Enabling Technology for Personalizing Mobile Services

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Abstract

A major trend in the current information society is personalization, which is considered a key business enabler for mobile services because the mobile device is a personal assistant that offers unique opportunities such as real-time adaptation of services to a dynamic user environment. To offer personalized services in a consistent manner and to speed up the development of such services, we present a Personal Service Environment (PSE) that, besides profile management, provides generic service discovery, content adaptation and service adaptation functionality.

The PSE implementation is based on a loosely coupled architecture based on the Web services paradigm. Specific PSE components will be generated on a development and deployment environment for negotiating brokerage agents with learning, anticipating, and adaptive capabilities. These brokerage agents are intended to handle matching and adaptation of service content and logic, ensuring optimal quality of service delivery.

We illustrate the implementation of our PSE with a 'Personalized Messaging' prototype, which is based on the concepts of Unified Messaging and Instant Messaging, combined with new mobile network features such as location awareness.

1 Introduction

Research and development for mobile services more and more focus on the personal aspect of the mobile phone. There is a growing awareness that the unique selling points of the mobile are not its anytime/anywhere capabilities, but the fact that it is a truly personal device, and enables context-aware and personalized data services. Examples are travel information while travelling, your local news, up-to-date schedules, your messages always on time, you local shopping guide, your nearest cinema, horse races betting at the latest possible moment, etcetera. In order to enable these unique selling points, it is necessary that a future mobile network infrastructure contain a personalization-enabling service infrastructure. In such a personalization infrastructure, metadata on users (often referred to as user profiles) and metadata on services are indispensable for adapting the content and service to the person and his location. But there is more. Besides user profiles and service characteristics, terminal and network capabilities are also necessary to adapt the quality of the content and service to the specific terminal and network capacities in use. In the near future, it will not only be GSM-evolved networks such as GPRS and UMTS, but also wireless LAN's, Bluetooth and other wireless technologies that have to be integrated. Furthermore, mobility profiles (data on location, speed, direction, physical environment and ambient conditions) are of course an essential input to location-based services.

Our paper is organized as follows. In section 2 we lay down our PSE specifications in terms of various standards. In section 3 we propose our PSE functional architecture, whereas in section we 4 we treat the agent technologies needed to make specific PSE components of the architecture operational. Finally, in section 5 we describe a prototype in which our PSE has been partially implemented.

2 Specification of a Personal Service Environment

In 3G standardization bodies such as the 3GPP, the concept of the Virtual Home Environment (VHE) [1], [2] is an example of such a personalization-enabling infrastructure. However, the VHE is limited to the management of profiles. We propose a Personal Service Environment (PSE), which in addition provides generic discovery services (of potentially interested users in mobile services and, vice versa, potentially interesting services for users) as well as adaptation services to accommodate changing conditions and situations (e.g. in roaming, etc.). The PSE is a holistic approach to the personalization of mobile data services in a scalable and efficient way by making use of both centralized as well as distributed functionality and intelligence.

A PSE, in our definition, assists a user in finding, adapting and using services that fulfil his needs given his personal profile, his mobility and his context [4]. Different stakeholders are involved in PSE provisioning and usage:

end-users and user groups, network operators, content and application (service) providers, and governmental bodies. In principle, personalization, and therefore the PSE, is concerned with matching and negotiation between user requirements and abilities on the one hand and service offerings and resulting adaptation of network and application level services on the other hand.

In defining and implementing a PSE, three key issues arise:

1) *Profile management*:
   How can a PSE manage the collection, storage and use of information about users, services, networks, devices, and other aspects relevant for personalization?
2) *Service discovery*:
   How can a PSE assist a user in finding and selecting appropriate services, and conversely, how should services be assisted in finding (potential) users?
3) *Service adaptation*:
   How can a PSE assist in initializing, controlling, and adapting services with respect to the user's needs and abilities, as expressed in his user profile, mobility (e.g. location, speed, direction of travel), terminal & network, and remaining profile data (e.g. content, business rules, queries, etc)?

