Software Architecture for Mobile Interaction in Intelligent Environments

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Abstract. *Since the latest years, Intelligent Environments (IE) has been becoming a very discussed and recurrent subject. Part of such success is given by the meaningful diffusion and offer of portable electronic devices, with great power of computation, low energy consumption and, mainly, high level of connectivity. This paper proposes a software architecture for mobile interaction in IE. The proposed architecture has three main characteristics: (i) discovery and remote composition of available services in the IE; (ii) adaptation of services and functionalities according to the user's profile; (iii) flexibility in the insertion of new home automation devices, adding, dynamically, services to the IE.*

1. Introduction

With the advance in home automation and the technologies that are more present in the Intelligent Environments (IE), the ubiquitous computation starts becoming reality, defined by Mark Weiser [Weiser 1991] and that includes a technological level where computational systems provide information and services to people, anywhere and anytime. Ubiquitous and pervasive computation can be seen as a group of characteristics and functionalities that composes an IE [Anastasopoulos 2005].

In the IE there is the vision of a world surrounded by a big amount of devices that offer intelligent assistance on users daily activities. The IE consists of a technological information paradigm in which the computerized objects are introduced in a specific physical environment that adapts itself to the users' different necessities and situations [Kirste 2005], [Arts 2002] having autonomy to act [Lindwer 2003] and with possibilities to be programmed to recognize and learn the user's behavior who lives inside that environment [Yang 2004], [Hagras 2004].

The home automation is inserted in the context of IE, with projects that need automated physical spaces, including sensors, actuators and, mainly, intelligent systems for tasks management and optimization [Nazari 2007], [Edwards 2006]. A large variety of services in fields like security (access control, users' identification), comfort (temperature and humidity control, illumination) and entertainment are emerging daily, indicating problems to be solved, as the electric energy consumption in these environments, that can be minimized through the utilization of intelligent computational systems that concern energy optimization and management. Other problems are related

to mobility, adaptability and heterogeneity aspects in these environments, due to the large number of solutions, both in hardware and in software.

A great variety of intelligent devices networks may be found inside an IE, that admit the integration of electronic devices and people, providing information, communication, services and entertainment [Arts 2004]. The utilization of communication networks in these environments is one of the primordial points for projects execution, because they can be related to both the information exchange among electrical appliances – through power line communication (PLC) – and with wireless access to this same information, through mobile computation devices – such as Personal Digital Assistants (PDAs) and smartphones. This way, there is a necessity of creating strategies that consider the most different points, like: the users' mobility, the discovery and dynamic composition of new services and the flexibility with the automation devices that are inserted in the IE.

2. Related Works

2.1. Architectures and Middlewares

The μJini architecture [Lee 2006] was proposed with the objective of offering a discovery of services that is aware of the context for mobile devices with limited resources. The main point of this architecture is defined by a proxy in charge of controlling discovery processes and services delivery. Inside the μJini proxy system are the service discovery components that supply the aware discovery to the context for μJini proxy, which utilizes three approaches: (i) having a service code executed completely in the client computational platform, with MIDLets Java 2 Micro Edition (J2ME) or with Java 2 Standard Edition (J2SE) services, through a network that sends up-to-date screens to the client. The decision about which way to utilize is clearly made to the users. μJini proxy is able to select the best adaptation, according to the service context.

Basically, the μJini architecture was projected to overcome limitations related to mobile devices, communication networks and services. The proposal offers a solution that comprehends the request of mobile services and their distribution to the clients' devices. Although, some challenges still proceed, such as the dynamic composition of new services and the limitation about the applications requiring a Java virtual machine (JVM) available in the client mobile device.

The Mobile Context Explorer proposal – or, simply, MoCE [Kang 2006] – as it is known the architecture of a middleware that is aware about the context, was projected to find, gather and provide context to services in a mobile environment. Besides, a context discovery protocol was developed in order to discover contexts efficiently in unknown contexts providers, both for mobile devices and for embedded devices based on Wi-Fi networks. The MoCE architecture was specifically defined in order to offer support to services based on context, and this one is shared by the data communication network. Making reference to context sharing, there is the necessity of a mediating architecture to interface and control the context request and offer among different devices. Thus, some components in the architecture were defined in order to identify and support context consumers.

