# A Home-Automation Platform towards Ubiquitous Spaces Based on a Decentralized P2P Architecture

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**Abstract.** The vision of Home Environment is changing towards living interaction space populated of interconnected devices, services that encapsulate the functionality, and multiple interfaces through which the user can interact with these devices, in accordance with vision of ubiquitous computing. This paper presents a pervasive services platform for ubiquitous spaces based on distributed architecture P2P using JXTA technology, with an innovative approach, that favors the building of collaborative services from proactive entities, the peers. These ones are able to establish dynamic intercommunications synchronizing with others, form coalitions to cooperate with others for a common purpose, and are self-organized into groups.

**Keywords:** Home-Automation, Ubiquitous Computing, SOA, P2P, JXTA.

## 1 Introduction

Home-automation is an application domain where the problems of heterogeneity on devices, networks, hardware platforms and software frameworks have led to the proposal of multiple technologies and commercial products. Most of them are incompatible with each other and provide a partial management of some devices of home such as the surveillance, energy consumption or multimedia entertainment systems, making difficult an integrated solution to manage all of them. Other problems are the complexity, lack on security and high costs on installation, deployment and maintenance of these systems. To overcome these problems in our opinion we should change our vision towards pervasive spaces [1]. A pervasive space can be seen as an abstract logical environment where the devices provide compositions of functionality that users claim to consume. The development of software platforms that provide such abstraction should deal with the heterogeneity of devices, the mobility of devices or users, the seamless access to functionality and information resources, secure and reliable communications with fault tolerance, the interoperability between different networks, the evolving, extension and adaptations of functionality, and finally the interfaces between user and devices [2]. A large number of middleware technologies have emerged giving support to ubiquitous computing based on centralized and decentralized architecture such as Gaia, Aura, etc [2]. Distributed decentralized computing marked the next step toward pervasive computing by introducing seamless access to remote information resources and communication with fault tolerance, high availability, and security [3]. Currently, most middleware proposals are based on SOA (service oriented architecture) paradigm. SOA is an architectural style that establishes the

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organization model between the devices in terms of collaboration of loosely-coupled entities, the services. This work presents a new proposal for the design of a ubiquitous services platform to home-automation using Java technologies based on a decentralized P2P architecture. The new platform is based on JXTA [4], which is more scalable, interoperable, dynamic and extensible than other middleware platforms based on centralized client-server architectures. We are intent on leaving the classical model of residential gateway, leading to a large model, where services can be used beyond the living space.

The remainder of this paper is organized as follows. Section 2 presents the services platform for home-automation, its architecture and design decisions made during the platform development. Section 3 compares our approach with other related works. Finally, we present the conclusions of this work.

## 2 Dynamic Open Home-Automation Services Platform

A new distributed, ubiquitous, decentralized and dynamic platform is developed to facilitate the access, control and management of pervasive spaces from any computing device such as portable computer, portable device or embedded platform. This platform, named Dynamic Open Home Automation (DOHA), is based on JXTA architecture [4] and provides a full remote control of living environment in terms of services, according to SOA paradigm [5]. A service in the context of DOHA is an autonomous self-contained component which is able to perform specific activities or functions independently, that accepts one or more requests and returns one or more responses through a well-defined, standard interface. A service that provides functionality is a provider service, while the service that requests a service is a consumer service.

DOHA hides the physical distribution of devices as JXTA peers. This abstraction allows working with logical spaces based on services at high level. The cooperation between services at *services net* level involves communications between peers at *virtual net* level, and finally point-to-point communications between devices placed in different subnets at the lowest level, the *physical net*. DOHA is designed to ease interconnection of widely dispersed service nodes across the network, with loose coupling services and a dynamic model of operation.

### 2.1 DOHA Platform Design

We have taken some design decisions during the DOHA platform development to ensure robustness, scalability and security features, of great importance in ubiquitous computing systems. With these decisions we also guarantee the SOA principles of loose coupling, encapsulation, abstraction, reusability, composability, autonomy, optimization and discoverability.

Each service of DOHA is characterized by a multilayer architecture. The multilayer structure consists of several design layers that decouples the tasks performed by a service in components. This procedure facilitates the implementation and deployment of services, providing components to control the state of the service when a requested is accepted, the interactions of the service with the rest of services, etc. The *Interface Layer* guarantees the widespread access to services from any other element

