Agent Architecture for Providing Accessibility Content and Services in an Ambient Intelligence Context

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Abstract

This paper provides an insight on the special requirements of accessibility content and services in an ambient intelligence context and proposes an agent-based approach and architecture for addressing them. It is based on previous approaches for systems regarding infomobility services adding the mobility impaired people special requirements. The result is an architecture with multiple agents on the user's nomad device that address the ambient intelligence issue and a family of dedicated personal assistance agents to each type of mobility impairment whose deliberation provides the best solutions for people that have a combination of impairments.

Keywords

Agent Architectures, Intelligent Infomobility Services, Ambient Intelligence, Mobility Impaired, Personal Assistance.

1. Introduction

Agent technology has been applied to the infomobility services sector in recent years. Such services include location-based services like mapping and points of interest search, travel planning and, recently, trip progression monitoring and pushing information and events to the user. Works like the ones carried out in CRUMPET (Poslad et al., 2001), IMAGE (Moraitis et al., 2003), ADAMANT (Wang et al., 2004) and the most recent Im@gine IT (Moraitis et al., 2005) projects have addressed the state of the art and some of them (e.g. Im@gine IT) even furthered it. Recently, agent technology was also applied for supporting virtual elderly assistance communities, in the context of the TeleCARE project (Afsarmanesh et al., 2003). The overall goal in TeleCARE is the design and development of a configurable framework and new technological solutions for tele-supervision and tele-assistance, based on the integration of a multi-agent and a federated information management approach, including both stationary and mobile intelligent agents, combined with the services likely to be offered by the emerging ubiquitous computing and intelligent home appliances, and applied to assist elderly people.

An agent-based approach was selected for all referenced projects, since the following requirements that can be dealt with nicely by agent technology (Weiss, 1999) are inherent to infomobility services provisioning:

- distribution: timely and geographical distribution of users and services have to be taken into account,
- heterogeneity: user support, services, devices and networks are provided by different sources,
- co-ordination and communication: optimal user satisfaction can only be achieved if co-ordination and communication between users and service providers is provided,
- mobility: users and user devices may change their physical and logical position over time.

Moreover, a recent research has proposed that elderly and disabled people compose a segment of the population that would profit very much from ambient intelligence (AmI) if it is accessible (Abascal, 2004). Furthermore, O'Hare et al. (2004) advocate the use of agents as a key enabler in the delivery of ambient intelligence. Thus in an AmI framework for servicing elderly and disabled (mobility impaired people) the role of agent technology is crucial.

AmI relies on launching agents on lightweight devices. However, lightweight devices pose certain limitations on the available resources (CPU speed, memory capacity, storage capacity, etc) for programming applications. The agent community since the Leap project (Bauer et al., 2001) has the tools to launch agents on lightweight devices and has defined protocols (Caire et al., 2002) for brokering services that have not, though, been used for integrating heterogeneous services available throughout the World Wide Web.

The European Commission Information Society Technologies (IST) Programme and specifically the Integrated Project (IP) “Ambient Intelligence System of Agents for Knowledge-based and Integrated Services for Mobility Impaired users” (ASK-IT, IST-2003-511298) project aims to offer infomobility service to mobility impaired people and support them while on the move. Adding to the results of the works presented this far, this task involves reasoning over the needs of different types (mobility impairments) of users or possible combinations of these types, while different (and sometimes conflicting) knowledge describes the needs of people with different impairments. Moreover, ambient intelligence must be employed so that the impaired people receive special and context based support while on the move. In this paper we aim to propose an agent-based architecture for addressing these challenges. The architecture will include the participating agent types and outline their interactions for achieving their goals.

In the next section we present the related work in more detail. In section 3 we provide an insight on the requirements of the ASK-IT project that are also the motivation behind this work. Then, in the fourth section, we propose an agent-based architecture for addressing these requirements/challenges, after examining the state of the art and the technical implications of the new needs proposed by ASK-IT. We conclude in the fifth section with a discussion.