2.1 Profile Management

We take a broad approach to profile management and include user, service, mobility, network & terminal, and other profile management:

- User profiles describe user-related information: user preferences, user history, user interest, user roles/tasks, etc.;
- Service profiles describe the characteristics of services: what the service delivers (e.g. type of information or communication), pricing information, requirements to network and devices, etc.;
- Mobility profiles concern location-related information: physical coordinates, velocity, direction of movement, environment (e.g. indoors, outdoors), etc.;
- Network & terminal profiles describe the network characteristics and terminal capabilities.
- Remaining profile data describe other information: content-related preferences (e.g. presentation format, encoding, language), process-oriented data, business rules that apply, etc.

Many parties are involved in gathering, storing, and using these profiles. The implementation of a PSE will therefore necessarily have a distributed architecture. Because of this distributed nature, standardization of the formats and contents of profiles is a key element in provisioning a PSE.

Besides the VHE's description of profiles, other international standards that are currently developed, such as MPEG-7 [27] and MPEG-21 [26], are concerned with describing user preferences pertaining to audio-visual content, enabling personalization of content access, queries and consumption [27]. Several standards also exist on the exchange of network and terminal capabilities. The Composite Capabilities/Preference Profiles (CC/PP) framework [28] aims to define how a user agent profile can be specified. The user agent (client device) may be a workstation, personal computer, mobile terminal, or set-top box. CC/PP is a standardized way of expressing device capabilities, and is used in the User Agent Profile (UAProf) of WAP [37] to specify capability and preference information. For networks, examples are the Open Pluggable Edge Services (OPES, [30]), the Content Distribution Internetworking (CDI, [9]), and the Web Intermediaries (WEBI, [WEBI]) working groups of the IETF, who develop frameworks and standards for communication between intermediaries within the network, especially for content peering and adaptation purposes. Also important are the OSA/Parlay specifications, most notably the mobility APIs [31].

In managing these personal profiles, security and privacy concerns are of great importance, especially in the user-related profiles. In the sense of the current paper we deal with information privacy, also called data protection, which involves the establishment of rules governing the collection and handling of personal data. Typically, governmental bodies are concerned with legislation and enforcement. Legislation on data protection should be considered from a global view, since this is an inherent requirement that comes from mobile services and the globalization and virtualization of society [20]. Due to the nature of mobile applications, one typically has to deal with inter-country-data protection.

Besides the "objective" privacy that one can capture in laws and regulations, even more important for the commercial success of services is the perception of the users: perceived privacy is a (mobile) business enabler. It reflects how individuals feel and experience the care that is taken in the use of their personal information. With a satisfactory perception of privacy, users are more likely to give other parties access to their personal data. This in turn enables personalized mobile services to exist and become successful.

An example: if a user gives access to his preferences with regard to his favorite food and also to his location, a mobile service might alert him around his usual dinner time when he comes in the neighborhood of a potentially interesting restaurant. From a business point of view, it is essential to have access to the profile data, and it is of vital importance to have the users' trust with regard to the protection of his privacy. Interesting in this respect is the widely practiced coupling of on-line tracking and profiling by second and third parties to off-line database storage, which happened in the last decade. This for instance puts questions to the use of Intelligent Software Agents, since these are often run by the same companies that violated the user's privacy in the past. Summarizing, the user's privacy, and especially his perception of this privacy, poses additional challenges on the storage and management of all profile data by the PSE.

