Reference Architecture for Ambient Intelligence

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Abstract. A lot of software infrastructures for distributed device ensembles with quite different approaches have been developed in the past. This article describes the need of a reference architecture for real ad-hoc cooperation of distributed device ensembles which must support self-organization of its components. Self-organization means that the independence of the ensembles' components is ensured, that the ensemble is dynamically extensible by new components and that real distributed implementation is possible.

Keywords: Ambient Intelligence, Self Organization, Ad-hoc Communication, Reference Model, Goal-driven Interaction.

1 Introduction

The vision of Ambient Intelligence (AmI) [1-3] promise a future in which we are surrounded by intelligent, intuitive, and user-friendly devices that support us in the planning, organization and running of our daily lives, which recognize human needs and perceptions and that react to human goals and requirements and that autonomously provide the services to fulfil the user's goals. Consequently the realization of the Ambient Intelligence vision means the creation of reactive environments in order to support an appropriate goal-driven service execution.

2 Need of a Reference Architecture

A variety of research projects in the areas of ubiquitous/pervasive computing have produced interesting results. However, from an architectural point of view, today there exist only isolated point solutions for rather constrained scenarios but no holistic solution that would allow the integration of sensor-actor systems, devices with widely differing capabilities and a wide variety of services provided by the infrastructure into dynamically reconfigurable ensembles to support the user's needs across multiple domains.

The cost of developing point solutions and the lack of compatibility and interoperability across scenarios and domains are a major hurdle for the widespread adoption of Ambient Intelligence technologies. The goal of the ambient technology to

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provide domain and technology invariance can only be accomplished through a suitable reference architecture. The need for a reference architecture has also been articulated by industry. However, a single reference architecture may be an elusive target given the richness of the environment and the fast pace of technological change. The complexity of an architecture increases whenever the abstract computational structures meet the physical objects surrounding us.

These projects should strive to provide an architectural framework from which specific architecture instances can be derived. The first step must be a thorough understanding of the requirements imposed on the architecture by the various application scenarios across domains. These could be extracted both from relevant scenarios and from existing solutions which already distill the requirements of their underlying scenarios.

Once there exists a common framework that specifies the appropriate modules or architectural building blocks, the available technologies for the realization of the individual functions can be defined. Based on clear rules for composability it becomes now feasible to exchange modules, to accommodate new devices and functionality, or to interact across various point solutions. Different architecture realizations will have varying extra-functional properties. Therefore, it is also a goal to be able to anticipate the behavior of a system built according to a given architectural specification with respect to extra-functional properties, such as security, availability or scalability.

3 Ambient Intelligence Reference Model

Prior projects like EMBASSI [4, 5], MAP [6, 7] Smartkom [8], or VESPER [9] show that the effort that is required to create domain-specific solutions for the assistance of the user is considerable. The results of the different project are not interchangeable with each other. Mostly they are hard-wired to fulfil the requirements of a specific application scenario. The reasons are obvious: Each project possesses an own approach to control possible cooperation of devices and of functionalities that are available among the distributed heterogeneous devices. Consequently each new application has to be constructed from the scratch, because there are no generally accepted definitions and solutions available that map still existing solutions to new scenarios and application challenges.

Our approach in the EU-IST project PERSONA will diminish the still existing lack of definitions and will identify the fundamental functional components for reactive Ambient Intelligence Environments, which define the basic communication and cooperation patterns between these components and will provide exemplary middleware technology as well as functional components that will form a basic tool-set for fast prototyping purposes of Ambient Intelligence scenarios. This Ambient Intelligence Reference Model will provide application developers with detailed instructions, which operates as a blue-print, for further Ambient Intelligence applications.

The concept of Ambient Intelligence is used where intelligence is pervasive and unobtrusive in the surrounding environment. Such an environment is sensitive to the presence of living creatures (persons, groups of persons and maybe even animals) in it, and supports their activities and their goals. It remembers and anticipates in its behaviour. Consequently Ambient Intelligence extends the technical foundation that was laid by former initiatives like Ubiquitous Computing resp. Pervasive Computing [10].

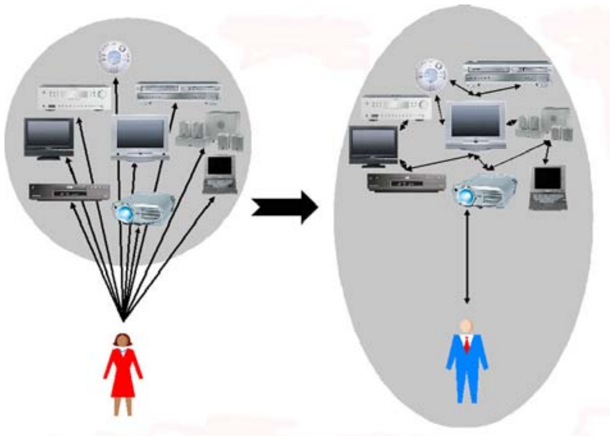

Fig. 1. The paradigm shift of Ambient Intelligence that requires a self-organized cooperation of the environment's heterogeneous physical objects in order to support a goal-driven service execution (right hand side).

These technologies triggered the diffusion of information technology into various appliances and objects of the everyday life. But now, Ambient Intelligence has to guarantee that those smart devices behave reasonably and that they unburden - instead of burden - the user. This means, the approach of the former initiatives, which is more technology-oriented (innovations by technology-push), must be replaced by a more user- resp. scenario-oriented approach (innovations by user-pull). The principle paradigm shift of Ambient Intelligence (see Figure 1) follows the recognize-act-cycle (like described in [11]) that defines the Principle Workflow of Ambient Intelligence [10, 12]: The environment (and its devices) must be aware of the user's situation, his interactions within his environment and its own current state Then the environment must be able to interpret those occurrences into user goals and, accordingly, into possible reactions that enable a cooperative, proactive support for the user.

In a final step, the environment must be able to translate the interpreted goals into strategies and actions. With this in mind, the AmI should aim:

- The investigation of the most important application domains for the user (automotive-domain and house-domain)
- The identification of a functional architecture and its typical communication patterns that supports the principle workflows of the considered application domains
- The development of a basic set of technologies for developing Ambient Intelligent prototypes in an easy and fast fashion

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