In respect to data access in the IE, an architecture designated by Ubiquitous Data Access (UbiData) [Helal 2004] was specified with the purpose of concerning some challenges originated by the proliferation of devices and mobile applications, as well as additional requirements of clear access to ubiquitous data. Among the challenges discussed by UbiData architecture, are in relief: (i) access to data anywhere and anytime; (ii) access to data independently on the device, which is possible for the user to alternate among different mobile devices with different access capabilities; (iii) data access and update independently on the application, enabling the users to modify documents and files.

Another important project is Gator Tech [Helal 2005] that considers the existence of execution environments and software libraries for the development of programmable IE. Services discovery and gateways protocols automatically integrate systems components, using a generic middleware that supports a service definition to each sensor and actuator in the environment. There are mechanisms in the Gator Tech which consist from intelligent e-mails treatment – with perception and notification to users – up to points like the use of Radio-Frequency Identification (RFID) to access and identify users inside the environment, intelligent bathrooms, residential security and monitoring.

2.2. Services Discovery and Composition

The Open Services Gateway initiative/Business Process Execution Language (OSGi/BPEL) is the proposal of a framework [Redondo 2007] that suggests to increase the services OSGi composition support present in IE. Due to the fact that, usually, there are lots of services in these environments, such as energy control and optimization, security, illumination control, alarm system for fire and others, composed services are the ones that activate a group of OSGi services, where each one is led to a specific activity.

In the OSGI/BPEL, the idea is to encapsulate logical information of services composition inside an OSGi application, registering it in the framework. When the composed service is required, an execution engine interprets the composition description to require and manage the processes under execution. The proposal tries to be clear both for required composition services and for OSGi registration service. That is why virtual bundles are defined, in charge of specifying composed services, which use the BPEL for composition in the OSGi framework.

2.3. Mobile Interaction

The possibility of controlling a smart home using the TV appears from a proposal [Cabrer 2006] which integrates IE, digital TV and domestic networks. The adopted technologies in the proposal are the Multimedia Home Platform (MHP), for Digital TV and the OSGi as a platform for residential gateways settings. According to the proposal, the main point is to permit the user to control the whole IE assisted by the TV. This way, MHP and OSGi are utilized – the later is oriented to services and the former is oriented to functions. As both technologies have quite different architectures, there is integration between them, and the problem is solved by creating an Xbundlet – an application that permits the natural interaction between MHP and OSGi. A Xbundlet not only defines a communication link between these platforms, but also constitutes a hybrid software element that can be executed in both architectures.

As regards to the use of mobile devices in IE, there is a proposal [Helal and Mann 2002] intending to increase life quality and reduce old people dependence or limitation, somehow, at home. One of these research activities concerns, precisely, the utilization of smartphones as a tool to offer support to elderly in the IE. Smartphones become something like a "magic wand" that provides, among other things, functionalities of a universal remote control for all kinds of automation devices present in the intelligent environment.

The idea of using smartphones appears as an offer to several services for elderly, by not moving in the ambient, or asking favors to another person in the same place. According to researchers, the proposal greatest challenge is to have an open integration of the different involved technologies, neither endangering nor limiting an architecture.

2.4. Users Profile

From the attractions offered by ubiquitous computation – in which are available the information mobility and the networked devices, some efforts come to sight with the objective of concerning security mechanisms and techniques in IE. One of the choices for this kind of security is the profile management, proposed by a middleware [Loeser 2005] which is able to integrate data bases of several profiles, with generic mechanisms of authentication that permit the management in the OSGi framework. Users' profiles are utilized to have information about their basic preferences and abilities, whereas devices profiles provide the main characteristics and describe the present situations of each device. There are, also, the definitions of the safe access kinds in each environment, having confidential information of identification that must be preserved. Because of this reason, there are several levels of security for different services and users, defining a distributed architecture, in which the communication component may utilize TCP/IP on technologies with Wireless Local Area Network (WLAN) and Bluetooth. On the other hand, the security guarantee in distributed systems is given by a communication based on Secure Sockets Layer (SSL) / Transport Layer Security (TLS) with certificates X.509.