Concluding, first the PSE's profile management should cover data storage in multiple locations and multiple systems; thus interoperability is needed. Second, tailoring of mobile services and content according to the profiles "in the PSE" is required. This makes it necessary for the PSE to be flexible and adjustable to profile standards from different fields, such as multimedia content engineering (MPEG community), the telecommunications sector (3GPP/VHE, Parlay), and the Internet community (IETF, PAM Forum). Third, privacy concerns can partly be solved by using privacy enhancing technologies in which a user decides which part of the data is available for which stakeholder and which part is protected, e.g. by encryption. All these three requirements have led us to the choice of using XML for storing information by the PSE, with XML schemas from the MPEG-7 committee draft, combined with specifications from the PAM Forum, and adaptations resulting from our own research (e.g. from user evaluations [8]). To partly enable data protection we use the so-called Secure Extensible Mark-up Language XML-S. XML-S offers authentication, confidentiality and integrity protection [21]. XML-S aims to provide end-to-end and multilevel security. The data is always stored and transported in encrypted form, providing end-to-end security. Furthermore, the data has different access rights at a number of levels. This is implemented by encrypting data with a different key at each level. The level of encryption is determined by the role of the user/stakeholder. The data that is protected is surrounded by additional tags, </secure> and <secure>, denoting the starting and ending points of encryption.

3 An Architecture for a Personal Service Environment

To provide a common frame of reference in designing and analyzing personalized services, we have defined a high-level functional architecture that describes the functional elements needed for service personalization. This architecture is intended as a first step towards the design of an infrastructure and service platform for personal mobile services. In the architecture, the focus is on functionality that enables personalization of services to accommodate the preferences, mobility, and (networking) context of the end-user.

The architecture has been inspired by many different sources. First of all, current n-tier Web architectures heavily influenced the design. Furthermore, inspiration has been taken from the 3GPP's development of the Virtual Home Environment [1], [2], the Mobile People architecture [22], results from the OnTheMove project [25], the Cameleon project [14], and the VESPER project [33].

The starting point for our architecture has been the definition of a set of business roles. In providing personalized services to the user, the natural roles are of course that of the service provider and the end-user, as shown in Figure 1.

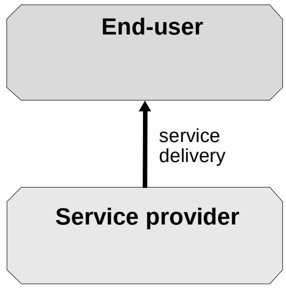

Figure 1. Basic client-server model of service provisioning.

If we take a closer look, we can identify additional roles (Figure 2). The network provider supplies the network infrastructure over which the services are delivered. In adapting the service to the available resources, this network provider may play an important part. We might even consider a "personal information provider", a third party entrusted by the user with managing his personal data and providing the service and network providers with information about user preferences, device capabilities, network characteristics, and context, etc. However, in most current contexts the same party fulfils both the service provider and the personal information provider role.

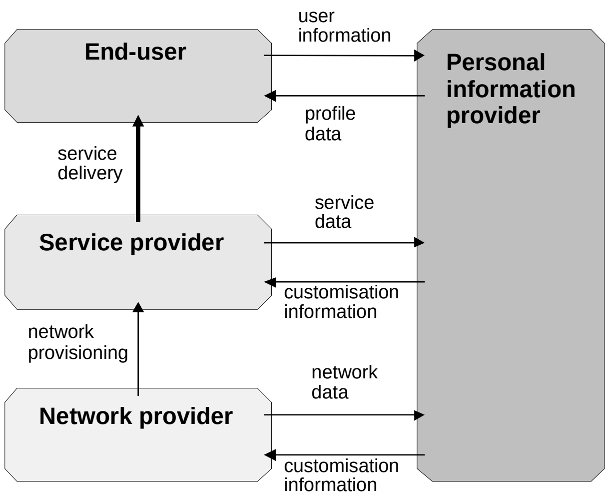

Figure 2. Roles and information flows in personalized service provisioning.

