# Using the Connected Home Platform to support user tasks as orchestrations of smart objects services

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**ABSTRACT**

The ATRACO project uses the ambient ecology metaphor to conceptualize a space populated by connected smart objects and services that are interrelated with each other, the environment and the people. User activities are supported by the implementation of ubiquitous computing applications deployed over this ambient intelligence space. In this paper we present a possible realization of the ATRACO vision using the Connected Home Platform, a commercially available system adopted and evolved by ATRACO in order to provide network adaptation and context-aware services. A flexible and distributed context-aware service model is introduced using the OSGi and UPnP frameworks. UPnP is used to unify the existing network infrastructure comprising of heterogeneous technologies and protocols at the IP level. Furthermore, we introduce a context-aware service model and provide an example of orchestrating context aware services with the support of the platform.

**Author keywords**

Ubiquitous computing, smart objects, service oriented architecture

**INTRODUCTION**

Context-aware systems are an emerging genre of computer systems that help add some forms of intelligence to our surroundings. It is well-established that context-aware (sentient) systems should address three basic requirements, i.e. sensing, inference and actuation [3]. In the ATRACO project [2] we use the *Ambient Ecology* metaphor to conceptualize a space (Ambient Intelligence – AmI – space) populated by appliances, devices, and context aware artefacts and services that are interrelated with each other and the environment [5]. Adding context awareness to artefacts can increase their usability and enable new user interaction and experiences.



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Ubiquitous context-aware computing has been around for several years. Several projects have produced a host of different applications. Research in these projects is mainly driven by scenarios of AmI introduction into people's activities, which can be classified into six main activity domains: home, office, health, shopping, learning and mobility. Research issues can be clustered in those concerning computing, communications, interfaces, embedded intelligence, sensors and actuators [7].

In the context of Disappearing Computer initiative [4], the concepts of smart tags and smart objects were developed; these were used to compose distributed ubiquitous computing systems. The research that was initiated with Disappearing Computer, and other related initiatives (Presence, Global Computing) continued into FP6 in the context of several IPs. Among these, the Amigo project [1] focused on the usability of a networked home system by developing open, standardized, interoperable middleware, which will guarantee automatic dynamic configuration of the devices and services within this home system thus supporting interoperable intelligent user services and application prototypes. Along the same lines, TEAHA (The European Application Home Alliance) is proposing a method of secure service usage and discovery using a common proposed interface and set of methods that ensure the ease of use, privacy and interaction between clusters that implement different communication protocols [8].

In this paper we present the application of the Connected Home Platform (CHP) in supporting the realization of ambient ecologies. CHP uses a flexible and distributed context-aware service model based on the OSGi and UPnP frameworks. Furthermore, we introduce the context-aware service model and provide paradigms of context aware services that build upon perceptual and context aware components of the platform.

## ACTIVITY SPHERES

Nowadays, people achieve their goals by decomposing them into tasks (that is, by forming plans) and them by realizing these tasks with the help of objects or services in their surroundings. Goal achievement depends on the availability of the appropriate objects or services (henceforth called resources); people adapt their plans according to the available resources or the special characteristics of the environment. Thus there is a tight coupling between plans and resources that determines the degree of goal achievement.

One of the research goals of the ATRACO project is to decouple plans from resources. The basic concept we use is the "Ambient Intelligence sphere" or "activity sphere". An activity sphere is intentionally created in order to support the realization of a person's specific goal, which is described as a set of interrelated abstract tasks. This plan is abstract and contains only descriptions of the resources it requires; thus, it is independent from any particular configuration. The sphere is deployed over a particular AmI space and uses its resources to help its owner realize the tasks that lead to the achievement of the goal.

The ATRACO system supports this context-based transition from abstract to concrete. For each sphere, an ATRACO system is realized by the respective Control Agent, which can run on a PDA or a home server and contains the user goals and associated plans. Based on these, it discovers the available resources which could be used for task realization. When such resources are discovered, abstract tasks become concrete and each is assigned to a Task Agent; the realization of each concrete task can be thought of as a ubiquitous computing application. Thus, the AmI space becomes the platform on which ubiquitous computing applications that are part of an ATRACO sphere are realized.

The explicit configuration of a sphere requires the discovery of the resources in the ecology and their orchestration based on virtualized descriptions of their properties, capabilities and services. One could assume that these descriptions are made available through standardized protocols (i.e. as UPnP headers) or not (i.e. using proprietary meta-data).