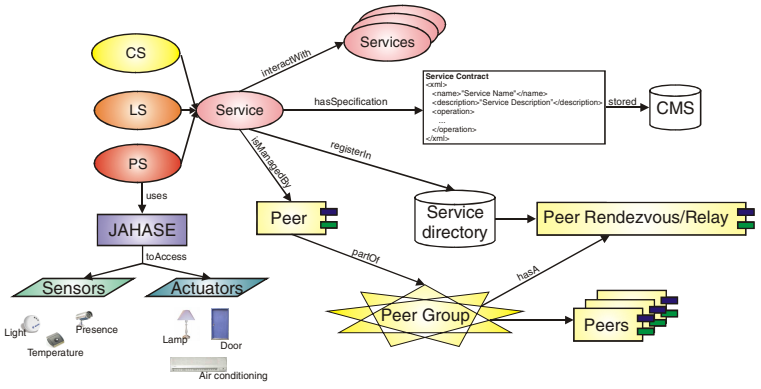


**Fig. 1.** Main elements of developed DOHA platform based in SOA principles

of the system. The *Application Layer* abstracts the functionality itself of a particular service. Finally, the *Interaction Layer* contains the logic needed to be able to communicate and collaborate with other services.

In Fig. 1 we can show the main ingredients to develop and deploy services in the DOHA platform. We have identified three types of system services depending on its role and responsibility: Customer Service (CS), Physical Service (PS) and Logic Service (LS). The applications may have different roles, and consequently can act with several service roles in the system. The *Customer Service* invokes the use of a specific service (provider service) or several services to satisfy the users requirements. Since the users will interact with them, they should provide a simple and natural way to modify the behavior of their living environment. The *Physical Service* is a provider service which interacts directly with hardware devices of the system (sensor or actuator). It can provide the state of the living environment, or change it, depending on the requests performed by other CS services. Finally, the *Logic Service* has specific functions to provide a specific task in either case, alone or in collaboration with other services. The services have a specification in XML, the *service contract*, to describe the services, its functionality and its methods. This specification is registered in a public directory of the service and it can be access via CMS (Content Manager Service) remotely. Although XML is used in the service contract, the developers are free to implement the data protocol more adequate to their purposes. The development of PS services requires the interaction with JAHASE as general platform to access hardware devices [7]. It hides the particularities of each hardware device such as sensors or actuators, and eases its management. Each service is managed by a peer that it is part of a peer group. The peer group is composed of many peers that it can interact with. The peer group has a Rendezvous/Relay peer allowing the discovery and communication between remote peers; thus, it eases the services interaction in a transparent fashion over different networks. We make the availability of services for multiple consumer services possible by the implementation of multithreaded peers and reliable communication channels between peers. This is possible with a controlled pool of channels to manage concurrently the requests made from other services. To more information about these aspects consult [8].

## 3 Discussion of Results and Related Works

In our study we have used the peer-to-peer architecture based on a SOA approach in order to obtain a system with the major characteristics associated with ubiquitous computing. In DOHA platform we have designed autonomous services capable of developing a collaborative behavior to carry out its functionality, with the publication and discovery mechanism associated with them. A set of adaptations have been made on JXTA middleware to optimize the system operation and obtain a behavior as independent and distributed as possible, such us the use of multithreaded pipes, detection and control of network failures, and the periodic search of advertisement to accelerate the discovery.

In the literature several studies in trends of construct ubiquitous systems from a peer-to-peer architecture can be found. The AMUN middleware (Autonomic Middleware for Ubiquitous Environment) is employed in the ubiquitous mobile agent system UbiMAS [9] and uses the JXTA as communication infrastructure based on an Event Dispatcher. In our approach, all services publish advertisements in the network when are available, and these events are filtered in each service, without the need of a centralized event dispatcher. Other similar approach is GAS-OS Architecture [10]. The GAS-OS Kernel Communication Module is responsible for communication between GAS-OS nodes and implements a P2P communication. In addition, DOHA complements the P2P features of JXTA with some design considerations such as multithreaded pipes, and detection and control of network failures. In CoCA a Collaboration Manager to share computing resources in a service platform is implemented [11]. The central figure of the Collaboration Manager might be a bottleneck in the system operations, which is resolved in DOHA using CMS among services. JXTA extensions are used in [12], proposing several modifications to the JXTA functionality that was proven successful in a mobile environment. In our case, the DOHA services platform has been tested in a home automation model with limited resource devices and we have obtained a satisfactory operation of the whole system [13].

## 4 Conclusions

With the development of DOHA we have been obtained a services platform, open, dynamic, reliable and extensible. The DOHA platform uses a peer-to-peer architecture instead of the traditional centralized client-server architecture that is generally used in the home-automation proposals. With the decision to use a P2P network based on JXTA technology, the DOHA platform has increased its modularity, scalability and independence characteristics.

The DOHA services platform eases the design, implementation and deployment of services that are independent in terms of functionality, based on the overall structure established. The platform is successfully applied to large-scale embedded devices [13], but when the memory resources are scarce, there is not space for JXTA middleware. A variation of JXTA for J2ME (CLDC-MIDP2) recently appeared is expected to be used.

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