Figure 3 depicts a high-level view on the functional architecture itself. In this architecture, PSE information management is regarded as a separate functional component. In order for services to be personalized, the end-user not only interacts with the (primary) service itself, but also provides information on his or her personal preferences, and access rights to this personal information. This is shown in the relations between *End-user functions* and the other functional components. The other three functional blocks comprise the functionality needed for offering the services. The first, *End-user service provisioning*, comprises all functionality needed to execute the end-user services themselves. The second, *PSE information management*, provides and collects all information needed to deliver the services to the users. It is mainly involved in manipulating meta-information, i.e., information about users, their context, the available services, and their usage. The third main function, *Session & network management*, is concerned with the infrastructure needed to execute the services, and manages sessions, resources, quality of service (QoS), roaming and other network-related issues.

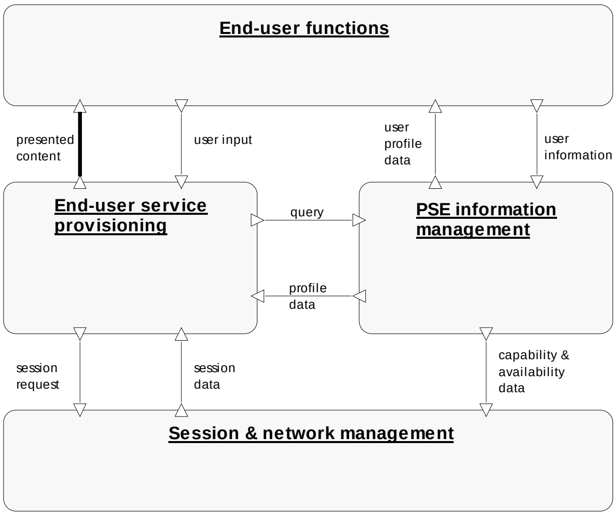

Figure 3. Top level of the functional architecture.

3.1 PSE information management

The function *PSE information management* (Figure 4) provides and collects all information needed to deliver the customized services to the users. As stated in Section 2, this information can be about users (e.g. preferences, filters, history), services (e.g. type of service, price), mobility (e.g. location, environment), and device, network, content, and business environment. In the remainder of this section, we zoom in on specific functions within *PSE information management*.

The function *User discovery* covers all functionality regarding discovery and management of users with respect to user preferences, demands and wishes. It has three main responsibilities:

- It manages the user's profile data itself, and manages access to (other) information stored in user directories.
- It controls the access to user profile data. This includes accessibility to different parts of the profile data to different stakeholders, providing the user with a sufficient level of privacy as required in Section 2.
- It covers search and selection functionality in e.g. user directories. Selection is achieved by functionality for matching between descriptive profile information of users and a given query. Matching can range from simple one-to-one matching to complex multi-parameter many-to-many matching. In the latter case, negotiation functionality is also encompassed in this function.

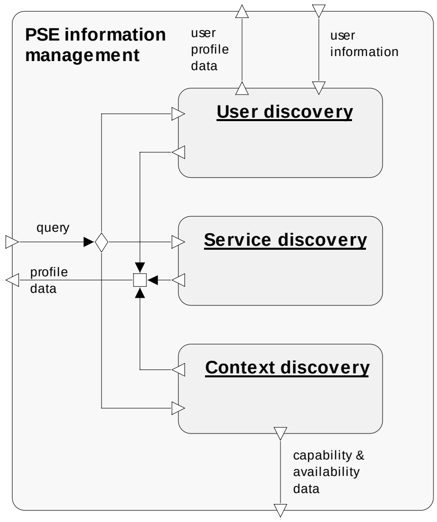

Figure 4. Refinement of *PSE information management.*

Service discovery allows users to find services, by naming or specifying the (type of) service that they are looking for (e.g., "find me a local news service"). The function covers all functionality regarding discovery and management of services with respect to user profiles. The function is has two responsibilities:

It controls and manages access to the information stored in the service directory. It performs access control and create, read, update, and delete (CRUD) operations on this information.

It covers search and selection functionality in service directories. Selection is achieved by functionality for brokerage between descriptive profile information of users, service capabilities and characteristics, and a given query. Matching can range from simple one-to-one matching to complex multi-parameter many-to-many matching. In the latter case negotiation functionality is also encompassed in this function.