In the former case, the approach adopted in ATRACO is to use the services of the Connected Home Platform, which provides the Control Agent and the Task Agents with descriptions of resources and protocols. In the latter case, we first construct a local ontology for each resource and then we apply ontology alignment in order to merge local ontologies into a global sphere ontology which contains all data and knowledge necessary to realize an activity sphere [6]. In the rest of the paper, we shall focus on the former case.

## CONNECTED HOME PLATFORM

The Connected Home Platform (CHP) is a commercially available platform that offers a complete set of smart home services running on top of existing broadband service bundles, thus implementing a connected home environment. It is based on the flexible MRG-110-6 Home Controller (referred also as Domotic Controller) of inAccess Networks, which can be easily integrated into wireless or wired LAN and provides access over LonWorks and KNX/EIB control nodes.

The main platform module is the home gateway, which coordinates all the individual smart objects and provides add-on functionality. Figure 1 depicts the home gateway software architecture. We assume that smart objects can be found in the AmI space, which offer a variety of services. The communication between the artifacts and the home gateway is based on the Lonworks and wireless Z-Wave and Zigbee protocols. Moreover, a Service Node is hosted at the operator premises. It is responsible for service provision and management, as well as for providing secure remote access to the home. The service node contains all necessary elements for service lifecycle management, introduction of new services, remote monitoring, watchdog timers, handling of user subscriptions per service package, ratter & charger, plus the ability to render the graphical or audio content depending on the user terminal capabilities for home remote access.

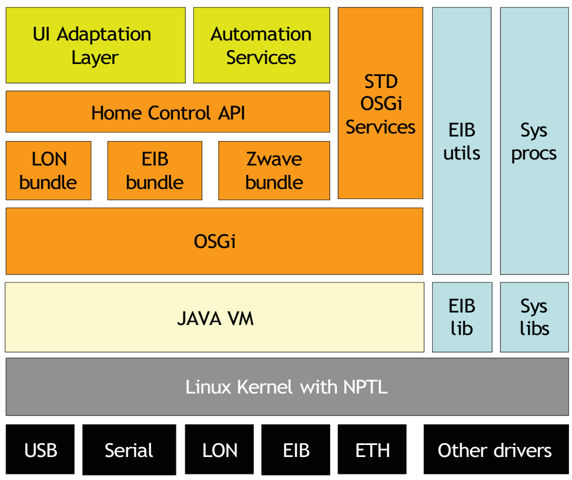


**Figure 1. Home controller software architecture**

## CONTEXT AWARE SERVICE MODEL

The CHP endorses the development, deployment and management of advanced, human-centric, context-aware services. Applications can exploit the context-aware services, the advanced user interfaces, and the virtualization of the home network infrastructure, through high-level mechanisms offered by the platform. CHP adopts OSGi as the defacto standard framework for the creation, composition and deployment of services. The CHP provides a registry for the services and an orchestration engine taking care of the service interaction. CHP further adopts UPnP as the control and management plane to deliver its services. The CHP enables a flexible model for home application/service development and deployment, which distinguishes between the following roles:

*AmI space infrastructure*: The infrastructure consists of the full range of smart objects (including sensors, devices, actuators, residential gateways, computing and network equipment) used to provide sensing, networking and basic services in the home environment. All these UPnP compatible components, during bootstrapping, will send presence announcements advertising their supported services. On the other hand, every device or service will listen for discovery requests. Upon reception of a search request, the device will examine the search criteria and will respond if a match occurs. Each smart object or service provides, according to UPnP specification, information regarding service resources and how to use them.

*Perceptual Components*: The perceptual components process sensorial input based on the range of sensors installed. By using the UPnP model, each perceptual component will discover easily network resources, such as sensors, actuators, cameras, microphones, speakers etc. With the use of a control point entity a perceptual component can be fed with appropriate type of information. The perceptual components will provide services responsible for dispatching events to registered control points. These services will also accept actions for configuration and initiation of raw information processing.

*Context Model*: Having UPnP descriptions of perceptual components and infrastructure elements at hand, it is possible to calculate context states. Based on the plan, these states can be combined towards identifying higher level contextual states (i.e. extracting more sophisticated context).

*Activity spheres*: Activity spheres are considered as applications that use plans and context models to realize their tasks. In the current implementation, the application logic will be specified in terms of service actions to be executed over a UPnP object. UPnP objects exist in all levels of the functional chain and range from simple sensors to complicated software modules. The applications will have access: (i) At the infrastructure level, to control, tune or configure sensors, actuators, devices etc. (e.g. towards regulating the environment, or adapting a device to context). (ii) At the perceptual component level, to configure the perceptual component for optimal performance or to control it (e.g. start/stop it) through the application. (iii) At the context modeling level to dynamically adapt (e.g. augment or restrict) the context model. (iv) At the application level, to leverage any other computing service that might be available within the UPnP network (e.g. invocation of a software component or application).

