him.

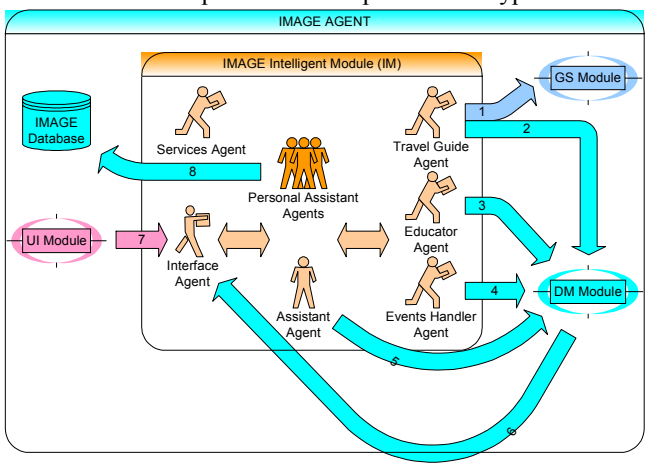

Figure 2 Intelligent Module's agents types and possible interactions

The Gaia model creates agent types by aggregating roles. In the IMAGE system all roles are implemented as agent types with the exception of the Social role, which is realized by all agents that need to be acquainted with their collaborative partners (see the resulting agent types in Figure 2). Thus, the IMAGE Intelligent Module is composed of several types of agents through a layered approach. These agent types and their interaction with one another and with the rest of the IMAGE modules are presented in Figure 2. The interaction among agents is accomplished through ACL messages with standard FIPA performatives [7]

The numbered interaction paths presented in Figure 2 between the agents of IM module and the other modules are:

1. Request geo-reference, request maps generation, request routes generation messages: all these requests are invocations of web services and are set up individually (a URL for each web service), so that any service provider can be used.
2. Request nearby points of interest (POIs), request user location messages: these are invocations of web services currently provided by the DM module, but any service provider can be used instead since they are set up individually. These web services are for requesting a type of a location point that is within a center range from an origin (e.g. find all restaurants within 100 meters from the user's location). The user's location in co-ordinates format is also requested in a similar fashion.
3. Request POIs service: this is an invocation of a web service for obtaining information about a specific POI from the DM module or an external provider.
4. Request push events: this is an invocation of a web service that requests DM to push information about an event to a specific user.
5. Inform about a user login or logout action: these are web services invocation messages that inform the DM about user login status.
6. Receive user's permission to be located, new recreation and traffic events from DM: the DM module can thus push information to the MAS. The first type of information that DM can push, concerns a user's permission to be located through his/her tracking client (i.e. a client software installed on his PDA or mobile phone) that can transmit his/her coordinates using GPS technology. Thus, the user can protect his privacy. The next type of pushing information is about new city events (e.g. a road that is closed, a new show). All such events have a time extent in which they are valid. The interface agent forwards the user's permission to be located to the interested personal assistant agent and broadcasts the new traffic and recreation events to all personal assistant agents.
7. Service UI requests: by the use of this communication channel (plain TCP/IP sockets) the UI can send user requests to the interface agent who decodes the XML message, identifies the request category and forwards the request to the appropriate personal assistant agent. As soon as the latter prepares the response to the user it sends it to the interface agent who encodes it in XML format and sends it back to the UI.
8. Get profile, update profile, register new user, etc: the IMAGE database is currently part of the DM module and is used for information storage.

3.4 Achievements

The major IM achievements for the provision of advanced infomobility services were, the complex "Where am I" and "Plan a trip" services, the transfer profile feature and finally, the learning about the user. Here we will present for space reasons, only the service "Where am I" and the transfer profile feature.

The complex service *"Where am I" (or WAI)* is one of the most important ones. It is realised as behaviours of the personalised assistant agent. The way the WAI is

implemented is as follows. It is JADE *FSMBehaviour*s with many states/sub-behaviours.