Likewise, another proposal concerns a framework [Groppe and Mueller 2005] for profile management in IE, customizing this environment according to each situation, with the users' preferences and the devices capability. Profiles customization methods are used based on evaluation and processing methods to expand, automatically, the users' preferences.

Profiles management applied to IE is motivated because these ones integrate a great variety of embedded computation devices, mobile, and the capability of communication, which offers agility and comfort to the users. That is why there is the proposal of a profile processing method that intends to adapt, automatically, the environment according to users' necessities and preferences. Possible conflicts and decision strategies in profile processing are investigated, as well as mechanisms for profile evaluation that assimilate modification in an environment. It is also analyzed a methodology by identifying the project, main points and involved requirements.

3. Proposed Architecture

In this paper, it is proposed an architecture that offers mobility in the remote interaction between the user and the IE, as well as the services remote management.

The architecture has three main characteristics: (i) discovery and remote composition of services available in the IE; (ii) functionalities and services adaptation according to the user's profile, utilizing security policies with different levels of accessing the system; (iii) flexibility in the insertion of home automation new devices, in which services are dynamically added to the IE.

3.1. Conceptual Model

The proposed architecture is presented in Figure 1 and is divided among five layers: (i) physical devices, (ii) logic devices, (iii) services layer, (iv) services composition layer and (v) management layer.

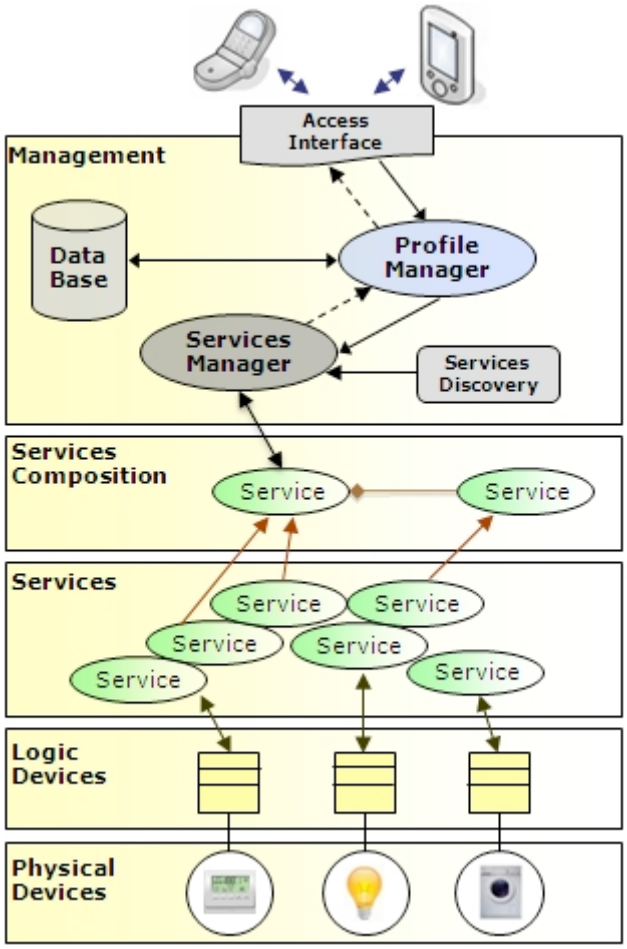

Figure 1. Proposed Architecture

The layers in the architecture are defined with the purpose of offering modularity to the system, in which new components may be inserted in the lower layers and available to the upper ones. This way, they are specified below:

Physical Devices Layer: It is composed by electro-electronic devices in home sceneries. Inserted in this layer are devices found in the real world, such as: lamps, televisions, set-top-boxes (STP), refrigerators, air-conditioners, thermostats, sensors, actuators and controllers, in general terms.