## UPNP VIRTUALIZATION OF HOME NETWORK INFRASTRUCTURE

CHP provides resource virtualization functionality, which adheres to the UPnP paradigm, for all the devices and networking technologies in the domestic environment. Home applications/services, and components for context awareness and advanced user interfaces regard resource virtualization components as a set of UPnP services, which can interact by invoking actions and receiving events. UPnP virtualizes all network resources from various heterogeneous networks into a common communication meta-medium. UPnP being agnostic for the origin (Zwave, Zigbee, Lonworks, IP, etc.), implementation (C, C++, Java, Python) and nature (software, hardware) of resources, unifies them as peer objects in the same abstraction layer.

The CHP will manage a complete, pervasive, unobtrusive and networked infrastructure. Figure 2 presents in general terms the infrastructure. There are various types of devices interconnected, using different wired or wireless network technologies:

*Home network infrastructure*. The CHP assumes that a modern home can have many devices that can be networked and controlled remotely. Devices can be computing, intelligent appliances (white/brown goods, cameras, microphones), sensors and actuators. The networking technologies may be wireline, relying on Ethernet, Firewire, Lonworks, KNX/EIB, or wireless, relying on WiFi, Bluetooth and ZigBee. Inside the home devices can communicate in ad-hoc mode. Such an option is imposed by the capabilities of many small devices, like wireless sensors.

*UPnP proxies to non IP networks*. The CHP will deliver high level context-aware services making use of a wide range of devices and appliances. These devices will eventually belong to heterogeneous networks and for that reason their virtualization as UPnP devices in the IP network is required. Special devices called UPnP proxies undertake this responsibility. UPnP proxies bridge IP networks with non IP networks representing at the same time devices belonging to non IP networks as UPnP entities. A UPnP proxy can interface more than one non IP networks.

*Service gateway*. The interconnection of the home network with the Internet is usually offered through a residential gateway (referred also as Home Controller), which is also manageable through UPnP regarding various network services like firewalling, routing, NAT, DNS and DHCP. The service gateway from its nature is provider-neutral and is empowered with OSGi. This enables the dynamic installation, update or removal of the software components (OSGi bundles), which finally will compose complex or simple services.

Virtualization of resources will facilitate infrastructure exploitation from context-aware components, advanced user interaction mechanisms and home applications/services. The platform will use UPnP mechanisms for the acquisition of signals from the network infrastructure (e.g. cameras, microphones). These signals will be the basis for the creation of (simple and advanced) contextual information that will trigger the home applications and services. Additionally, the CHP functionality will enable the home applications/services, perceptual and context-aware components to invoke actions, upon the underlying home network infrastructure.

The rationale for resource virtualization is that the abstraction and integration under a common umbrella (management/control interface) will provide to home application/service developers a platform that hides the details and the complexity of the underlying home network infrastructure.

Even when a smart object is connected to a non IP network, the system must make it available in the pool of available resources. Since it cannot join the IP network and advertise themselves as UPnP devices, the UPnP proxy undertakes the responsibility to do it on their behalf. A UPnP proxy performs all the necessary steps so as to ensure IP connectivity for all devices behind it. Acting as an inter-working unit between a non IP network and an IP one, the proxy starts a new IP session where the device is advertised as a UPnP device sending a multicast announcement. The proxy holds deferent profiles for each type of device it represents. For each new device type, the proxy updates its profile repository. The UPnP proxy is the key element of the infrastructure resource virtualization. Each device behind a proxy has the same IP address but a different UPnP address (a UPnP address is a URL pointing to device associated information). That way the proxy is able to accept remote procedure calls for many devices.