2. Related Work

The overall aim of CRUMPET was to implement, validate, and trial tourism-related value-added services for nomadic users (across mobile and fixed networks). The services provided by CRUMPET took 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 used multi-agent technology.

IMAGE proposed a very different business model (use local content and service providers) but also proposed a technical solution with some advantages in comparison to CRUMPET. First was the ability to access the IMAGE services through various devices (PDAs, mobile phones, PCs) due to the fact that user profiles were stored at the IMAGE server and not at the user's device. Secondly, IMAGE services could be offered by any network provider who could opt to use an entirely new user interface. The IMAGE system adapted the service to user habits and each IMAGE server had the ability to seamlessly interoperate with other servers (i.e. IMAGE servers). It innovated by proposing a personalized assistant agent that:

- handles the user profile and adapts the service to his/her needs, and,
- aggregates simple services from provider agents to offer the user a complex service.

ADAMANT exploited the use of agent technology for offering infomobility services in a local area (i.e. within an airport).

The most recent work in this context is the IM@GINE IT project, where a new package of services was offered that employed inter-city travel and kept the personalization and adaptation feature of IMAGE along with the flexibility of service provider choice. Inter-city multi-modal travel planning (i.e. travel plans including more than one transport types like airplane, car, boat, rail, bus, etc) was supported for the first time. Moreover, the reservation feature and timetable management during multi-modal travel enabled the user to plan a safe, comfortable, care-free journey.

In IM@GINE IT, heterogeneous services were supported with the use of wrapper agents and an Agent Communication Language (ACL), based on an ontology that was fully independent of the implementation framework.

Another innovation that this project proposed was the engineering of a brokering framework for providing semantic services to agents on lightweight devices. Using ontologies and ACL the proposed middle agent type (broker) acted as the semantic gateway for the device-resident agents to the IM@GINE IT services. It could identify collaborators of the service–requesting agents depending on location and service.

Finally, TeleCARE used the Aglets framework in order to develop agents that create and manage virtual communities of elderly people. They offer services like chat, email in order to support the virtual community. Moreover, they monitor the living status of the elderly persons and are able to undertake some action (social alarm, inform a relative, etc) when there is a need. Finally they offer an agenda reminder service, a “time bank” management system (a mechanism for collaborative community building) and entertainment in the form of games, music and education programs.

3. Application Requirements and Challenges

Let us now precisely define the new services that were the requirements of the ASK-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 impairment type and preferences (i.e. deaf, blind, etc) and will receive services that take these parameters into account. Actions will be taken to secure user’s sensitive personal information.
- 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 or services.
- 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 ASK-IT detailed requirements and use cases were presented by Simões et al. (2006). The projects presented in the related work section, though, scarcely address the case of an elderly or handicapped person requesting infomobility services. This is a very different situation, with the following characteristics:

- Personalization doesn’t only refer to learning user habits. It encapsulates the need for knowledge regarding the situation that this person is into. Therefore the personal assistant agent must employ powerful knowledge regarding the type of impairment of the person. It is highly different to request for and present a route to a person on wheelchair. The accessibility features of crossroads and of busses or trains must be taken into account. In the case of an elderly or sick person even the weather conditions must be taken into account. Thus, agents with knowledge sufficient to serve each impairment type must be developed. Furthermore (and for the case that a person has more than one types of impairment) these agents must be able to cooperate in order to serve that person. The experience that allows ASK-IT to undertake such an innovative task comes from work done by (Matsatsinis et al, 2004) but there only the concept of the team of agents that actually acts as one was proposed. Work within this sector will be wholly innovative and will address the coordination of a team of agents that decides over one subject. Moreover we will have to tackle emerging behaviour, since the combinations of types of impairments and their extent can be limitless.

- The immediate ambient plays a vital role for servicing the user (domotic services, ticketing services, etc.) and all these services must be accessible by the user agent on his/her device. Here the user agent doesn't only use a local service in order to present information to the user. The agent either:
    - needs to select and get the local service and then adapt it to the user's needs, or
    - it is the actual user of the service (e.g. switch on the air-condition) and must have the relevant knowledge and profile of the user.