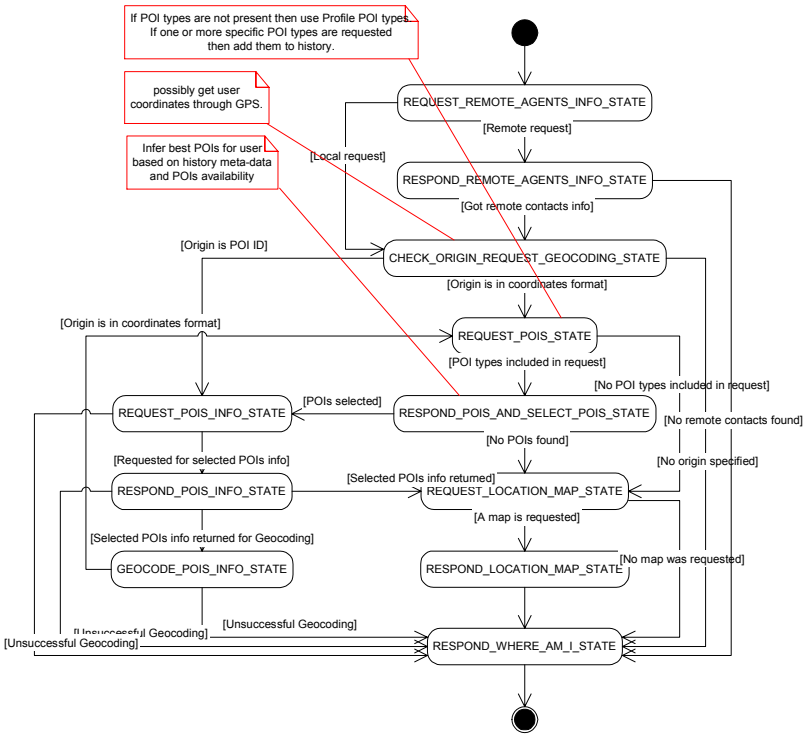

Figure 3 WAI behaviour

The finite state machine implemented behaviours are presented graphically in Figures 3. Thus, for example the *REQUEST_REMOTE_AGENTS_INFO_STATE* corresponds to the *RequestRemoteAgentsBehaviour* that sends a relevant request message to the interface agent. Depending on its reply, the next behaviour (i.e. *RespondRemoteAgentsBehaviour*) that actually listens for a reply from the interface agent in order to undertake some action when that arrives or another behaviour will be added to the agent scheduler. For example if the request is local the *CheckOriginAndRequestGeocodingBehaviour* will be the next scheduled behaviour for the WAI service. Regarding the WAI service the user request has a number of technical device-dependent parameters like screen size in pixels, but the important ones are the visibility around the user (range), the location of the user (origin) and the types of points of interest that he wants to see around him. A guest user will have to submit all this information (origin, though, can be either in coordinates format or the id of a POI that was previously displayed in the user's screen). In the registered user's case all this info can be either supplied (and this time the user can select one of his bookmarks as an origin) or inferred by the personalised assistant agent. Range and POI types can be extracted from his profile while his location can be obtained with the use of GPS.