Logic Devices Layer: It is composed by the computational representation of the devices that are inserted in the physical layer, which are mapped by the logical layer

through devices classes that implement a known communication interface. An advantage of this layer is the possibility of defining services in the upper layer, even if the physical layer is not aware of that.

Services Layer: It is composed by a group of services available in the IE, which may be requested and executed by the users. In this layer, there are the functionalities that an IE might offer to its users, like: conditioning the ambient, turning off the lights, verifying the state of any sensor, shutting the door, and so forth. Each service is associated to a logic device and, once implemented, it might be reused or adapted in the interaction with other devices.

Services Composition Layer: In this layer, it is possible to create composed systems, which integrate other services with the objective of executing a specific task. An example of composition could be applied to a situation in which the user wants to set the illumination level of the living room, according to a source of natural light got at the moment. In that case, the composed service would be the association of a sensor reading service with an illumination adjustment service. One of the composition advantages is the possibility of reusing services dynamically, offering flexibility in the execution of services that depend on others.

Management Layer: This layer is in charge of managing the IE, comprehending components that concern form the discovery and availability of services to users, up to the definition of what kinds of services a user may access. The five components present in this layer are specified as follows below:

Access Interface: Permits users to interact with the IE utilizing their mobile devices. The main point is that, facing an IE, the user is able to get information about what kinds of services that environment offers and which of them are available to him.

Data Base: It is responsible for storing the users' data, registering details reports, levels of safe access and profiles that do not really need to be stored at the moment.

Profile Manager: It is responsible for receiving the users' requests and deciding which will be the access level of each user according to his/her profile and a detail report that, occasionally, has been registered. A profile may be given by inserting a private or common password, under the domain of the desirable service.

Services Discovery: This component, in system execution time, searches for all services that are available at that moment in the services layer and, hence, to the IE.

Services Manager: Perceiving all the available services through the received information in the Services Discovery, this component provides users, by means of the Profile Manager, all the services that are available for execution. The Services Manager is in charge of executing single or composed services, according to each request and the user's profile. After passing through the Profile Manager, the list of available services in the IE is provided in the Access Interface to that particular user.

3.2. Architecture Implementation

With the definition of a conceptual model, the architecture is implemented and validated inside an IE scenery, which consists of a seminaries room that has a home automation system developed built by a company [Homesystems 2009] which develops researches

projects applied in cooperation with the Control, Automation and Robotics Group of the Federal University of Rio Grande do Sul. In this automation system, there is a central controller unit called Systembox, that is, basically, a computer with Linux operational system, responsible for controlling Homesystems Network (HSNET – proprietor protocol that works in the physical layer RS-485) and executing commands for a group of devices that can be utilized in illumination systems, air conditioners and security systems.

This way, in the physical layer of the proposed architecture, are inserted a group of lamps, the air conditioner, a luminosity sensor and the central controller (Systembox). In the logic layer, the classes are implemented, in Java language, that know the Systembox communication interface. The exchange of command messages between the logic devices (classes) and the physical devices (Systembox, lamps and air conditioner) is carried out through HyperText Transfer Protocol (HTTP), implemented on an Ethernet network and known both for the classes and for the Systembox.

On the services layer, the OSGi framework and the Knopflerfish implementation [Knopflerfish 2009] are used. OSGi has an architecture oriented to services and based on Java, providing the standardization of primitives that permit building applications with small components that are reusable. In this layer, execution components (bundles) are created, and these ones utilize and register services in the OSGi Service Registry. Thus, it is implemented three bundles that interact with the logic devices classes: the first bundle implements two services – turning the environment lights on and off; the second one verifies the light intensity level in this same environment; and the third one sets the air conditioner temperature.

On the management layer, it is used the MySQL as data base for storing the user's profiles and the system utilization detailed report. The components profile manager, services manager, services discovery and access interface are implemented into Java language, and the later is developed in Java Server Page (JSP). Java technology was chosen because of the platform portability that it offers. This layer still counts on Tomcat, which is a Java applications server for the web that provides the access interface between the mobile devices and the services offered by the IE.