4. Proposed Architecture

4.1. Background

FIPA (2001) specified an architecture for Personal Travel Assistance (PTA) applications. The architecture scheme is presented in Figure 1. The following agent types are proposed to participate in this architecture:

- The Travel Service Agent (TSA) is responsible for accessing services and replying in the requester's ontology. He is proposed to specialize in a domain, like global flight plans and hotel arrangements or local hotel, car and restaurant information, for example. Other services might specialize in tourism or restaurants, for example, but globally. In all cases, this agent type is responsible for maintaining the data access, interpretation and delivery to other service agents that might be implemented as a "wrapper" around legacy databases or web services.
- The Travel Broker Agent (TBA) is responsible for locating and contracting TSAs. He can obtain the travel options from several services, filter and select from the alternatives, and legally bind a contract and travel documents based on a final selection. He can schedule and incrementally reschedule the entire travel plan across several service types such as flight, train, hotel and special events.
- The Personal Travel Assistant (PTA) acts on behalf of a user and is legally authorized to do so, up to the level allowed by the user. While conceptually seen as one Personal Assistant (PA) for each user, the implementation should be assumed to use a multi-user, server-based design. This agent type has many similarities to a personal assistant and might simply be a cast in a similar role. This agent is responsible for remembering and following the user's instructions and learning the user's preferences based on choices or feedback after the trip. A Mini-Personal Travel Assistant (MPTA) is a lightweight agent that is typically device-dependent, such as an agent operating on a PDA or laptop computer, where, for instance, bandwidth and modality become special issues. Although this tends to cause a restriction on functionality, many additional functions such as GPS and GSM can be provided in this context.

FIPA also specifies a set of standard interaction protocols such as FIPA-request, FIPA-query, etc. that can be used as standard templates to build agent conversations. Moreover the possible heterogeneity of agents points to the use of as much as possible standardized practices. The JADE-Leap (Bauer et al., 2001) version allows for light-weight implementations of agents on nomad devices like PDAs, laptops and smart phones. Caire et al. (2002) presented a communication protocol for JADE-Leap agents taking into account the inherent problems of an agent platform executing on a dynamic and limited environment like that of a mobile phone. This platform provides the elements needed for the ASK-IT application.

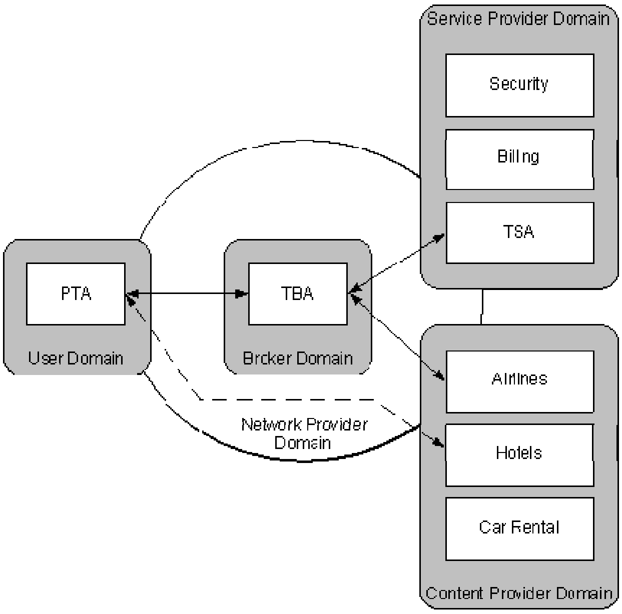

Figure 1. The FIPA PTA architecture

As is obvious, a lot of implementation specific issues are left for the application developer to decide. Also, FIPA admits that this architecture has some deficiencies. The Im@gine IT project (Moraitis et al., 2005) extended the FIPA architecture and addressed the open issues within the FIPA report. It proposed the architecture shown in Figure 2 and proposed the following agent types:

- Personal Assistant (PA) Agent: This agent (acting as a FIPA MPTA) resides on the end user's device servicing the user. 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 a first attempt to integrate ambient intelligence with PTA. 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 business to customer (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. This role is new in comparison with the FIPA PTA architecture.
- Middle Agent: The middle agent (actually a broker, acting as a FIPA BTA) resides on the server side 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.

