Seamless Home Services

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Abstract

The growing number of smart devices providing services in peoples' homes and the increasing number of services available via the Internet creates two separate worlds that have not been successfully integrated yet. To bridge these two worlds, we propose a Home Service Platform supporting the seamless integration of home-based and net-centric services in a smart home environment. A common Service Engine supporting inter-service communication and aggregation provides human accessible user interfaces via a Service Portal and allows representing devices through a Home Device Controller. The integration of the two worlds allows us to create a new type of service: Seamless Home Services.

Keywords

Ambient intelligence, home environment, smart home services, home service platform, service engine, service portal

1. Introduction[*]

Peoples' homes are currently flooded with a growing number of intelligent devices providing more and more "useful" features. New smart home devices are introduced as well as additional house control and telecommunication systems, each loaded with numerous complex functions making the handling increasingly difficult for end-users and developers. At the same time the number of available net-centric services grows continuously, providing personalized and ubiquitous access to information. These two environments are yet still separated, but there is an increasing need for a new generation of services aggregating functionality and integrating home-based and net-centric services. We call this new class of services enabling access, configuration and usage in an intuitive way "Seamless Home Services".

Seamless Home Services provide the end user with simple to use functionality instead of hard to use device controls by concealing complex functionality in

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adaptive user interfaces and automating repeating processes.

In this paper we present our solution for the easy provisioning of seamless services in form of an integrated runtime environment, facilitating the work of service engineers by bringing services and devices together in a straightforward manner.

The next chapter gives a summary of the related work in this area, followed by chapter 3 where we identify the challenges motivating the development of Seamless Home Services. Afterwards we describe our approach to face those challenges, the *Home Service Platform*, followed by chapter 5, introducing our home infrastructure and the services we implemented to test our approach. Finally chapter 6 summarizes our work and gives an outlook to future research work.

2. Related Work

The increasing number of home devices and home networks leads to heterogeneous home environments, consisting of different types of networks and incompatible devices. In the home automation area multiple vendor specific proprietary protocols compete with proposals for standardization like e.g. EIB, X10, OneWire and I2C or ZigBee and various standards like e.g. UPnP, DLNA, SLP, Jini and Havi have been proposed to enable interoperability between devices of different vendors. In addition, smart services for the home environment have been proposed on basis of OSGi [4] and several research efforts like UIUCs Gaia [14], Stanford's iROS [9] or MIT's Metaglue [5] aim for the development of platforms allowing service interactions based on software agents within intelligent environments. Several of the existing standards also try to address specific use cases for appliance aggregation [3] or service aggregation [15].

McGrath et al. describe a concept [11] to use semantic queries that refer to ontologies for a semantic service. The iCrafter service framework [13] focuses on an approach for automated service aggregation on the user interface level.

Different to these approaches, focusing on device control and device interoperability, we concentrate on the connection between home-based and net-centric
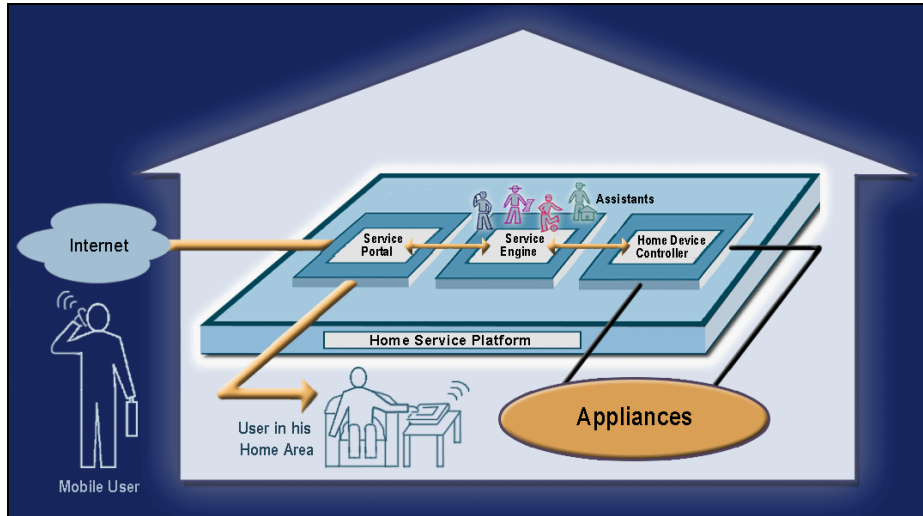
Figure 1: The home service platform consists of the Service Portal, a Service Engine and a Home Device Controller.

services. We thus take the aggregation of services one step further and unite home-based device specific services and net-centric services considering three aspects: abstraction from device specifics, user interface integration and service interoperability.

