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Mobile Users in Smart Spaces

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INTRODUCTION

Constant technological advances are making *pervasive computing* (Weiser, 1991) a reality. Such advances have been enabling the rise of devices increasingly smaller, with larger storage space, novel wireless interfaces, and lower battery consumption. These innovative technologies are contributing to the emergence of a new sort of personal portable device, as well as a large number of sensors and actuators. Sensors and actuators are embedded into objects spread across the environment, while portable devices quietly inform such environments how users wish to interact with them. Therefore, personal mobile devices stand out currently as the interface between people and smart spaces.

A basic requirement in the context of pervasive computing is to allow users to access services seamlessly as they move across environments. This requirement demands from the underlying infrastructure the ability to transfer user sessions among access points (*handoff*), which is a well-known concern in the context of pervasive computing (Cui, Nahrstedt, & Xu, 2004; Banerjee, Das, & Acharya, 2005). Nevertheless, the effective delivery of services in smart spaces requires conceiving mechanisms for handling localized scalability, availability, and redundancy of services; load balancing among providers; and on-demand content transformation for different devices (Satyanarayanan, 2001; Raatikainen, Christensen, & Nakajima, 2002; Raman et al., 2002), henceforth *QoS issues*. These requirements rise as fundamental for promoting transparency and invisibility to the service usage, as well as delivering some level of QoS and optimized resource utilization (Kalasapur, Kumar, & Shirazi, 2006).

Currently, there are still no efforts for conceiving solutions to provide ubiquitous access and seamless usage of services while taking into account QoS issues. In this context, we define the dynamic provision of services as a set of requirements relevant to the seamless provision of services for mobile users plus mechanisms for dealing with QoS issues.

In this article we define and present the basis of our work about dynamical services provisioning for mobile users in smart spaces. We present an overview about our envisioned service provision infrastructure, as well as the main research challenges related to it. Finally, we discuss issues related to the current state of our research and point out research directions in this field.

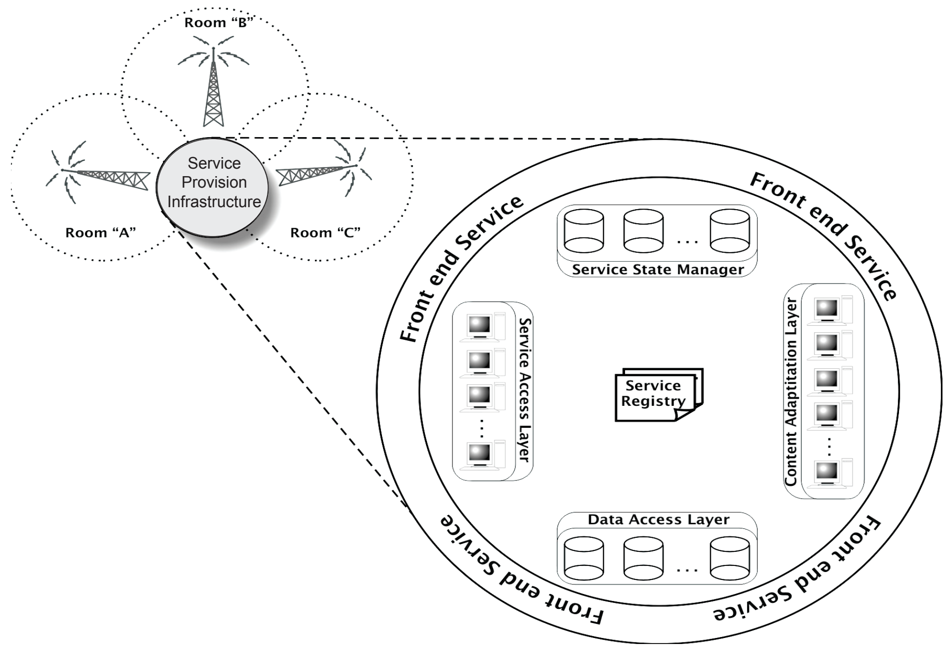
BACKGROUND

The interaction between users' devices and smart spaces occurs primarily through services advertised in those environments. The *service-oriented paradigm* (Papazoglou & Georgakopoulos, 2003) is especially suitable due to the dynamics of smart spaces, where resources may exist anywhere and applications running on mobile devices must be able to find out and use them at runtime.