- Service Provider Agent: This role (acting as a FIPA TSA) 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.

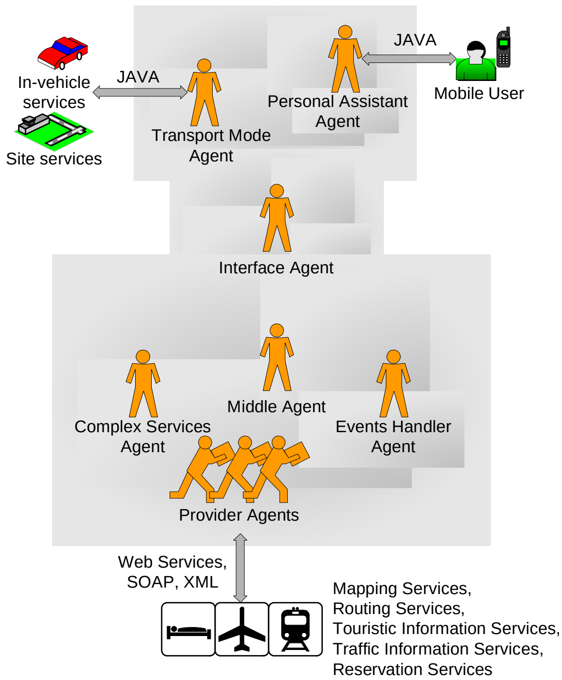

Figure 2. Im@gine IT MAS architecture. The personal assistant and transport mode agents reside on the nomad device. The interface agent resides on the B2C role server (network operator or service aggregator-portal) and the complex services, provider and events handler agents are scattered through the world wide web.

The Im@gine IT architecture provided solutions for the future personal travel assistant (PTA) developments as they were identified by FIPA [1]. It addressed 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). Finally, it provided a complete solution for the nomad devices service provisioning including not only simple services but also the delegation of complex tasks and subscription services. The solution is composed of a protocol, a service profiling scheme and the relevant matchmaking process (Spanoudakis and Moraitis, 2006).

4.2. ASK-IT Architecture

Taking all the above into consideration, the proposed ASK-IT architecture will be an evolution of the Im@gine IT architecture in two ways:
a) by integrating ambient intelligence to PTA (offering personal assistance in an ambient intelligence context), and,
b) by proposing a server side dynamic coalition formation aiming to serving users with one or more types of impairments.

Service discovery and provisioning will use the middle agent paradigm (see e.g. Klusch and Sycara, 2001). This approach assumes that agents that provide services are able to advertise them to middle agents. Moreover, the latter have profiles of available web services. Personal assistants or any service requester agents can then ask the middle agents for service providers that are suitable for the needed task.

The family of agents that will be able to address these challenges will include the following:

- The personal wearable intelligent device agent (PEDA, acting as a PA or MPTA for persons with impairments) that provides the personalized infomobility services to the user
- Provider agents that advertise and offer services to the ASK-IT service network (acting as TSA)
- Middle agents that have white and yellow page information about providers agents and cooperate in order to provide all available services through any contact point (acting as BTA)
- Elderly and Disabled assistant agents (EDA) that specialize in the mobility requirements and needs of any type of handicap (new type of agent)
- AmI service agents (AESA) that configure the environment of the user according to his habits/needs (new type of agent)
- The personal wearable communication device agents (PWDA) that monitor the user's sensors and provide information either directly to the user or the PEDA in cases of emergency (new type of agent).