Context discovery encompasses all functionality related to the discovery of information regarding the context and location of the end-user. It provides information on the position and mobility of a user, such as absolute or relative location, the direction and the speed of a mobile host. Here also the access to this information is managed. Positioning information can be as privacy-sensitive as any other type of personal data. Access to this information must therefore be protected in the same way as for user profiles. Furthermore, *Context discovery* provides information on terminal/device capabilities, and on characteristics and availability of networks, and also manages the access to this information.

4 Components of a Personal Service Environment

In order to satisfy and enable our PSE specifications and architecture, respectively, a (semi-)automatic brokerage management system is indispensable, because users', device manufacturers', network operators' and providers' requests and offerings should be matched such that their perceived quality of service levels, (QoS), are optimized. Besides functionality for integral representation of profiles, negotiating and matching service demands and offerings, our brokerage system needs deductive or inductive inferential structures capable to learn, anticipate, adapt and introduce service changes in m-commerce. In order to meet these brokerage system requirements, we propose a development and deployment environment for (mobile) agent technologies, envisioned by FIPA [11] and Cameleon [14], which supports a distributed intelligent collaboration during service delivery and evolution of brokerage agents to adapt to changes in user preferences, services and context. In section 4.1 we elaborate on the specific functionalities needed by our brokerage agents to enhance (mobile) service delivery. In section 4.2 we indicate which frameworks, environments and systems can help us setting up our evolutionary agent environment.

4.1 Brokerage agents

In automated evolutionary and game-theoretic negotiation theories, two types of negotiation are distinguished: competitive negotiation and co-operative negotiation [7]. Both these types are likely candidates for optimizing (mobile) service delivery. They can be characterized by the number of negotiation issues, number of agents, issue rating functions, private or public agent tactics and strategies, and agent ontologies, including agent communication languages. The settlement of negotiation issues by the agents can then be considered as a generalized form of optimally matching the dynamic requests and offerings of users, services and contexts (see section 3). In order to drive future m-commerce markets, the use of agent ontologies can enable auction-like, argumentation-based, alternating offers and/or mediated negotiation [10]. Equally important as issues, rating functions, and ontologies are the particular tactics and strategies adopted by agents. These tactics and strategies can be based on a rule-based approach [23], a case-based reasoning approach , a game-theoretic approach [7], or an adaptive learning and evolutionary approach [13], [23]. Note that all the negotiation aspects above may change, even during a single negotiation session. Furthermore, note that these aspects in turn directly relate to the profiles, mentioned in section 2, through e.g. multi-attribute rating functions [19], or in the form of ordered lists of preferences for the negotiation issues [36].

Following [23], we propose service-oriented agent negotiations, in which the communicating agents have conflicting roles and in which quantitative and qualitative issues, like user preferences, price and network load, are at stake. Our reasons for advocating evolutionary agent negotiations are twofold. On the one hand, time-dependent, resource-dependent and behavior dependent tactics and strategies in service-oriented agent negotiations also pop up in mobile service delivery negotiations. On the other hand, the service-oriented agent's mental state captures beliefs, knowledge about and attitudes towards other service delivery issues, which are in our PSE represented by profiles (see Section 2).

In order to implement suitable brokerage mechanisms, an agent system architecture is needed that allows us to create negotiation strategies and to assess their fitness (success) in achieving optimal QoS. For the purpose of mobile service delivery, a case-based architecture and a fuzzy architecture are the most suitable. These architectures are appropriate because they can look after the user, service, and context aspects of our PSE (see Section 3). Unfortunately, current game-theoretic architectures still do not incorporate incomplete knowledge and irrational behavior of the players, making them less useful.

Let us briefly specify the functionality represented by both architectures. A case-based architecture specifies a case-based system in which previous negotiations are represented, similar cases can be retrieved, filtered, selected, adapted according to particular rules and subsequently incorporated in a current negotiation thread. The architecture enables the storage of the new case and re-evaluation of all cases.

