AN AGENT-BASED SYSTEM FOR INFOMOBILITY SERVICES

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Abstract

This paper describes an agent-based service network architecture proposed for a real world application for the infomobility sector. This sector demands that mobile users (i.e. roaming users using mobile phones, PDAs, etc) have access to accurate real-time location-based services that are inherently distributed throughout the web. Such are traffic information, geo-reference, routing, or mapping services that are usually offered as web services. Thus, there is the need for a service network for the infomobility sector, which integrates electronic services for mobile users as well as it caters for services personalization. This issue was addressed using agent technology in the context of the IST project Im@gine IT. The overall system architecture and business model are presented along with a particular focus on the multi-agent system which is the core component of the Im@gine IT system.

1 Introduction

The infomobility business sector concerns the servicing of mobile users (usually using a mobile phone and/or a PDA, his car's system, etc) through wireless networks, based on a variety of technologies like GPS and GIS – routing and mapping systems – and different kinds of distributed content like public transport timetables, traffic information, etc. This complex environment motivates the combination of simple services in order to provide more complex ones [17]. In this context, a user can for example find a route from one place to another, see it in a map and be able to bookmark it.

Moreover, a service must be multi-modal in the sense that the user continuously changes his transportation means and thus this service has to support him differently each time, e.g. when he is in the car the messages should be audio messages rather than icons on the PDA (i.e. a palm-top computing device) screen.

Furthermore, the services may be accessible in a local area using technologies like WLAN or bluetooth. Such services and their utilization on behalf of a user constitute the ambient intelligence.

Finally, the users want accurate, up-to-date information and ability to roam through other countries. Thus, they need information that is generated at a local level and disseminated globally through a service network. This network should allow for the easy integration of dispersed service providers that provide different services, not necessarily known before system development. All these user demands constitute a brand new area of services, namely the mobile, global, personalized, multi-modal infomobility services.

These are the main goals for the Im@gine IT system, proposed in the context of the IST project Im@gine IT and mainly the multi-agent system (MAS) which is its core component. This paper aims to show, how such services will be offered, how they are going to be available world-wide through a service network and in parallel via this real world application, the added value that emerges from agent technology use (see e.g. [22]). In this context, the possibility for getting services through mobile devices based on distributed brokering is in our knowledge an innovative element.

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 benefits are discussed. Finally, Section 5 discusses related work and conclusions.

2 Problem description

Let us now precisely define the new services that were the requirements of the Im@gine IT system. Actually, this 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 himself/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. 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.

- Adapt the service according to user's habitual patterns. Also, supply any missing information based on user profiling. 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 user's route and automatically provide related events during the journey (i.e. info on traffic jams or emergencies on route).

- Support the user while he is roaming between countries. Always allow him to use local, real-time services that are accurate and quick to download.

- Support the user while he changes the modality of travel. Allow for audio messages while he/she is in the car, real-time information about next stop while he/she is in the train and information about the street name for the next turn while walking.

The Im@gine IT requirements and use cases were presented by Mizaras et al. [10].

2.1 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. [22]). 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 multi-agent system (MAS). In some cases, agents, due to their characteristic of pro-activeness, will be able to take the initiative to provide users with information related to their context. The MAS is the core module of the IM@GINE IT system that services mobile users through a variety of devices (i.e. mobile phones, PDAs, PCs). The Im@gine IT project foresees the use of several Im@gine IT 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. Web Services [21], the Semantic Web [20]), appropriate solutions for the interoperability issue among heterogeneous agents.

3 Application description

3.1 The Im@gine IT concept

The Im@gine IT project aims to create an information system that will satisfy the requirements presented above. The proposed services will be customizable, adapted to user habits (personalized service) and location based. The challenge is to integrate simple services, offered by different business entities, at different geographic areas and by heterogeneous information systems. Thus, the first step was to identify the interested parties and define a viable business model [8].