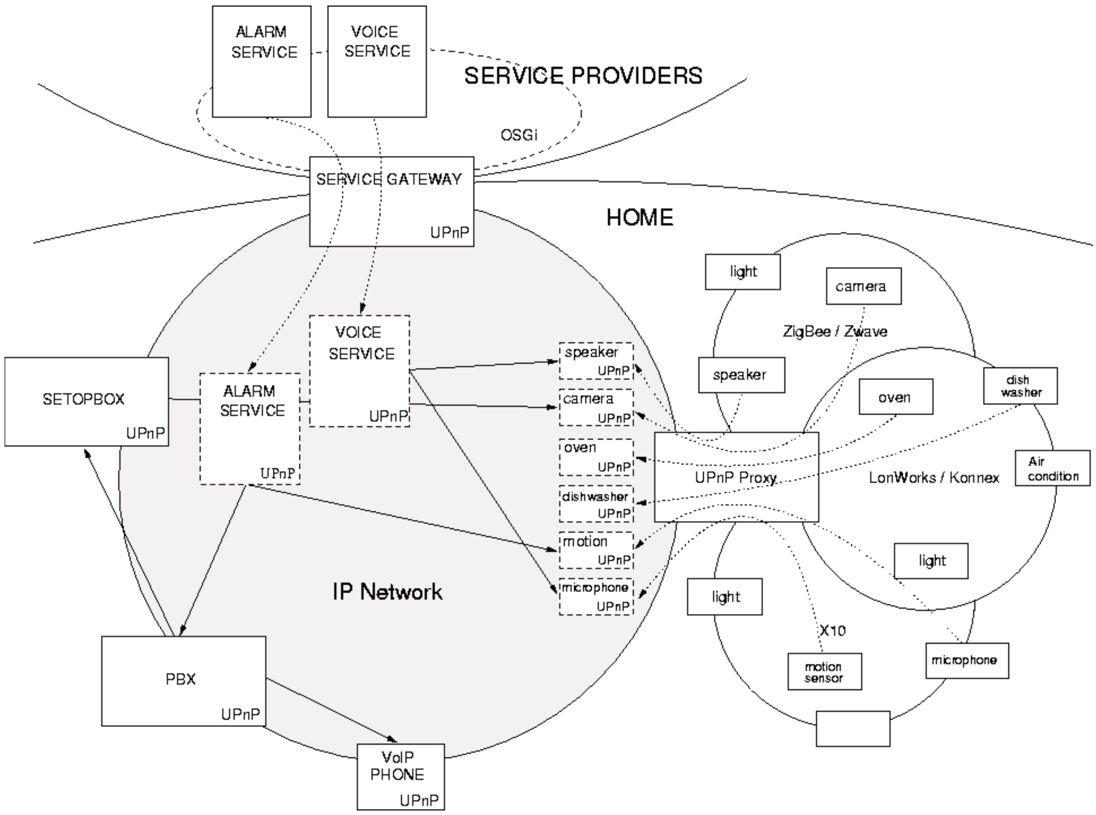


**Figure 2. General structure of the home network infrastructure**

The services, the context events and the actions that can be supported by a device are made known through the virtualization function performed by the UPnP proxies. Through the virtualization function, the user applications, the perceptual and the context-aware components can manage and use the infrastructure. Resource virtualization can be thought of as an abstraction of some defined device functionality and its public exposure as a service through the CHP platform.

## EXAMPLE APPLICATION SCENARIO

Consider the following scenario:

Suki's living room has embedded in the walls and ceiling a number of sensors reading inside temperature and brightness. He uses an air-conditioning as the main heating / cooling device. The windows are equipped with automated blinds, which can be turned in order to dim or brighten the room. For the same purpose, Suki can use the two lamps hanging from the ceiling. Suki's goal is to feel comfortable in his living room.

The Control Agent that manages the house contains an abstract plan, which states that, in order to achieve this goal, temperature and brightness have to be adjusted to a comfortable level. These tasks are "assigned" to two Task Agents. These retrieve abstract descriptions of the two tasks involved in this plan from the local database. Then it accesses the protocol independent Connected Home Platform installed in the house in order to discover the resources available in the living room and make the task description concrete (i.e. set air-conditioning temperature to 22 degrees C). With the help of CHP, each of these agents can access all devices in the house that relate to one concrete task.

A touch screen with voice recognition ability that is mounted near the room entrance is used as the main control point. Suki can use the mike in the screen to give voice commands to his home. All interaction between Suki and his home is managed by the interaction agent. This agent can receive Suki's commands and interpret them with the help of CHP. Then, this agent interacts with the various devices in order to provide output to Suki using their actuators.

Parts of this ambitious scenario will be realized in the context of ATRACO project. For example, Figure 3 shows how control of heating and lighting conditions can be achieved with the help of CHP in order to realize Suki's "feeling comfortable" sphere. The service can be triggered by two sources. The first is related to the identification of a user. This identification is done by components that offer context awareness. Alternatively, the second trigger is a command issued by a user. In the figure this is represented by the voice interaction agent. Having identified the user, and having at hand additional contextual information, the home application/service can decide on appropriate commands towards the networking infrastructure. In the example, there will be commands towards the lighting and the heating agents, in the context of a power and climate control services.