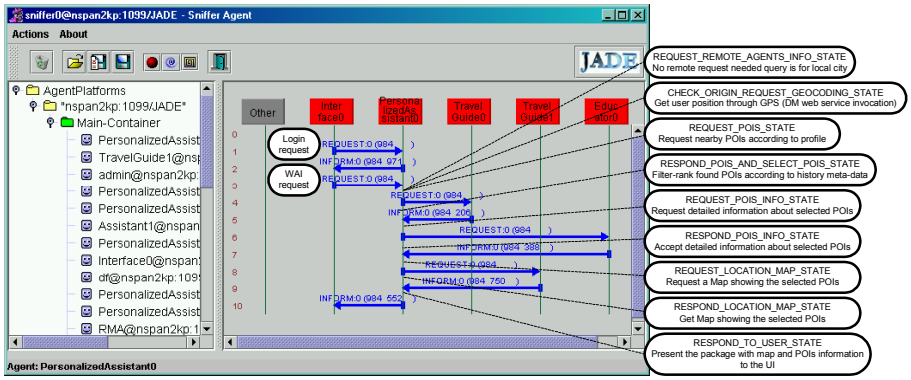

Figure 4 WAI sequence in IM

Figure 5 UI interaction with the user

An illustrative scenario that shows the WAI service is presented in Figure 4 (as a sequence of messages exchange by agents in the IM) and in user actions in Figure 5 (PDA usage). Notice that the user logs in and then selects the “guide” button. As soon as the WAI service is concluded he gets a link to the map and the links to the POIs visible on the map. He clicks the link to the map and sees the map screen. Notice that the only sent information is the size of the screen and the city at which the user is.

For the *transfer profile* use case there are two personalised assistants that participate in the process along with the two interface agents of the different Image platforms. The sequence for this service is presented in Figure 6 (the two participating personalised agents are referred to as the *initiator* and the *responder*). This service sequence commences as soon as a user requests that one of his profiles (i.e. commuter, tourist, business traveller) “accompanies” him during a trip to a remote city. The user would do so in order to use the remote city’s Image services and be informed about local events, there, corresponding to the migrating profile. It is a complex protocol that requires that a personal assistant in the remote city is not servicing, as usually, a registered user but he is dedicated to a user who will be arriving to the remote city. The *request_remote_agents_info* protocol (which can also be used by the WAI service) is also revealed by this sequence. Each interface

agent retains in his acquaintances only remote interface agents, who every time inform him about agents that perform specific services. After obtaining a remote personalised assistant contact, the *initiator* continues with the *transfer_profile* protocol, a three more steps process. At each step the process can be disrupted and in that case the *initiator* resumes servicing the user, informing him that the profile transfer request wasn't completed. At the first step the *initiator* sends to the *responder* a request message for an arrangement (when the user wishes to transfer his profile and for how long). If the response is affirmative the *initiator* continues serving the user normally until the date for the transfer arrives. At that time he sends the user profile to the *responder*. If the *responder* acknowledges the profile receipt the *initiator* stops servicing the user while the *responder* assumes responsibility of the service. From that time forward, the user has to login to the remote Image platform and be serviced from there. If the time frame of the arrangement expires or the user chooses to terminate his trip the profile is returned to the *initiator* and the service continues normally at the user's home.

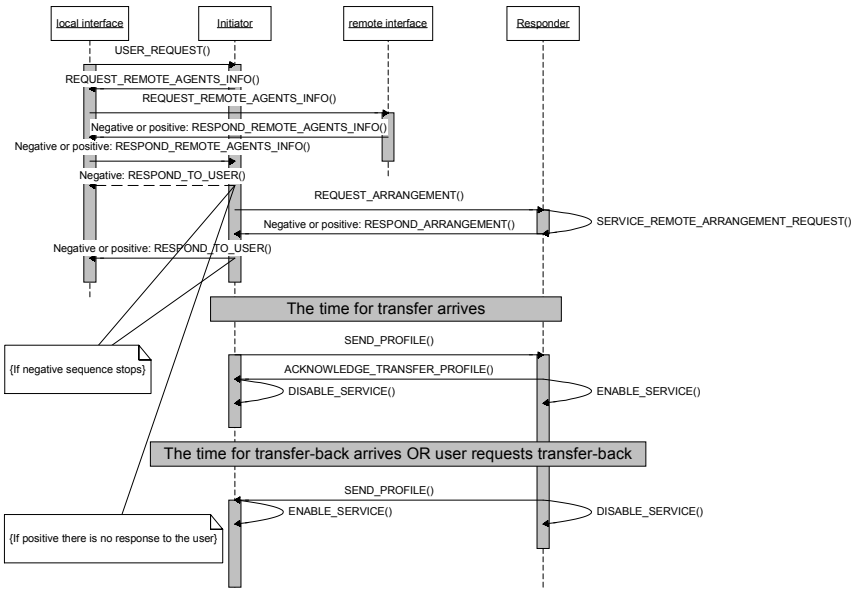

Figure 6 Transfer profile sequence

4. Application Building

The application was developed in one year's time. JADE is a framework implemented in the Java language so the IM application is a Java application that can be executed in every operating system that has installed the Java 1.4 version and later. The procedure is very simple; the application is packaged in a *jar* file and is accompanied by an IM administrator's manual that describes the parameters that can be changed at installation time by editing an *ini* file. These parameters are the

