A Pervasive Environment Based on Personal Self-Improving Smart Spaces

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Abstract. Ubiquitous computing (or ambient intelligence) has been the subject of research in the mobile telecommunications field for many years. Developments such as the Internet of Services and Grid computing have complemented and strengthened this work. The ubiquitous computing paradigm integrates information processing into the objects that surround us in our environment. One particular focus has been on the development of smart spaces in homes, offices and public areas, in which automation can be used to support the user. However, these are static spaces that offer ubiquitous characteristics in a limited environment, like islands in an ocean. When the user steps outside of this island, all of this is lost. The Persist project is investigating a novel approach which combines mobile communications with the notions of these static smart spaces to produce more general ubiquitous or pervasive systems in the form of the self-improving Personal Smart Space. The vision is that a Personal Smart Space will stay with the user as he/she moves around and provide an interface between the user and the various services and sensors which are available either directly or indirectly as well as with other neighbouring Personal Smart Spaces. Thus Personal Smart Spaces will be able to interface to local devices and services (even when no Internet connectivity is available to the user) and to interact with other Personal Smart Spaces to create a more powerful and flexible environment for the user and one which is more truly ubiquitous.

1. Introduction

Over the past two decades [1] , the notions of ubiquitous and pervasive computing [2] have been evolving, based on the idea that the user is surrounded by many different devices capable of capturing and processing information, and interacts with them as and when needed. The importance of this research area has been recognised by

researchers and funding bodies alike, and two of the major global challenges for Computer Science over the next decade have been identified in this area [3].

One example of this type of system is the Smart Home. Here research has been focused on developing techniques to support building automation (or domotics), such as intelligent light controls, window shutters, security systems, kitchen appliances, etc. In particular, there has been considerable interest in developing intelligent smart homes that can provide support for elderly and disabled residents, making it safe for them to live at home. This approach is basically concerned with a fixed space that is required to provide intelligent features that adapt to the needs of the user. This is the vision in a number of different projects and prototypes [4,5,6,7]

The mobile user presents different and more challenging problems. In this case the requirement is for services wherever the user may be. Whatever the user's location, a ubiquitous system would be expected to provide access to devices and services in the user's environment. For example, if the user wants to access a telephone service, the system might select a fixed line telephone if the user is at home, the user's mobile phone if the user is in town, the user's car computer system if the user is in a car, and so on. Likewise a user's location might be used to select different network options and services when the user is at work from when he/she is at home.

However, the research into fixed smart spaces associated with buildings is generally quite independent of that being conducted on ubiquitous or pervasive systems for mobile users. The result is that one will end up with islands of pervasiveness separated by voids in which the support for pervasiveness is limited. Thus the Smart Home will control devices within it and services it offers the user, but it cannot easily share these with the mobile network of the user or of any visitor. A typical example is that of the use of personal biometric sensors that might communicate with controls for illumination, heating or air conditioning in a room to provide the ideal environment for a user or the best compromise for a group of users.

Persist is a European research project, funded under the Seventh Framework programme, which aims to overcome this problem by developing the notion of a self-improving Personal Smart Space (PSS). The vision of Persist is that a Personal Smart Space will provide an interface between the user and the various services and devices that are available globally and locally (even when no Internet connectivity is available). These PSSs will replace both the fixed smart spaces associated with buildings and mobile ad hoc networks associated with users. These Personal Smart Spaces will interact with one another to create a powerful and flexible environment for the user. Thus, as the user moves around his/her Personal Smart Space may interact with those of other users and/or the fixed PSSs in the user's environment to provide a unique level of support. By monitoring the user's behaviour and using learning techniques, a PSS will be able to improve the services offered to the user by building up and maintaining a profile of user preferences.

The next section elaborates on the nature of these Personal Smart Spaces. In the final paper this will be followed by a section that provides an example scenario and another section giving some more detail on the major contributors.

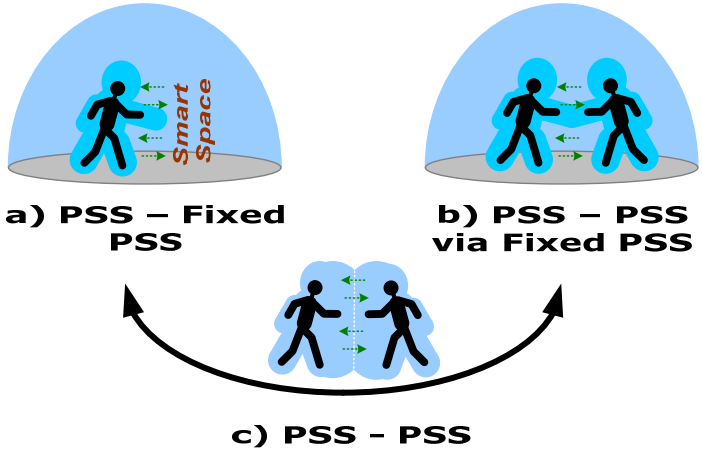

Fig. 1. Interaction between PSSs. a) a PSS interacts with a fixed PSS; b) two PSSs interact via a fixed PSS; c) two PSSs interact without a fixed PSS.