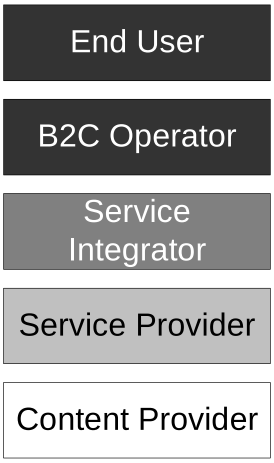

Figure 1: Im@gine IT business model

The overall Im@gine IT concept/business model is presented in Figure 1. In every box more than one player may be active. The identified business entities can be:

- End User. He/She is the owner of an enabled user device, or owner of a vehicle with an enabled in-car device through which he/she can access the Im@gine IT services.

- Business to Consumer (B2C). It is the entity that interconnects end users and their mobile devices with the Im@gine IT services. The B2C entity can be a mobile network operator company and may integrate the Im@gine IT services with the other voice and data services that already offers to its customers. It can advertise and sell the product to its customers, provide the necessary network infrastructure (GPRS) and is responsible for regular customer care.

- Service Integrator. This entity handles the marketplace between B2C entities and service providers. This entity does not have information about the end users; its purpose is to provide integrated services to B2C operators. It accepts the service advertisements coming from service provider entities and matches an incoming request to the appropriate service.

- Service Provider: It is the entity that owns or supplies (basic) content and (basic) services. The service provider can publish services on the service integrator’s platform.

- Content providers: entities that provide e-content such as a list of hotels for a city, points of interest (POIs), public transport time tables, real time traffic information, etc.

- According to the above business model the Im@gine IT system’s main goals are:

- To successfully personalize the service for the end user.

- To allow for seamless interoperation between all business entities in order to achieve a global service.

- To acquire services from different and possibly heterogeneous external – third party service providers.

3.2 Agent roles and types

We employed the Gaia methodology [23] for system analysis and design and the work proposed by Moraitis and Spanoudakis [12] on the use of the JADE [4] platform for implementing Gaia models. During the Gaia design phase the following roles were identified. The Im@gine IT MAS is composed of several types of agents that correspond to these roles and they are displayed in the MAS architecture presented in Figure 2.

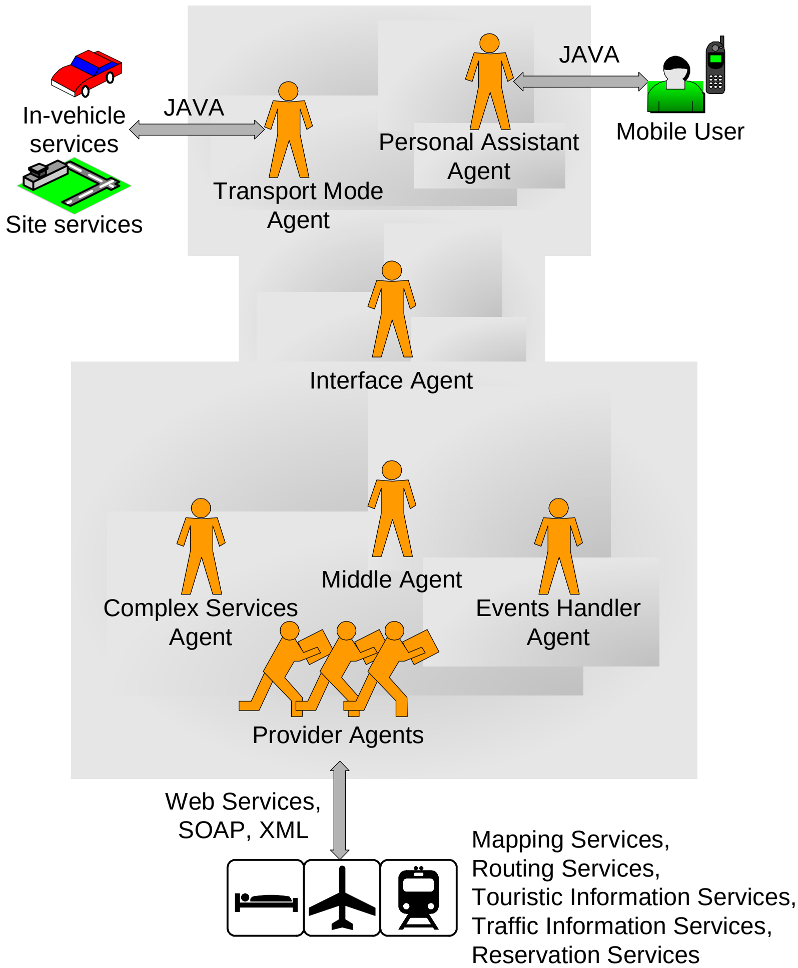

Figure 2: MAS architecture.