A fuzzy architecture specifies fuzzy rules to model negotiation strategies. These rules concern general agent behavior in terms of tactics, and agent mental state. The fuzzy architecture also supports fuzzification to assess the validity of the realization of the conditions related to the rules, rule evaluation and defuzzification to find an averaged negotiation strategy.

In order to automate the evolution of agent negotiation strategies—created and rated on top of a case-based or fuzzy architecture—we propose the use of Evolutionary Algorithms [12]. They have to be applied to the available rules and cases in order to find a set of optimally adapted rules and cases, respectively. In this respect, it may also be valuable to change the applied ontologies. To this end, it is necessary to come up with a codification of rules and cases, and with a measure for agent's negotiation strategy fitness in the service delivery problem at hand. Note that in this context of agent negotiation, common or related ontologies [16] are really of prime importance to ensure interoperability of agents.

4.2 Brokerage frameworks, environments and systems

Our envisioned generic automated evolving brokerage system makes the logic of the end-user functions, the PSE information management, end-user service provisioning, and session & network management explicit and formally operational. Simple parts of such logic are implemented and embedded in a mobile service delivery prototype, as described in section 5. In the previous section, this logic was defined in terms of simple components for classes of issues, tactics, strategies, mental states, case-based and fuzzy tools, (inter)actions and evolutions of agent systems [3]. In order to set up our system, particular frameworks, environments and systems are needed.

As a generic multi-agent modeling framework we propose to use the Agent Unified Modeling Language, AUML [29], in combination with a step transition system. AUML supports the syntax of data flows and agent interaction protocols, AIPs, and automatic computer code generation from the agent's specifications. A specific step transition system subsequently induces on those nets or on the AUML activity diagrams a formal semantics essential in stipulating the functionality of our generic brokerage component.

There are several environments available which support the advocated frameworks, such as IKV++'s Grasshopper platform [15] and Tryllian's Agent Development Kit [35]. Ensuring that the mobile agents freely communicate with such a platform, the best-breed agents can also be made available. The platform thus needs in addition enablers like evolutionary algorithms to select those agents from a population of agents that are subjected to changes with respect to their ontologies, rules (behaviors) and experiences over all negotiations.

As a PSE requires a representation of various aspects of users, devices, networks and service providers (see Section 2), ultimately a multi-context system should be integrated in the brokerage system [32]. Multi-context systems such as KaoS [5], dMARS [18] and DESIRE [6] can be used to represent different components of the agent architecture and specify the interactions between the components by means of so-called bridge rules. The agent in these systems may have units for theories of belief, desire and intention, whereas the architecture may have units for co-operation, assessment and plan execution.

5 Implementation of a Personal Service Environment

A PSE implementation will be integrated with several of our existing mobile service prototypes. These prototypes are used in the context of user experiments in which groups of pre-selected users evaluate the prototype's mobile service. This includes the evaluation of PSE aspects and functionality. The process of PSE integration with the prototypes has an iterative character: when one piece of functionality is fully integrated with the prototype, the next piece of PSE functionality follows.

Our PSE implementation is based on a distributed, loosely coupled system architecture, using the Web services paradigm with common Internet technologies such as SOAP, UDDI and WSDL for integrating subparts. This not only allows us to incrementally add features to the PSE, but also enables a physically distributed implementation, with PSE parts hosted by different parties that are located at different sites.

One demonstrator area in which a PSE implementation will be integrated is, what we call, the 'Personalized Messaging' line of prototypes. Personalized Messaging is based on the concepts of Unified Messaging and Instant Messaging, combined with new mobile network features such as location awareness. The PSE provides the mechanism that makes this enhanced messaging environment personalized.

