Chapter 5
Architecture Pattern for Context-Aware Smart Environments

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ABSTRACT

Recent years marked many smart environment solutions hitting the market and applying latest pervasive computing research advancements on an industrial scale. Context-aware smart environments are able to act accordingly to the immediate environment information in an intelligent, predefined, learned, or automatically inferred way, and are able to communicate to their users, thus increasing users' comfort and awareness level. Since the beginning of the 2000s, many projects have been designing and implementing smart environment systems. When looking post-factum at the architectures of these systems, one can notice a lot of similarities among them. With the same basic structure, the biggest differences usually arise at the level of individual components, aimed to satisfy different end-level requirements. Taking many successful and undergoing projects as case-studies, this chapter looks for the common structure, the common patterns, and the "best practices" that can help future projects to reduce the efforts spent on the general system frame, and redirect those efforts to more specific requirements that are unique in every project. It introduces several architecture layers that inevitably exist in one form or another, discusses the possible layer components and the common information flows, and mentions the most notable problems, such as scalability and fault tolerance. Several case studies of successful or undergoing smart building projects show that the presented pattern can be easily mapped to their architectures.

DOI: 10.4018/978-1-4666-4695-7.ch005

INTRODUCTION

The ability of pervasive systems to perceive the context of the surrounding environment and act accordingly proves to be an enormously powerful tool for raising immediate users' satisfaction and helping them to increase their own awareness and act in a more informed way. Therefore, recent years marked many smart environment solutions hitting the market and applying latest pervasive computing research advancements on an industrial scale.

Magnitude of context-aware smart spaces applications is enormous: it stretches from telephones that redirect the call to the room where the recipient is currently located, e.g. the Active Badge system (Want, Hopper, Falcão, & Gibbons, 1992), and simple coffee machines with the possibility to schedule the time of coffee preparation exactly to the time when you wake up to whole building automation systems with complex rules of behavior and planning techniques that are just waiting for your wink to launch the complex artificial intelligence reasoning that will understand and fulfill your unvoiced demands.

Going even further, smart environments matter not only on the Personal and the Social scale, but on the bigger Urban scale as well. Sometimes whole neighborhoods can be considered as smart spaces, as shown by many Smart Grid enabling projects (Georgievski, Degeler, Pagani, Nguyen, Lazovik, & Aiello, 2012), (Capodieci, Pagani, Cabri, & Aiello, 2011). By introducing small scale energy generating facilities, such as wind turbines or solar panels, it is possible for individual buildings to produce more energy than they consume at certain points of time. To avoid losing this precious energy (which becomes even more precious considering its "green" sustainable origin), peer-to-peer-like energy transfer connections are introduced between buildings, with full featured automated negotiation techniques that enable one building to sell excessive energy to another neighboring building. First field-testing projects, such as PowerMatching City project in the Netherlands (Bliek, et al., 2010), which features 25 interconnected households, show that not only such energy comes with a cheaper price, but also the "transfer overhead" is severely reduced, as now the average energy travel distance is much shorter.

As can be seen, context-aware smart environments come in many different faces and on many different scales, but underlying idea remains the same: the system is aware of its context, i.e. the environment around, is able to act accordingly in an intelligent, predefined, learned, or automatically inferred way, and is able to communicate to its users, thus increasing their comfort and awareness level as well. Seng Loke in his book (Loke, 2006) defines the three main elements of the context-aware pervasive system: sensing, thinking, acting.

In just a few years after the first introduction of smart environments, the topic became booming, and many projects both in research and in industry were dedicated specifically to advancements in this area. As happened in many other research fields where a big number of different research groups and industrial companies started to work separately on the same topic, in the context-aware environments area the problems that the groups face are to a large extent similar, and some of them were solved several times, sometimes in a similar manner.

One of such problems, and an important one, is the high-level architecture design of smart context-aware systems. Since the beginning of the 2000s, many projects have been designing and implementing smart environment systems from scratch. However, when looking post-factum at the architectures of these systems, one can notice a lot of similarities among them. With the same basic structure, the biggest differences usually arise at the level of individual components, aimed to satisfy different end-level requirements.

Naturally appeared the idea to unify the architecture design for such smart environments projects. Taking many successful and undergoing projects as case-studies, we tried to find the

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