In the context of smart spaces, user mobility is the main cause of such disturbances, but other factors may also cause temporary unavailability or degradation of services, for example, crash failures in the service providers, temporary network congestion, or peaks of overload on service providers. Smart spaces are primarily service-oriented environments, where part of the application logic is at the client side (e.g., in the form of helper applications for user profiles) and part at the server side (e.g., in the form of services offering some extra features for the users). When losing network connection, client applications also lose part of their capabilities, which are deployed as services in these environments. This scenario illustrates the first requirement of the applications aimed at smart spaces: the ability to switch between connected and disconnected modes. Applications and service implementations may utilize this connectionless period for performing some sort of preparation for when the connectivity is reestablished (Sairamesh, Goh, Stanoi, Padmanabhan, & Li, 2004).

When able to cope with off-line operations, both applications and the underlying infrastructure need to provide means for bringing transparency to the service usage, even when users move across access points. Sessions specify which client is using which services in a given access point.

Figure 1. Conceptual infrastructure for dynamic provision of services



When users move across access points, sessions need to be transferred between them, service providers need to be contacted, and the use of services needs to be reestablished from the point at which they were interrupted due to the change of location (handoff).

Currently there are several alternatives for dealing with application mobility, such as mobile IP (in short MIP), hierarchical MIP, cellular IP, teleMIP, and dynamic mobile agent (Saha, Mukherjee, Misra, Chakraborty, & Subhash, 2004). All these alternatives are suitable for IP-based applications and are embedded in the transport layer of the IP protocol stack. The major issue of these solutions is their unsuitability for dealing with *real-time traffic* management (Saha et al., 2004). In the context of smart spaces, this is an important limitation since these environments have many multimedia services, such as video and/or audio streaming services. New mechanisms need to be developed for providing multimedia services for mobile users (Cui et al., 2004; Banerjee et al., 2005).

Nevertheless, a great many issues may affect the quality of the provided service, such as adaptability to changes in the execution and communication environments, efficient use of communication resources, and high *availability* and stringent *fault-tolerance* (Raatikainen et al., 2002). The requirements for data accessed by these applications are quite similar. The underlying infrastructure must provide consistent, efficiently accessible, reliable, and a highly available information base (Raatikainen et al., 2002).

Presently, there are many approaches to deal with QoS issues in the context of smart spaces (Kumar & Song, 2005; Panagiotakis et al., 2003; Hingne, Joshi, Finin, Kargupta, & Houstis, 2003). However, current efforts focus on the implementation of mechanisms for only coping with QoS issues in isolation, that is, they do not provide any support for handoff. In the same manner, current solutions for dealing with handoff focus only on the handoff mechanisms and neglect other aspects that also impact the quality of the provided services.

The fact that distinct solutions regarding handoff management and *QoS assurance* for service provision are available does not imply that it is possible to aggregate these two features into one unique solution. Bridging two distinct solutions may be prohibitively burdensome, may introduce bugs and/or restrict interaction between the two software modules, and after that may also perform poorly because the two software modules were not designed for working together. Therefore, designing and implementing infrastructures able to not only deal with handoff, but also capable of delivering extra levels of QoS, is certainly the next step towards conceiving service provision infrastructures that better approximate from the pervasive computing principle of invisibility (Satyanarayanan, 2001).

DYNAMIC PROVISION OF SERVICES

We define dynamic provision of services as a set of requirements relevant to the seamless provision of services for mobile users plus mechanisms for dealing with QoS issues. The goal is to conceive an infrastructure for dealing