addresses of the web services (of DM and GS modules), along with other system parameters like name of local city, number of agents of each type that are to be instantiated, etc. The system is demonstrated in its full functionality in the Tampere city (Finland) and Turin city (Italy). There, the same IM, UI and DM modules are used but different service providers are used as GS and PM for each city. The evaluation procedure will finish at the end of summer 2003, at which time, about 100 users in both sites will respond to a relevant questionnaire. The first public demonstration of the system will take place in the Image user forum in Turin at the 3 and 4 of July 2003.

5. Application Benefits

As we already said before the application presented in this paper is not yet in public use. Therefore the full benefits of its use cannot for the moment been really evaluated. However we believe that the benefits are quite clear. The proposed system allows mobile users to exploit many different personalized services (e.g. traffic information, transport solutions and tourist services from a various set of providers according to their profiles) by only using their personal devices like PDA, PC or mobile phone. Without such an application a user normally is obliged to search each of the above services to different providers separately, some of them even supposing his physical presence in the service's provider place (e.g. a trip organisation agency) which is not very often easy for a mobile user.

6. Related Work and Conclusions

In this paper, a real world application, the IMAGE system, and more particularly a multi-agent system implementing the functionalities of the Intelligent Module within the IMAGE system as proposed in the context of the IMAGE IST project, is presented. This system integrates a set of intelligent agents having different functionalities (e.g. personalized assistance, travel information, cultural events information), which are necessary in order to cover the needs presented by this specific application field called "mobile, personalized location-based services". In this paper, through the detailed description of the implemented system, we have shown that agent technology responds perfectly to the basic requirements of such applications and thus is well suited for developing information systems for a modern and important domain of application, the one providing integrated services for mobile users.

To our knowledge, relevant work in this area is sparse and mainly in the research field. A relevant European Union research project is CRUMPET [14]. The overall aim of CRUMPET is to implement, validate, and trial tourism-related value-added services for nomadic users (across mobile and fixed networks). The services provided by CRUMPET take advantage of integrating four key emerging technology domains and applying them to the tourist domain: location-aware services, personalized user interaction, seamlessly accessible multi-media mobile communication and smart component-based middleware that uses multi-agent technology. Comparing to this work, the system we propose presents some

advantages. Firstly is the ability to access the IMAGE services through various devices (PDAs, mobile phones, PCs) due to the fact that user profiles are stored at the IMAGE server and not at the user's device. Secondly, IMAGE services can be offered by any network provider who can opt to use an entirely new user interface. PTA [8] used agents on the devices, like CRUMPET, and agents on the service providers. This is a difference with IMAGE, because our agents exploit existing web services of different service providers. Another difference is that in our architecture agents have knowledge of the other agents with whom they need to cooperate. Thus, the system is more robust because we avoid the use of a unique broker agent whose failure can lead to system malfunction. Lastly, the IMAGE system adapts the service to user habits. There also exist works that don't use agent technology like Maporama [13] and Kivera [10]. The advantages of our work compared to these works (besides the previously mentioned) are the ability to exploit external to IMAGE electronic service and middleware providers as well as the ability to seamlessly interoperate with other servers (i.e. IMAGE servers). Other advantages, directly linked to agent technology use, are the expandability, which means that new agents may appear offering new or evolved services with no modifications to the existent ones.

Our future work aims on one hand to expanding the IMAGE service in order to offer inter-regional and international trip planning and management, and on the other hand to offer the IMAGE services to other, possibly heterogeneous agents built using different frameworks. The latter will be achieved by exploiting developments in the semantic web [11].

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