## CONCLUSIONS

The ATRACO project uses the ambient ecology metaphor to conceptualize a space populated by connected smart objects and services that are interrelated with each other, the environment and the people, supporting the users' everyday activities in a meaningful way. Everyday appliances, devices, and context aware artefacts are part of ambient ecologies. A context-aware artefact uses sensors to perceive the context of humans or other artefacts and sensibly respond to it. Adding context awareness to artefacts can increase their usability and enable new user interaction and experiences. Given this fundamental capability single artefacts have the opportunity to participate in artefact-based service orchestration ranging from simple co-operation to developing smart behavior. Smart behaviour, then, either in individual or collective levels, is possible because of the artefacts' abilities to perceive and interpret their environment.

In this paper, we presented one of possible implementations of ATRACO activity spheres, which uses the Connected Home Platform. The CHP enables network adaptation and supports context awareness for artefacts that participate in the ambient ecologies using a flexible and distributed service model based on the OSGi and UPnP frameworks. UPnP virtualizes the home network environment into a common communication meta-medium.

Nevertheless, the vision of ATRACO is to enable the bottom-up composition of services and capabilities of smart objects, in order to support user task realization in unknown AmI spaces. To achieve this, a semantically rich layer will be developed on top of the CHP, which will contain ontologies and agents. The former will describe heterogeneous services and the latter will use CHP resources to adapt the implementation of user tasks.

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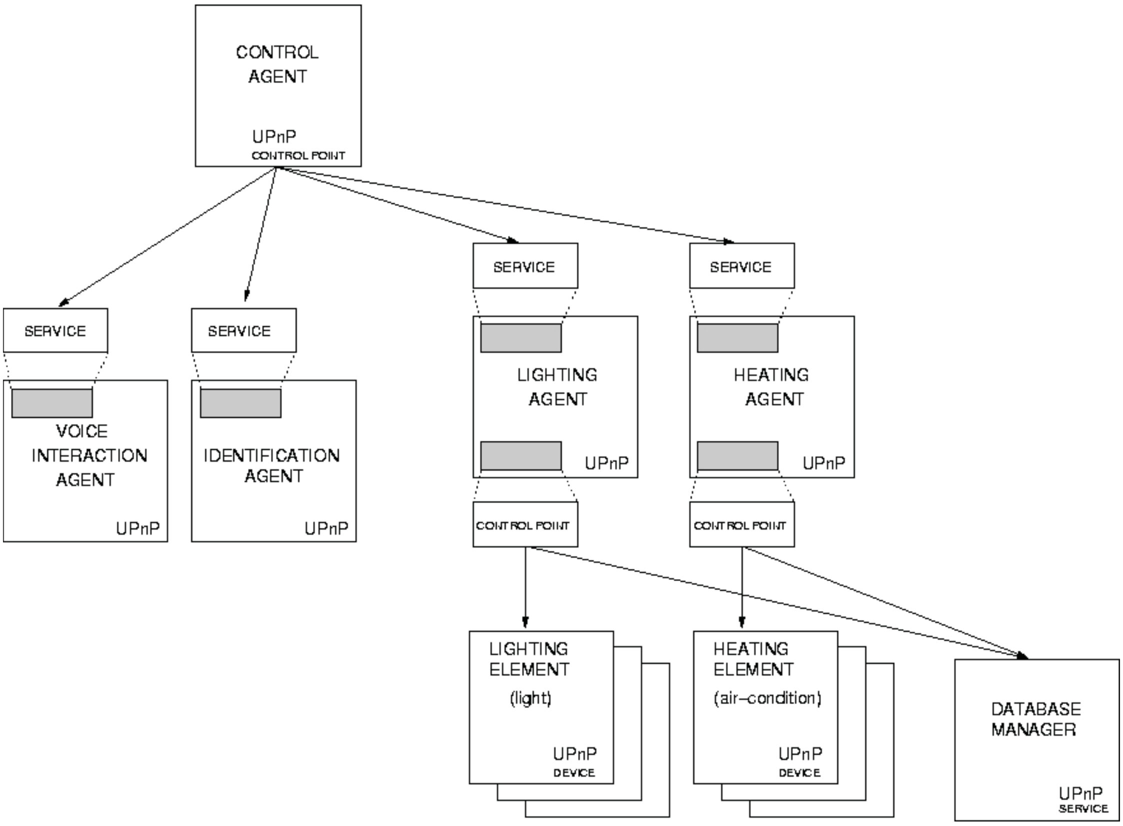


**Figure 3. Heating and lighting control using CHP services**