Figure 3 provides an insight on the proposed architecture. The ASK-IT server has a broker agent and the EDA agents. Provider agents can be deployed either on the ASK-IT server or in other computers accessible through the Web. The personal space (or personal area network-PAN) includes the devices on the user's person. On the center there is the nomad device that has the connection to the internet and where the PEDA, AESA and PWDA agents will be deployed. The body area network (BAN) includes devices that sense the user (sensors). Finally, the immediate ambient (or local area network-LAN) includes services that are available only when a user is in a specific area (e.g. in a building, in his car, etc).

As far as system implementation is concerned, most – if not all – of the projects mentioned as related work use open-source, FIPA compliant development environments, like JADE (Bellifemine et al., 2005). The latter provides standard agent technologies and offers to the developer a number of features in order to simplify the development process:

- Distributed agent platform. The agent platform can be distributed on several hosts, each one of them executes one Java Virtual Machine.
- FIPA-Compliant agent platform, which includes the Agent Management System the Directory Facilitator and the Agent Communication Channel.
- Efficient transport of ACL messages between agents.

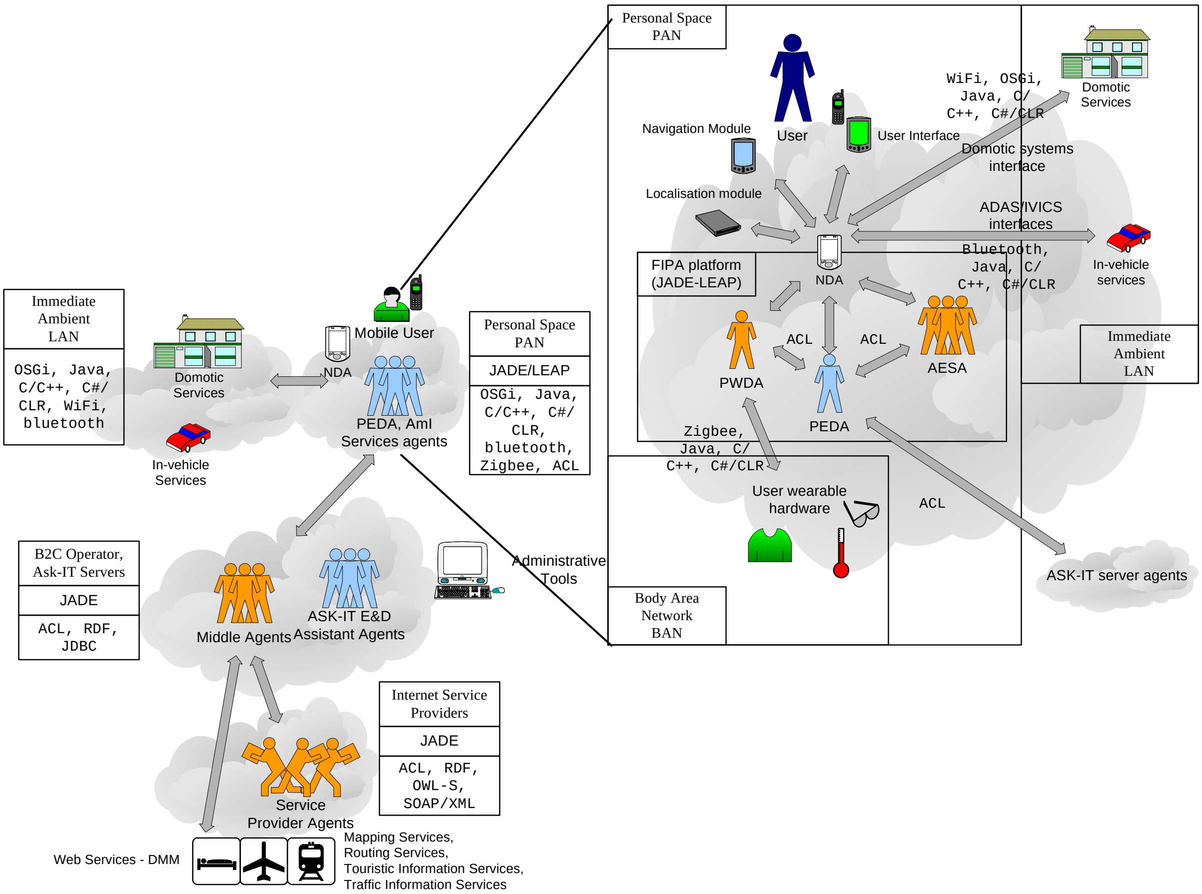

Figure 3. ASK-IT architecture

4.2.1. Inter-agent protocols

A better insight on the architecture will be achieved by studying a preliminary version of the inter-agent protocols that will be realized by the participant agents. Figure 4 shows the different agent types and the protocols that they realize. The reader will notice a specific type of EDA shown with the name “coalition creator”. He is responsible for accepting requests aimed for the EDA and dynamically forming the coalition of different EDA experts that will have to deliberate on the user’s goal.

Here, a few words on the EDA functionality and their cooperation with the PEDA are necessary. The PEDA acts as an MPTA and has two types of knowledge when he prepares a request for servicing a user:

- His profile data that can be:

  - o dynamic (learned behaviour), or
  - o static (user defined),
- His current context (on the move, in a building, etc) that is determined by the AESA.

What the PEDA doesn't have is the knowledge regarding the needs of different mobility impaired types with regard to movement. This knowledge can be vast and/or conflicting if it tries to encompass all types of impairments. Therefore we decided that it will be defined separately for each type of impairment and then in the case of a person that has more than one type of impairments a coalition of agents with the knowledge of the different impairments will deliberate on the needs of the user. Therefore, whenever the user wants to plan a trip the PEDA will add the context and profile relevant data to the request. Then the EDA on the server side will add the relevant data based to the user's impairment type(s) and make the relevant requests to the broker (who will now find the real service providers to offer their proposals). When the EDA receive the service invocation results from the broker they will sort the proposed routes according to the user's context and type of impairment and send them to the mobile device (again through the broker). The "services" protocol (shown as "R/I services" in Figure 4) is the one developed in Im@gine IT (Spanoudakis and Moraitis, 2006), while, all the others are new.