The 'video wall' prototype is an example of a Personalized Messaging application. This application provides access to video mail messages through two different channels. The user reads the content of his Inbox using a PDA, which is continuously connected to the public Internet, for example by means of a GPRS telephone. The Inbox stores, amongst others, high-quality video mail messages that cannot be shown on the PDA due to screen, CPU and/or network bandwidth resource limitations. A separate device, the video wall, enables the user to play his video message. This device has a fixed high-bandwidth connection to the public Internet. The user transfers the current session from his mobile terminal to the video wall device by directly connecting the PDA to the video wall using a short-range mobile network technology such as Bluetooth. After the transfer of the session, the PDA is used as a remote control for the video wall. One could think of a video wall service to be available in a public place such as a market square or station, and paid for by advertisements that are shown together with the requested video mail message. Also, when the user connects to the video wall device, his location can be very precisely determined.

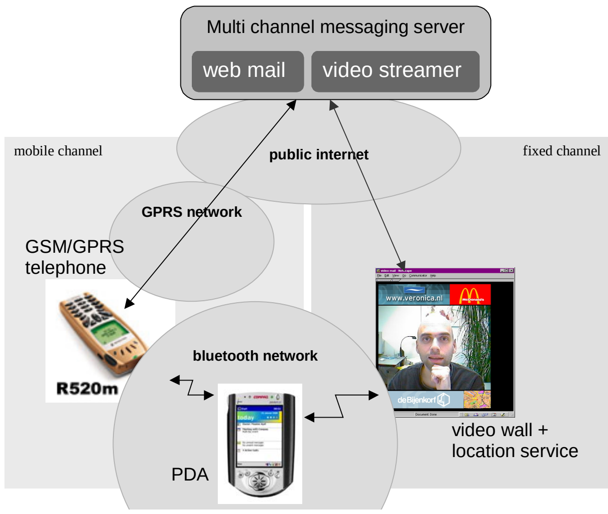

Figure 5. Overview of the video wall prototype.

At potentially many points in this prototype, PSE aspects can be introduced. We identify three parts where usage of PSE functionality is obvious. First, it is necessary to store the user profile for the messaging service, in order to adapt this service to the wishes of the user, e.g., for filtering messages. For this, the PSE profile management functionality is used. Second, when the user wants to connect to a video wall to display his video mail messages, the mobile terminal must discover the video wall service(s) in its neighborhood. The PSE service discovery mechanism can be used here. Third, when advertisements are displayed during video wall usage, an intelligent match must be made between the user's personal interests, the location of the user and the currently running advertisements. For this, the PSE brokerage functionality is used.

The introduction of the PSE aspects at the different points in the prototype takes place in a step-by-step manner: this reduces the implementation complexity and allows for a gradual evolution towards a system that uses many aspects of the PSE. Also, by taking this iterative approach, we are better able to study the effects of the different PSE subparts on the entire prototype service.

6 Conclusions and Future Work

We have argued that to offer personalized services in a consistent manner and to speed up the development of such services, generic support for personalization is needed. To accommodate this requirement, we propose a Personal Service Environment, which, besides profile management, provides generic functionality for matching and brokering between users and services, and provides content adaptation and service adaptation functionality.

Our PSE implementation is based on a distributed, loosely coupled system architecture using the Web services paradigm. This not allows us to build the PSE in an iterative fashion, adding features when necessary. The PSE is integrated in several prototypes, and we outlined the implementation of a Personalized Messaging application. To assess the functionality of the PSE in this context, user studies are going to be performed in a mobile business-to-employee setting, where we will evaluate user experiences and requirements on personalization of these B2E services. This will then be input for the next iteration of our implementation.

For implementing the brokerage between users and services, we proposed an evolutionary agent-based framework. In implementing the agent-based brokerage framework, we see three major research issues:

Finding empirically the most suitable ontologies and behavior patterns for the agents of different actors that involved in the mobile service delivery;

Finding fitness functions that ensure that the agents of the actors together reach an acceptable quality of service for all the issues at stake in the service discovery and delivery problem;

Setting up truly intelligent brokerage mechanisms that learn to solve, anticipate and control mobile service delivery issues.

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