3. Challenges

We identified three challenging objectives that our approach has to meet to unite the home environment with the services offered by the internet for the creation of Seamless Home Services:

Interconnecting devices

The first challenge to face is the integration of various devices from different vendors as our anticipated home environment has to be able to interact with the devices and services available in the home. This requires an open system allowing the integration of devices from different manufacturers, supporting different standards and communication protocols.

Merging home-based and net-centric services

Once devices in the home are connected, the provided home-based services have to be merged with net-centric services to allow the provisioning of new and innovative services based on the available home infrastructure. This requires a home infrastructure mediating between home-based and net-centric services enabling both to expose their capabilities to each other.

Accessing services

Mediating between different services is one aspect of the anticipated architecture, mediating between the services and the user is another one. All provided services and devices have to provide a consistent user interface that can be personalized and integrated in the home environment, providing easy access to the various services.

Derived from these identified challenges, it appears that an integrated architecture uniting services, device controls and user interfaces is needed to benefit from the increasing range of functions and the convergence of modern devices and service providers. In the following we propose a solution for an architecture, targeting the identified objectives.

4. The Home Service Platform

We propose a common Home Service Platform (HSP) acting as a bridge between users and devices, providing the main service infrastructure in the home environment. This HSP aggregates the available services, supports developers with a common infrastructure for the integration of services and provides a common and consistent user interface to the end user. In our approach, the proposed Home Service Platform (Figure 1) consists of three building blocks, representing an architecture similar to a classic three-tier-architecture:

- A *Home Device Controller,* handling the discovery and control of devices and sensors at home and abstracting from the device specific protocols and networks.
- A *Service Engine*, implementing a virtual machine as service runtime environment bridging the currently existing gap between home-based and net-centric services.

- A *Service Portal*, providing unified and seamless access to services and devices.

In the following sections we give a more detailed description of the three building blocks of our Home Service Platform implementation.

4.1. Home Device Controller

The Home Device Controller (HDC) is the back-end of our architecture, responsible for discovering devices and the provided services and exposing these to the Home Service Platform. To provide a homogenous access to different home devices, we created an ontology, containing multiple categories representing devices with specific functionalities like sensors or power switches for example. These categories describe the functionalities of the devices and may be seen as device profiles creating an abstract layer encapsulating heterogeneous devices. This information is then used in various services to control the behavior of the home environment. To access devices the HDC encapsulates each connected device by a controller, responsible for the communication with the device via device specific mechanisms (i.e. UPnP, Jini, or plain HTTP).

The controller exposes the device capabilities via the device ontology which allows other services to access the devices in a generic manner. Changes of the device status are propagated via an eventing mechanism broadcasting status updates.

One of the main goals of our development was to ensure easy extensibility of the *HDC* architecture, to be able to easily integrate new device standards. We have provided means for integration of new controllers and device discovery architectures. On this basis, we have implemented support for numerous device types, based-on UPnP device profiles. Although the architecture is designed to integrate device specific services into the HSP, it is not limited to these. Any service can be encapsulated by a controller and presented to the system as a device which is directly accessible from the Service Engine to allow the easy integration of device functionalities into complex home services.

4.2. Service Engine

The Service Engine is our basic runtime environment uniting the Service Portal and the Home Device Controller to bridge the gap between home-based and net-centric services. It thus executes and manages the Seamless Home Services and offers a component-based approach to bundle services and enable remote administration and management. As we experimented with OSGi and Jini, we noticed that service interoperability becomes complex as soon as an unknown configuration of services at the target environment is considered. Thus, looking at scalability requirements, the loose coupling of components, and an elegant way for automatic services composition, we decided to implement a Service Engine that is driven by an agent environment [16].