Each identified role was mapped to an agent type. Briefly, the main characteristics of each agent type are:

- Personal Assistant (PA) Agent: This agent resides on the end user's device servicing the user in a personalized and intelligent way. He interacts with the on the device graphical user interface, accepting the user's requests and providing the results of the accomplished service. He maintains the user's profile that enables him to manipulate the requests and the results according to the specific user's preferences.

- Transport Mode Agent: This agent is also implemented on the end user's device and supports the personal assistant role. He monitors the user's active route and tracks his progress notifying the PA whenever a route segment has been completed. He also can send information to the user, e.g. about the next bus-stop. It is also used for accessing nearby services supplying the results to the personal assistant for further processing (e.g. can understand when the user enters his car).

- Interface Agent: This role controls the access of the end user to the local main MAS platform. The interface role is a part of a B2C operator site in which the user authentication and profile data reside. He provides the end user an ID which will be used in all subsequent interactions with the main MAS platform. The interface role is also responsible of maintaining a backup copy of the user's profile.

- Middle Agent: The middle agent resides on the main MAS platform acting as service integrator. The middle agent accepts advertisements from complex or simple service provider agents and also accepts requests for service from the personal assistant agents. A received service request is matched with the available advertisements and if the middle agent finds a successful match forwards the user request to the selected advertisement service provider. When he gets the answer he forwards it to the personal assistant agent. The middle agents are federated so if a request asks for a service that is made available to the network through another middle agent closer to the user location, the request is forwarded to the latter. With the type of middle agent we use (i.e. broker) the roles that participate to the transaction are unknown to each other.

- Service Provider Agent: This role provides a service to the network advertising it to the geographically closest middle agent and subsequently accepting and servicing any requests that concern the specific service. The advertising of the service is a specification of the service accompanied by metadata that specify conditions under which the service will be offered (geographical area that the service can be achieved, price, availability, etc). In the MAS architecture a provider role can be:

  - Simple. The simple service provider role advertises and accepts simple services such as mapping or geocoding.
  - Complex. The complex service provider role is capable of synthesizing a complex service requested by the user (e.g. plan a trip), interacting with one or more simple service providers.
  - Events Handler (subscription service). This role accepts events and forwards them to the interested personal assistant agent. The events can be traffic events along a specific route that a certain user has activated and submitted to the events handler.

3.3 Middle agents

In order to realize the service brokering layer we used the middle agent concept. The middle agent type that covered the needs of our application was the broker agent [6]. A broker agent can actively interface between the requester and provider agents by facilitating the requested service transaction. Thus, all communication between requester and provider agents has to go through the broker. As soon as he gets a request, the broker performs a matchmaking process aiming to locate the most relevant service with an available description, previously advertised by a provider agent. Then he contacts the associated provider agent to that service description, negotiates for, executes and controls appropriate transactions and returns the result of the services to the requester. Moreover, in our system brokers can be distributed and each one can specialize to a specific domain of services. In this process the requester's identity is unknown to the service provider. Thus, assuming the business role of a service aggregator the broker services his customers using providers as resources.

The service requesters are assumed to be aware of the services that they need. In our system, the role of the broker is to either select the best service for the requester, or to redirect the request to the appropriate broker. In Im@gine IT the brokers are based on location that means that each of them is responsible for a specific geographical area. For this type of project there could be many competing service providers per area.

The greatest challenge in designing a broker is to model the service descriptions and requests, and to define the matchmaking process. These two tasks are highly interrelated since the input to the matchmaking process is the service request and the descriptions of available services.