2. Personal Smart Spaces (PSSs)

To understand better what a Personal Smart Space (PSS) is, it is necessary to identify its key features. Consider first the notion of a smart space. Smart Spaces usually target real physical spaces, as in HP's Cooltown project [8]. From this point of view a smart space can be defined as "*a multi-user, multi-device, dynamic interaction environment that enhances a physical space by virtual services*" [8, 9].The services are the means of interaction between participants, objects and the smart spaces.

Another definition describes them as "*ordinary environments equipped with visual and audio sensing systems that can perceive and react to people without requiring them to wear any special equipment.*" [10],. The common aspect in these definitions and most approaches to smart spaces is the focus on infrastructure and sensor-equipped rooms. They neglect the costs of installation and maintenance and the related difficulties to a market entry. If PSSs are to have a wider impact than Smart Spaces they must be enabled to work without sophisticated infrastructure in specially enhanced rooms and to allow for user mobility.

Thus the key features of a PSS are as follows:

(1) A **PSS is mobile** in that its physical boundary moves with the user, and the boundary must be defined in logical terms. Thus, the services in a PSS are defined by reach-ability, and a set of rules defining admissibility to the PSS. This allows the PSS to overlap with other PSSs in a given physical area.

(2) A **PSS has an "owner"**, the person or legal entity on whose behalf it operates. This allows it to maintain a set of preferences of the owner that are used to personalise the PSS, and, by extension, services from another visited PSS, subject to group conflict resolution on those preferences. For example, temperature for a room.

(3) A **PSS must support an ad-hoc environment**, and be capable of operating in both infrastructure and ad-hoc network environments, thereby allowing the widest possible use as an integrator of devices.

(4) Applications within a **PSS must be able to adapt** to the current situation in their environment, through the use of context and preference information as well as privacy, and application management., and react on any notified changes.

(5) A **PSS can learn from previous interactions**. A self improving PSS can learn from monitoring the user to identify trends, and infer conditions for when preference or user behaviour changes are manifested. This allows recommendations to be made when a PSS interacts with a neighbouring PSS, or to act proactively based on reasoning on user intent.

Figure 2 shows the major contributors to the PSS. The PSS operates over many devices (D1,D2,D3,…) covered by a network layer that provides the abstraction from the underlying networking technology as well as mechanisms for auto-configuring transport addresses, and routing between devices. Above this an abstraction is needed to allow services to address named nodes, without caring about multiple transports available in the network infrastructure. Some middleware services are also needed to support the basic decision making and operation of the PSS, such as management of context, preferences, privacy and services .

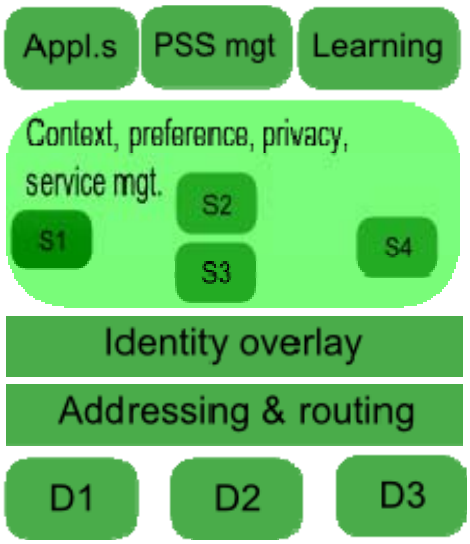

Fig. 2. The major contributors to a Personal Smart Space.

An application service may interact with any of these “enabling” services and make use of context, preference, and trust information. By monitoring user interactions with these services, it is possible to learn when application services are started, or stopped or when a user changes an application preference. This learnt behaviour can be used to improve user preferences and enable proactive actions.

A PSS is then defined as a digital representation of an environment which includes devices and services, context information, user preferences, and a set of behaviours

that define what it is possible to do with the PSS, and governs interactions with other PSSs. A self improving PSS is one whose governing behaviour is augmented with learning and reasoning techniques to improve preferences and support proactive decisions to be made on behalf of the user

3. Conclusion

Self-improving Personal Smart Spaces are a new vision for ubiquitous or pervasive computing that enable a more powerful and flexible environment for the user and one which is more truly ubiquitous. This paper explores this new concept, its key features and the major contributors that will realise these.

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