Our Service Engine is based on the Java-based Intelligent Agent Componentware (JIAC) [7][16][17], which is compliant to the FIPA agent management specification [6], defining an infrastructure consisting of an agent communication channel (ACC) (for inter-service communication), an agent management system (AMS) (allowing to address services and to control their lifecycles) and a directory service (DF) storing descriptions of available services. We refer to ontologies [8] in order to describe service functionalities such as their specific conditions, as well as their supposed effects. These descriptions are the basis for a partial-order planning algorithm [12] enabling the installed services to make use of new, yet unknown services. Currently we are using our Service Engine as a runtime environment for both, net-centric and home-based services, bridging the gap between home-based and net-centric services by allowing service concatenation and inter-service communication.

4.3. Service Portal

Access for human users to the services provided by the service engine is realized via a web-based Service Portal. The portal offers service access by aggregating service user interfaces into one consistent and unified home portal. Each service user interface is realized as a portlet based on a JSR-168 [10] standard provided via the Multi-Access Service Platform (MASP) [1][2], which mediates between the services and the user interface representation. The MASP renders multimodal user interfaces for HTML, WML and VoiceXML-based browsers by processing an abstract XML-based interaction description. This abstraction layer allows delivering our user interfaces to a wide range of devices supporting voice and visual interaction. The portal-based approach allows the aggregation of service user interfaces making service and device control much easier for users. The device independence of the MASP approach ensures ubiquitously available services that adapt to specific situations of the user by allowing seamless switching between voice-based and graphic-based interaction depending on the users' specific situation.
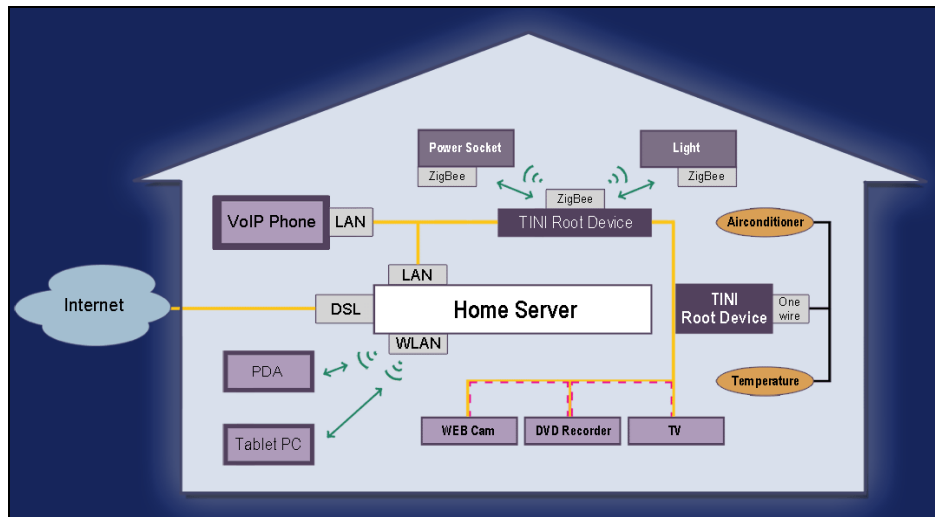
Figure 2: A technical overview of our home infrastructure testbed.

In combination with the intelligent home environment and ambient utilities like localization services, device discovery and automated device selection, the described features provided by the Home Service Platform allow to increase the usability and automation of the home environment.

5. Seamless Home Services

To validate our approach, we set up a testbed that reflects a typical home infrastructure and allows merging home-based and net-centric services. We deployed the Home Service Platform presented in the previous section and implemented a set of services that seamlessly integrate into the home environment.

5.1. Home Infrastructure

Our home infrastructure testbed (Figure 2) consists of a central home server merging different types of networks, devices and services. It connects to the Internet on one side and to the home IP network on the other side. The home IP network transfers content and IP based communication (i.e. UPnP messages) and provides access to other home automation networks like OneWire and I2C bus systems. Proprietary networks like ZigBee, X10, EIB or OneWire are mapped to IP by using root devices as mediators. We implemented two reference root devices by using a TINI board that can be programmed using Java to map a proprietary protocol to our IP infrastructure. To create a realistic home environment we then connected different devices to our network including DVD recorders, TVs, cameras, computers (storing media

files, etc.), handcrafted ZigBee-based controllable power sockets with devices, sensors and various terminal devices.

Based on this infrastructure we developed several Home Services, presented in the following section to test our implementation and to provide a controllable home environment as basis for further research activities in this area.