Similarly to the work of Li and Horrocks [7] both the service advertisements and requests are accompanied by a service profile. The service profile (SP) defines the type of the service (e.g. mapping service), describes input and output parameters, as well as preconditions and post-conditions. The service advertisement defines this profile while the service request, defines the type of requested service, describes input and output parameters and also places values to input parameters. For the definition of the service profile we use the relevant specification by OWL-S [9]. Then we use the FIPA request/inform performatives in order to provide a service provisioning protocol (see Figure 3).

The matchmaking process can be now facilitated since the input requests and profiles are well defined. We need to match a service advertisement to a service request. Two types of matching were found to best serve our needs [7, 18]:

- the exact matching, which demands that the advertised service has the same semantics and equal inputs/outputs with the requested service, and

- the plug-in matching, which will allow for the advertisement to have more inputs/outputs than the ones requested. The exact matching is obviously always preferable.

The matchmaking algorithm that we conceived gradually filters the repository of advertisements until the one best to serve the request is found. Three types of filters, originally proposed by Sycara et al. [18] were used:

- Semantic Match (SM). This type of matching searches the service profile advertisements (PAs) for a service that matches the request (RP). In our case, SM will be selecting all the "routing" services for example.

- Profile Match (PM). This type of matching searches the PAs provided by the SM for input and output parameters that match those of the request. PM determines which PAs are exact or plug-in matches and sorts them accordingly.

- Constraint Match (CM). This type of matching shall determine which of the PAs provided by the SM, matches the constraints of a request (e.g. language should be Greek). CM is performed to the sorted list provided by PM and the first PA that successfully matches the constraints will be the selected service.

A special CM is needed before SM (named Pre-CM) so that the broker agent (BA) can determine if he can serve the request or it needs to redirect the request to another broker. This CM will be based on a broker capability property. In Im@gine IT the distributed broker capability will be the location of the request (i.e. the country).

For querying the PAs repository we use RDQL (RDF Query Language) of the Jena [5] open source tool.

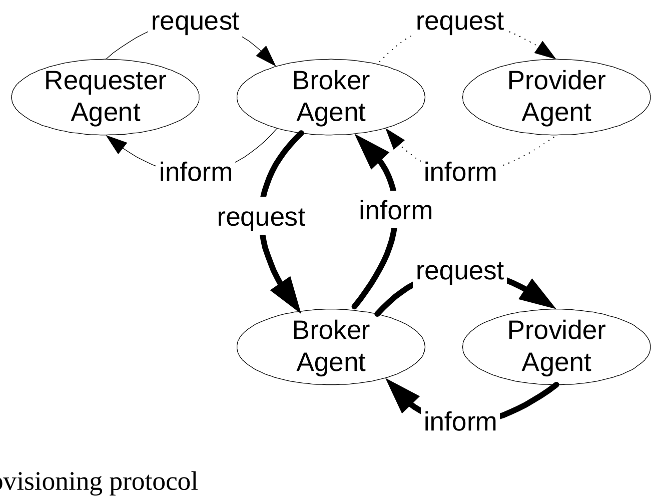

Figure 3: Service provisioning protocol

Thus, according to our matchmaking algorithm, the broker first applies the pre-CM filter. If he can handle the request, he then sequentially applies the three other filters (SM, PM, CM) to his PA repository. Otherwise, he forwards the request to the broker that can facilitate him and waits for the answer which he subsequently forwards to the user. The service provisioning protocol is presented in Figure 3.

3.4 The agent-based service network

The agents of our system form a service network if looked from a business viewpoint (see Figure 4). It is conceptually a brokering network where new services appear while old ones disappear, allowing for dynamic value flows throughout the value chain. Moreover, it allows for the introduction of new services not known before system deployment.

This service network is synthesized by four different layers (Figure 4). The top layer is the consumer layer. Here are two business entities, the end users and the resellers namely the network operators or other B2C entities that advertise and sell the services to the end user. The users are represented by their personal assistant agents, while the B2C entities by their interface agent.