In the considered scenery to the case study, by entering the seminaries room with his/her mobile device, the user solicits the manager layer what services are offered by this environment and which of them are available to him/her. Thus, the profile manager verifies, in the data base, the access level that will be allowed. After that, the Services Discovery component researches inside the OSGi framework and finds the registered services (turning the lights on/off, verifying the illumination intensity and setting the air conditioner temperature). At this moment, the Services Manager creates a list of available services and sends it to the Profile Manager, in order to provide it to the user. In Figure 2, it is shown the communication scenery utilized in the case study.

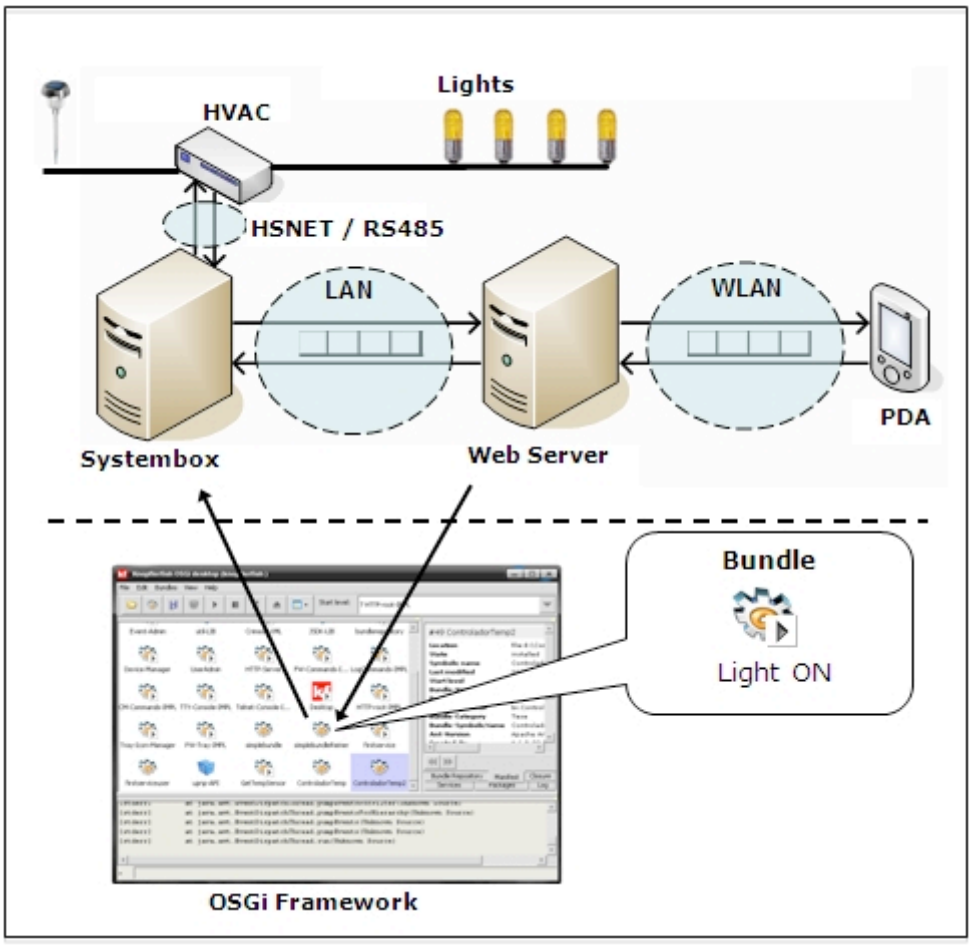

Figure 2. IE Scenery

4. Conclusion

In this paper, it has been proposed a software architecture for mobile interaction in IE. In the architecture, it is presented components which concern form the discovery and composition of services up to the user's profiles management in his/her interaction with the IE. One of the main advantages presented is the possibility offered to the user to create different sceneries in environments with residential automation devices, without the necessity of being acquainted with them previously.

Another advantage is that, even being indispensable an JVM for performing most of the components in the architecture, it is not necessary to have it in the mobile devices, because the interface with the user happens according to JSP pages which are interpreted in the server. This way, the user's mobile device must have a web navigator to access the available services in the IE, making the architecture flexible according to the several computational resources found in mobile devices. At last, it is opportune to mention that all the architecture components were implemented and are perfectly working in the automated seminaries room. However, new strategies and technologies for services discovery and composition continue being investigated.