5.2. Implemented Services

To test our approach, we identified four service categories that we consider important for the residents of a home and implemented each service category by means of a software agent that can act on behalf of the user, as it knows about the user's preferences and is able to sense and control the user's environment. All developed services have been aggregated in a home portal providing a central point and a consistent interface to unify the access to all home services (Figure 3).

A *Home Control Assistant* offers an integrated view of all appliances and sensors embedded in the home environment by using the Home Device Controller. All connected appliances can be controlled through the home portal via different connected devices, such as a PDA, a web browser running on a (tablet) PC or a voice based interface. The Home Control Assistant can be easily extended to integrate new standards for home automation which we tested by integrating various sensors, UPnP and ZigBee devices and some legacy systems for home automation.

Figure 3: The home portal displaying the four service categories, each implemented as an intelligent home assistant.

A *Home Care Assistant* is able to automate tasks on behalf of the user by allowing the definition of rules to control devices and services in the intelligent home. Rules basically describe actions to trigger if specific events take place. A scenario could turn on the TV and dim the light if it is after 8 o'clock, the user is in the living room and the news are on TV.

A *Home Entertainment Assistant* realizes a media control module, allowing the creation of media connections for A/V playback as well as a Personal Video Recorder (PVR) that can record movies on behalf of the user.

Finally, a *Home Information Assistant* implements a personalized news service for the home environment which continuously gathers information from the web on behalf of the user. Different from the other assistants, the Home Information Assistant is realized as a set of net-centric services, since it is a multi-user system that requires a high-bandwidth connection to continuously retrieve information and a lot of CPU power for its filtering algorithms.

Each assistant provides a value for the user on its own, but the power of our approach lies in the possibility to combine the services provided by the assistants. As all assistants are implemented on basis of our service engine, the Home Service Platform can now make the assistants aware of each other. Thus the

Home Entertainment Assistant and the Home Information Assistant can be connected to learn from each other about the user's interests. In our prototype the Home Information Assistant is able to communicate with the Home Entertainment Assistant to program the users' personal video recorder to record films based on what the user likes to read about. The other way around, the Home Entertainment Assistant can give the Home Information Assistant feedback if and how long the user watched the recorded film, which is used to optimize user profiles for the personalized newspaper service. Further experimentation with the combination of Home Care Assistant, Home Entertainment Assistant and Home Information Assistant showed that this approach can be further extended. Based on presence information of the user, gathered by the Home Care Assistant it is for example possible to decide between several possibilities if the users favorite show is on TV. The show could be recorded if the user is absent, if could be directly played back on TV or a previously recorded or time shifted show could be played if the user arrives late. By dynamically combining home-based and net-centric services we successfully demonstrated, how we can gain a more convenient service usage in the home environment.

6. Conclusion

We realized a Home Service Framework that consists of a Home Service Platform and several basic services supporting the easy creation of Seamless

Home Services and their integration into the home environment. Our approach combines three components, we identified as suitable to realize a comprehensive environment to support the creation of these services:

1) a Home Device Controller, allowing the integration of various home devices,
2) a Service Engine, uniting home-based and net-centric services,
3) a Service Portal, supporting multimodal access for users.

To test the feasibility of this approach we developed several services supporting the user in his daily life and successfully combined home-based and net-centric services. Our approach enables end-users to integrate net-centric services in their home environment allowing them to communicate with home appliances. This allows the development of Seamless Home Services that integrate well in the users' homes.

The connection between the services can further be used to enhance services with home-based information like the users position, information about the environment and the context of the service usage. We already started experimenting with localization infrastructure based on current state-of-the-art RFID and face detection technology to further enhance our demonstration environment, which works with simulated location information at the moment. The connection of this data to additional information about the home environment will allow us to better utilize available devices in the current direct neighborhood of the user.

During the work with the Home Service Platform in the home environment we also recognized the manifold possibilities that such a system provides for enhanced user interactions. In our future work we thus want to focus on the delivery of home services to the user via seamless multimodal user interfaces that easily integrate in the user's environment and utilize various available devices and modalities for user interaction. We expect our approach of a common Home Service Platform to be generic and comprehensive enough to provide the basic infrastructure necessary to realize ubiquitous and seamless access to services, net-centric or home-based, via adaptive multimodal user interfaces.

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