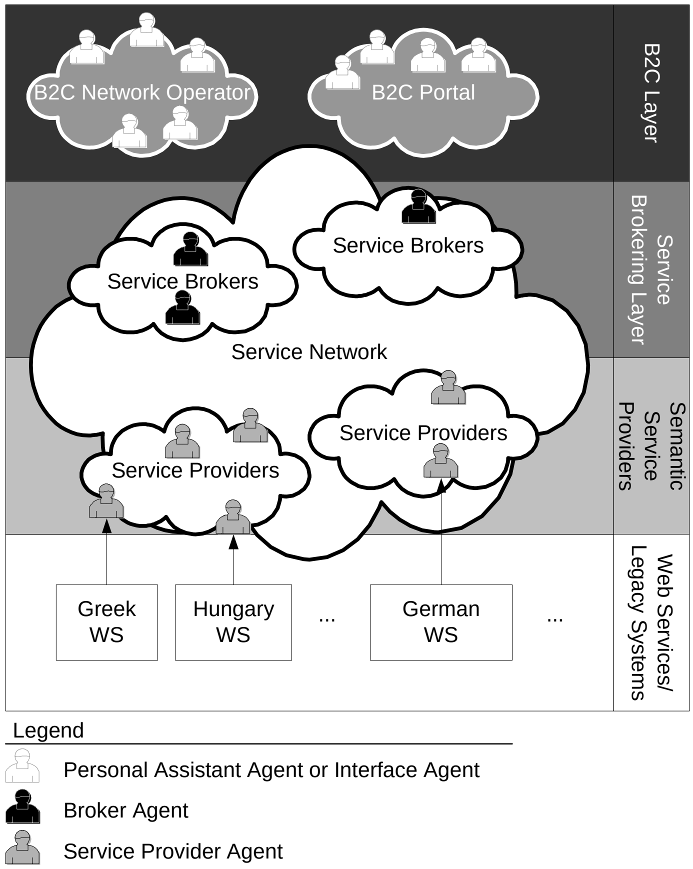

Figure 4: Im@gine IT service network

The next layer is the service aggregator layer namely the delivery channel. Here are the middle agents, who know the service providers (i.e. the goods producer agents) and play the role of the brokers.

The following two layers are of the service providers and the external legacy systems that through web services offer the actual services. Content and service providers can enter the service network either using their own agent (in that case there is not a 4th layer) or using legacy systems (e.g. a web service). If they use their own agent they should use the ACL protocols that the Im@gine IT system uses. The content of the ACL messages exchanged between a broker and a service provider is encoded in RDF format, so the provider can use his own ontology provided that there is an OWL file that can map concepts between the two ontologies. Those that use legacy systems should create the appropriate provider agent that wraps their services.

3.5 Federation of agents – MAS deployment

The Im@gine IT system is distributed across different geographical areas, each of them serviced by one service integrator (i.e. broker agent), one or more service providers (i.e. simple & complex service provider agents and events handler agents) and one or more B2C operator platforms (interface agent, see Figure 5). The area-relevant services that are advertised from the service provider agents to the local broker agents may differ in quantity and nature from other geographical areas. However, these services can be accessed by the end users everywhere since the broker agents of the entire Im@gine IT distribution cooperate, forming a consortium. Each broker agent is aware of the network addresses of the other broker agents in the community as well as the geographical area they cover. A request for a cross boundary service, for example a trip to another country, can be serviced for the initial part of the trip by the local broker agent and be forwarded for completion to the appropriate remote broker agent. This collaboration among the broker agents is transparent to the end user who shall receive a complete description of the requested trip.