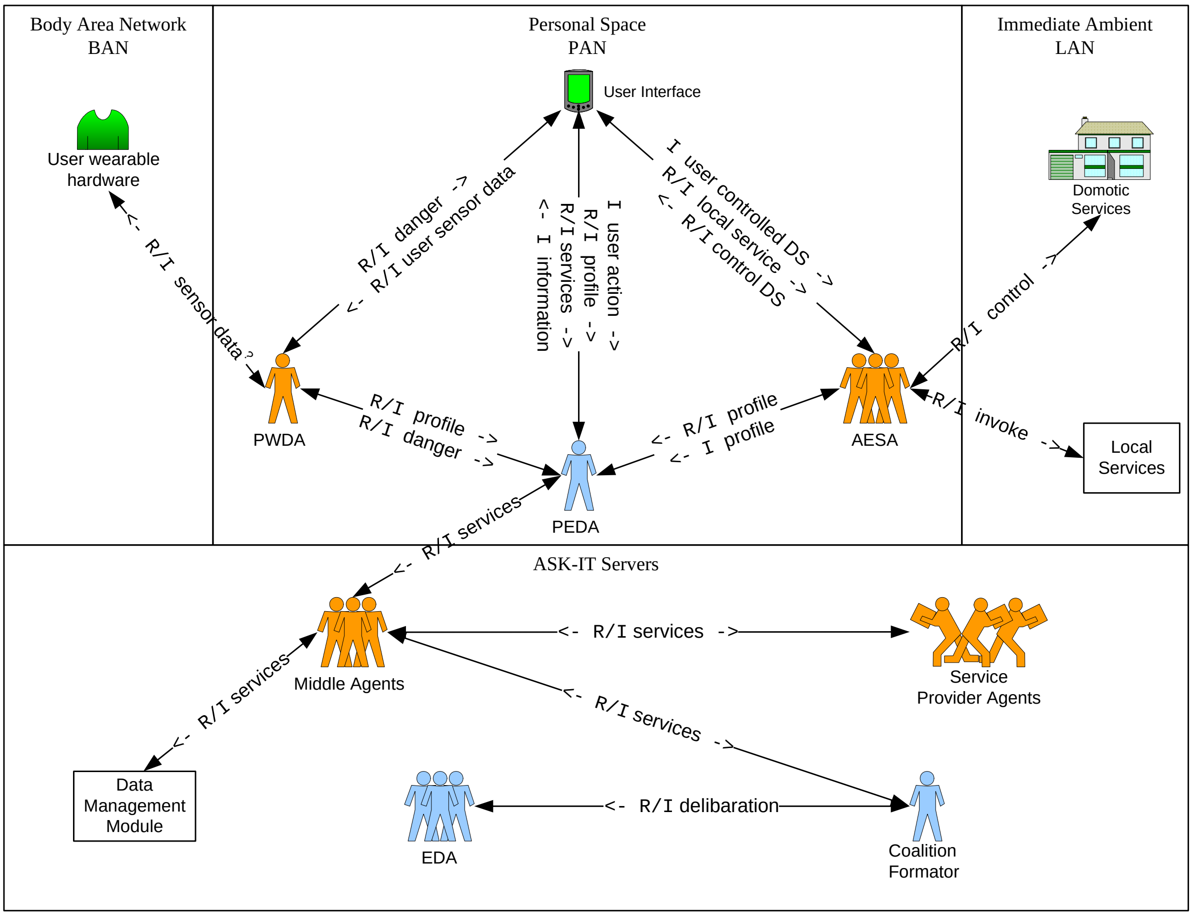

Figure 4. Inter-agent protocols. The arrows connect interacting entities." R/I" stands for a protocol based on the FIPA request protocol, "I" stands for just an inform message, and, the arrow " ->" points from the initiator of the interaction to his counterpart.

Focusing on the inter-agent protocols (and not to the ones between the agents and the external systems like emergency module, domotic services, user interface, etc) all are of type FIPA request (either for the user's profile, a service location and invocation) except of the "R/I deliberation" interaction between the EDAs. It is initiated by the coalition creator and through it the EDA coalition will deliberate on the user's needs in order to finalize the service request and then, when the coalition creator gets the results to sort them according to the user's context, profile and impairment(s).

The other novelty of our architecture will emerge through the cooperation of the PWDA, AESA and PEDA agents on the user's personal space (ambient intelligence and PTA integration). There, the PEDA will inform the AESA about the user's context (e.g. returning home) and the AESA will act on the user's environment according to his habits (e.g. turn on the heater so that the user finds it hot when he arrives at home), and vice-versa, the AESA will be able to inform the PEDA that the user is now indoors (e.g. he arrived at home).

Moreover, the PWDA will be able to provide to the PEDA information about the health status of the user. Through this interaction the PEDA may decide to proactively call for help (use the service protocol aiming to invoking an emergency service).

5. Discussion

In this paper we propose an agent-based architecture for the personal travel assistance domain that addresses a) the need for integration with ambient intelligence and b) the need to service mobility impaired users, allowing for the usage of an extensive knowledge for each type of impairment and also the service of combinations of impairments.

We extend the state of the art with regard to the FIPA PTA standard and work done in previous projects on this domain. Specifically, we propose that the personal assistant agent on the user's nomad device cooperates with ambient intelligence related agents that can monitor and act on the user's environment, or read information available through different sensors on his person. Moreover, we propose that the user's context and profile knowledge is taken into account when forming service requests and that his impairments-related knowledge is also taken into account before finally searching for the relevant service to his needs. The latter step takes place on the server side due to the limited capabilities of processing on the nomad devices. Finally, the service results are filtered and sorted according to the user's needs, also on the server side, so that he gets only the needed information on his device, thus overcoming possible bandwidth problems but also saving time.

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