References

Anastasopoulos, M., et al. (2005) “Towards a Reference Middleware Architecture for Ambient Intelligent Systems”, In: Proceedings of the Workshop for Building Software for Pervasive Computing..

Arts, E. (2004) “Ambient intelligence: a multimedia perspective”. In: IEEE. Vol. 11. Issue 1, Jan-Mar, pp. 12–19.

Arts, E., et al. (2002) “Ambient intelligence”. In: McGraw-Hill, Inc., New York, NY, USA, pp. 235–250.

Cabrer, M. R., et al. (2006) “Controlling the Smart Home form TV” In: Proceedings of the International Conference on Consumer Electronics, IEEE, Las Vegas p. 421-429.

Edwards, W. K. (2006) “Discovery systems in ubiquitous computing”. In: Proceedings of the Pervasive Computing, IEEE. Vol. 5, Issue 2, April-June, pp. 70-77.

Groppe, J. and Mueller, W. (2005) “Profile Management Technology for Smart Customizations in Private Home Applications”. In: Proceedings of the International Workshop on Database and Expert Systems Applications, IEEE, Copenhagen, p. 226-230.

Hagras H., et al. (2004) “Creating an ambient-intelligence environment using embedded agents”. In: Proceedings of the Intelligent Systems, IEEE. Vol. 19, Issue 6, Nov-Dec, pp. 12-20.

Helal, A. and Hammer, J. (2004) “UbiData: Requirements and Architecture for Ubiquitous Data Access”. In: SIGMOD Rec Journal… New York: ACM, p. 71–76.

Helal, S. et al. (2005) “The Gator Tech Smart House: A Programmable Pervasive Space”. In: IEEE Pervasive Computing, p 64-74.

Helal, S., Mann, W. (2002) “Smart Phones for the Elders: Boosting the Intelligence of Smart Homes”. In: Proceedings of the Workshop Automation as Caregiver: The Role of Intelligent Technology in Elder Care, Edmonton, AAAI Press, p. 74-79.

Homesystems (2009) Intelligent Environments. <http://www.homesystems.com.br>.

Kang, B. S., et al. (2006) “Context-aware Middleware Architecture for Intelligent Service in Mobile Environment”, Proceedings of the International conference on Computer and Information Technology, IEEE, p. 240–244.

Kirste, T. (2005) “Smart environments and self-organizing appliance ensembles”. In: Aarts E, Encarnação J. L. (eds): True Visions, Springer.

Knopflerfish (2009) “Open Source OSGi”. <http://www.knopflerfish.org>.

Lee, C., et al. (2006) “The μJini Proxy Architecture for Impromptu Mobile Services”. In: Proceedings of the International Symposium on Applications and The Internet Workshops, IEEE, 2006, Phoenix, p. 23–27.

Lindwer, M. et al. (2003) “Ambient intelligence visions and achievements: linking abstract ideas to real-world concepts”. In: Design, Automation and Test in Europe Conf and Exhib., pp. 10–15.

Loeser, C., et al. (2005) “Secure Profile Management in Smart Home Networks”. In: Proceedings of the International Workshop on Database and Expert Systems Applications, IEEE, Copenhagen, p. 209-213.

Nazari, A. S., et al. (2007) ”3DSim: Rapid Prototyping Ambient Intelligence”. <http://www.igd.fhg.de/igd-a1/projects/amilab/index.html>.

Redondo, R. P. D. et al (2007) “Enhancing Residential Gateways: OSGi Services Composition”. In: Proceedings of the International Conference on Consumer Electronics, IEEE, Las Vegas, p. 1-2.

Weiser, M. (1991) “The Computer for the 21st Century”. In: Scientific American 265 n.3, p. 94-104.

Yang, H., et al. (2004) “An evolutionary system development approach in a pervasive computing environment”. In: Proceedings of the International conference on Cyberworlds, pp. 194-199, 2004.