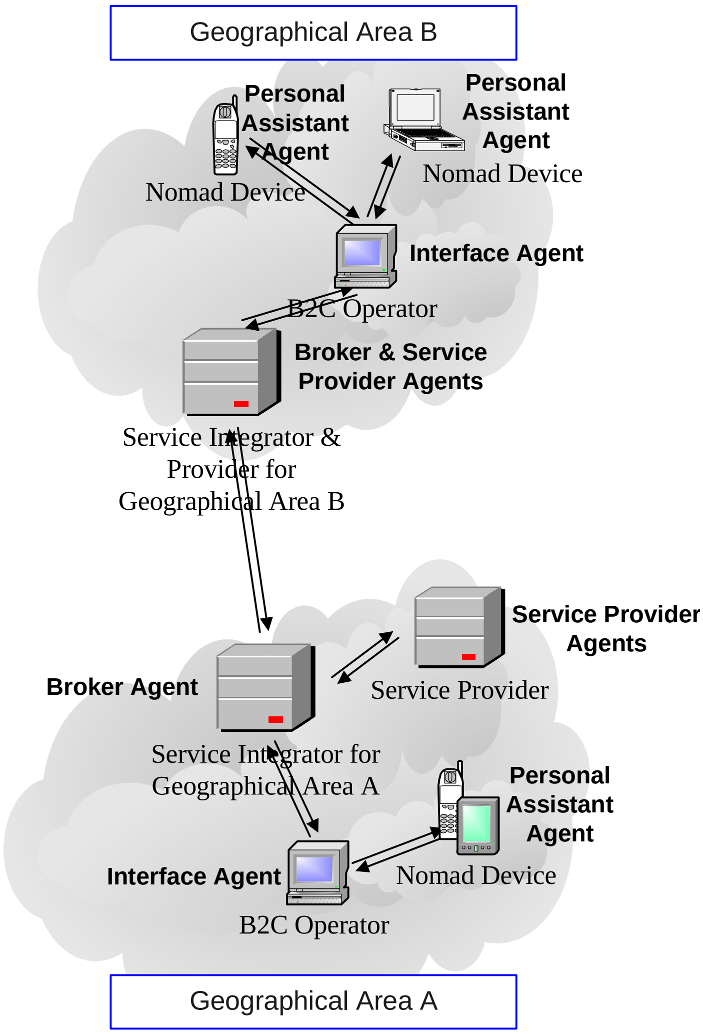

Figure 5: Federation of agents

This federation scheme allows for a seamless expansion of the Im@gine IT service network as new geographical areas and their service integrators and providers can dynamically be introduced and made available to the rest of the community. Each geographical area can support a number of independent B2C operators that can host, maintain and authenticate end users and grant them access to the Im@gine IT services, acting as portals. All the functionalities of a B2C operator are accomplished by the interface agent who after the successful authentication, assigns a user ID that is subsequently used for accessing the Im@gine IT services. In the case of the roaming user the authentication procedure is initiated on the local business partner of the B2C operator that he/she was initially registered. The local partner is responsible to contact the remote B2C operator and to forward the authentication request. As soon as the end user is authenticated he/she can access directly the local broker agent with the assigned ID and bestow his/hers requests. With this scheme the end user can benefit from the Im@gine IT services regardless of his/hers location.

3.6 Achievements

An Im@gine IT prototype has been developed and deployed using a subset of the initially declared services. Through this prototype an end user can access directly a service integrator and request a "plan a trip" and a "show me around" service. A "plan a trip" service can automatically decode the current user's position, decide the desired destination if one is not provided, calculate a number of routes according to the user's preferences in his/hers profile, and present the routes to the user. Similarly the "show me around" service presents a map around the automatically calculated user position that contains the points of interest (POIs) that fit to the user's profile.

We used the JADE-LEAP [5] framework for the development of the agents both on the user's mobile device (personal assistant agent) and in the service integrator and provider platforms (broker agent & simple and complex provider agents respectively).

The advertisement of the services is realized with the RDF codec embedded in the JADE framework and the ontology necessary for the interpretation of the message content was developed with the Protégé tool [16]. A problem that we had to overcome is that FIPA ACL allows for a single ontology to be included in the content of an ACL message. Thus, it is not possible to use different existing ontologies when defining the ACL protocols, and thus we had to create a new one with all the concepts that we need.

The FIPA [2] ACL SL0 was employed for modeling the agent coordination protocols using the request, inform, failure and refuse performatives. Finally, the actual services are accessed using SOAP and WSDL [21].

With this prototype we managed to address the system requirements and accommodate through the use of appropriate agents all entities described in the business model.

4 Application benefits

The proposed architecture offers many major advantages compared to others [15, 14, 11, 3]. First of all it is modular, allowing for dynamic addition and removal of various components. Actually, the MAS that we developed consist of three different products:

- The personal assistant and the transport mode agents (device application) that any user can purchase and install on his device (PC, mobile phone, PDA, in-car device).

- The interface agent that manages the users of a portal or network operator. Note that any mobile network operator can choose to supply the device application for free.

- The broker agent with optional add-ons in the form of service provider agents.

Secondly, the user (using a personal assistant) can access all available infomobility services through any known access node (i.e. broker agent). New services appear dynamically (even new types of services), along with new personal assistants that can take advantage of them. Thus the system is expandable and FIPA compliant, thus allowing for heterogeneous agents to fit in (either as service providers or requesters).

Moreover, the user can have a service tailored to his needs. The personal assistant not only profiles the user but using a statistical learning method can anticipate his needs and successfully personalize the service. Compared to [11] the innovation is on an algorithm that learns the maximum number of transportation type changes (e.g. a trip with the user changing three buses/trains to get to his destination involves 3 changes of transportation type) that are acceptable by the user in a multi-modal trip chain. Thus the personal assistant agent proposes only the routes that the user is more likely to select.

Additionally, the user can access the Im@gine IT services anonymously (through the broker), thus ensuring his privacy.

Furthermore, the concept of complex provider agents that provide added value services allows for the anonymous submission of user profile information by the personal assistant, so that the information filtering for the specific user takes place on the server side. This is an advantage since the transfer of redundant information on a user device can be time consuming (low wireless bandwidth, e.g. GPRS) and expensive. When the user asks “show me around” there may be hundreds of POIs in his vicinity, while after the relevant filtering only a small number will be shown to him (e.g. 10).

5 Related work and conclusions

This paper presented an agent based, real world application in the context of the proposed Im@gine IT IST project. This system integrates a set of intelligent agents having different functionalities that are necessary in order to cover the infomobility services application field. Through the detailed description of the conceived 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.

The characteristics of Im@gine IT system are presented in Table 1, side by side with other products of similar research projects and Maporama. The latter included as a commercial product that offers a wide range of services, typical in this domain of services provisioning. This table provides a user-centric comparison on the capabilities of these systems.

Characteristic \ System	**Im@gine IT**	**Image**	**Crumpet**	**PTA**	**Maporama**
Use external service providers	✓	✓			
Route to POI	✓	✓			
User profiling	✓	✓	✓	✓	
Adaptive to user habits	✓	✓	✓		
Bookmarking	✓	✓			✓
Agent on the device	✓		✓	✓	
World-wide coverage	✓				✓
Multi-modal trip planning	✓				
Ambient Intelligence	✓				

Table 1: Comparison of infomobility services products

The implementation advantages of our approach related to these approaches have already been presented in Section 4. The presented architecture provides solutions for the future personal travel assistant (PTA) developments as they have been identified by FIPA [1]. We address the challenges: a) of agent mobility in a network (the personal assistant agent delegates the task of filtering huge amounts of data to the complex provider agent by sending parts of the user profile along with the user request), b) travel monitoring (through the concept of complex provider and events handler agents) and c) inter-operation between agents and workflow (by allowing the interface agent to manage value flows between the user and the brokers, the latter managing the value flow towards the provider agents).

We extend the work of Varga and Hajnal [19] who propose a methodology for providing web services through the usage of wrapper agents. We put forward another way to engineer web service wrapper agents that is in-line with semantic web developments [20]. In our notion any service aggregator entity will be offering services using ontology for defining concepts and services. The problem is not to translate a service to ontology but to map the service to the broker ontology. This can be done at the broker or provider agent level since the ACL messages are RDF encoded and an OWL file providing the translation can be dynamically used by both agents.

In comparison to Infosleuth (that uses distributed brokers, [13]), our approach provides many advantages. The first one is its compatibility with FIPA standards that allows for heterogeneous FIPA compliant agents to easily request/provide services. The second and most important is that brokers do not simply exchange their advertisements. They rather define their special capabilities over the provided services in the domain (e.g. transport and tourism). Finally, in our approach the personal assistant agent doesn't have to define a search policy for the broker. He doesn’t have such knowledge he just knows a broker and requests for a service.

Acknowledgements

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