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Deploying Pervasive Technologies

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INTRODUCTION

Communication technologies are currently addressing our daily lives. Internet, fixed-line networks, wireless networks, and sensor technologies are converging, and seamless communication is expected to become widely available. Meanwhile, the miniaturization of devices and the rapid proliferation of handheld devices have paved the path towards pervasive computing and ubiquitous scenarios.

The term *ubiquitous and pervasive computing* refers to making many computing devices available throughout the physical environment, while making them effectively invisible to the user (Weiser, 1991). Thanks to advances in the devices' processing power, extended battery life, and the proliferation of mobile computing services, the realization of ubiquitous computing has become more apparent, being a major motivation for developing location and context-aware information delivery systems.

Strongly related to ubiquitous computing is *context-aware computing.* In context-aware computing, the applications may change or adapt their functions, information, and user interface depending on the context and the client's profile (Weiser, 1993). Many research centers and industries are actively working on the issues of context-awareness or more generally on ubiquitous computing (Baldauf, Dustdar, & Rosenberg, 2007). In particular, several proposals focus on smart spaces and intelligent environments (Harter, Hopper, Steggeles, Ward, & Webster, 1999; Kindberg et al., 2002; Smart-its, 2007), where it is expected that smart devices all around us will maintain updated information about their locations, the contexts in which they are being used, and relevant data about the users.

Clearly, contextual services represent a milestone in today's mobile computing paradigm, providing timely information anytime, anywhere. Nevertheless, there are still few examples of pervasive computing environments moving out from academic laboratories into our everyday lives. This occurs since pervasive technologies are still premature, and also because it is hard to define what a real pervasive system should be like. Moreover, despite the wide range of services and potential smart applications that can benefit from using such systems, there is still no clear insight about a realistic killer application.

BACKGROUND

Pervasive computing has been in development for more than 15 years. In this section we briefly review some of the most relevant prototypes.

Various companies are already working to extend wireless technologies that will seamlessly connect to other nearby devices. However, despite the wide range of services and potential smart applications that can benefit from using such tools, there is still no clear understanding about a realistic killer. One critical question that still needs to be addressed is the identification of business scenarios that can move ubiquitous computing from academic and research laboratories into our everyday lives.

Tourism was one of the first areas to yield the business application area for the development of such potential applications. To this end, context-aware services combined with content-oriented applications could exploit wireless technology to provide personalized tours that could guide and assist tourists in museums or historical sites. One on the earlier prototypes of a mobile context-aware tour guide is the Cyberguide project (Abowd et al., 1997). The Cyberguide prototype uses the current location of users to provide visitors with services concerning location and information. For indoor applications, Cyberguide uses infrared technology as a positioning solution. On the other hand, for outdoor applications, they replace the infrared positioning module with a GPS unit. Cyberguide presents an innovative architecture, which mainly focuses on the development of location-aware applications. However, further efforts are needed to improve on context awareness. Systems similar to Cyberguide have also been proposed by other researchers, including the GUIDE (Davies, Mitchell, Cheverst, & Blair, 1998) project proposed at Lancaster University. Cyberguide and GUIDE were influenced by earlier location-aware works such as the PARCTab at Xerox PARC (Want, Hopper, Falcao, & Gibbons, 1992), the InfoPad project at Berkeley (Long, Kooper, Abowd, & Atkeson, 1996), and the Personal Shopping Assistant at AT&T (Asthana, Cravatts, & Krzyzanouski, 1994).

The CoolTown project (Kindberg et al., 2002) at HP Laboratories focuses on building ubiquitous computing systems by embodying Web technologies into the physical environment. The Websign project (Pradhan, Brignone, Cui, McReynolds, & Smith, 2004) is a component of the CoolTown research program which allows users to visualize services related to physical objects of interest. While Websign could be adapted to offer tourist guide services, its intended use is more general, providing user interactions for services associated with physical objects. The Rememberer tool (Fleck et al., 2002) is another interesting approach, which, similarly to the CoolTown project, chooses museums as an environment to implement context-aware applications. Rememberer is a tool that offers visitors of museums services to record their visits. Each record, which can be consulted after the user's visit, consists of a set of Web pages with multimedia data describing the visit. The location of the visitor is identified using infrared technology and RFID sensors. Other works related to the CoolTown project include Spasojevic, Mirjana, and Kindberg (2001) and Semper and Spasojevic (2002).

The Digital museum project (Sakamura, 1998) at Tokyo University uses smartcards to detect the proximity of visitors and then provide information about the exhibited objects. The information provided can be based on a static profile stored previously in the smartcard. Similar work has also been done by Davin and Ing (1999) where infrared infrastructure and wireless LAN connections were used for connectivity and location awareness respectively.

Cano, Ferrández, and Manzoni (2005) used a network simulator to evaluate the feasibility and performance of using Bluetooth as the underlying networking technology to establish context-aware services. They compare results obtained from simulation with those obtained from a real test-bed. Authors observed that simulation results show a much smoother behavior than those obtained in real experiments.

The Massachusetts Institute of Technology (MIT) has a project called Oxygen (Rudolph, 2001). They envision a future where ubiquitous computing devices are as freely available and easily accessible as oxygen is today.

More recently, many of the ubiquitous and pervasive proposals are characterized by their focus on real-world deployments. In fact, some of the most valuable experiences when dealing with pervasive systems come not only from the design and implementation of a particular system, but also from the experience of trying to move those systems out of the laboratory into the real world.

Thomas, Jakob, and Mads (2006) create an interactive and pervasive system to be used in hospitals. The authors highlighted how issues that seem to be trivial in the laboratory, such as calibrating location systems or finding places for interactive displays, might become major obstacles when deploying systems in real-world settings. Other interesting works related to smart and interactive spaces can be found in Fitton et al. (2005) and Oliver et al. (2006).

Overall, we can state that, although new technologies are emerging and a number of leading technological organizations are exploring pervasive computing, the most crucial objective is not necessarily to develop new technologies, but to find ways to integrate existing technologies with a wireless infrastructure.

EXPERIENCES ON DEVELOPING PERVASIVE SERVICES

Next we present our vision on ubiquitous computing by reporting our experiences building the BlueHospital system, a pervasive prototype that provides context-aware information and location-based services to clinicians on hospitals' recovery wards. BlueHospital leverages Bluetooth technologies and Java services to offer patient information to clinical personnel based on the patient's profile and the clinicians' preferences and requirements.

When developing a suite for a pervasive computing system, two main lessons were confirmed from our previous experience. First, we require a low-cost solution that offers computation and communication capabilities to an ordinary object. Second, minimizing power consumption and size are mandatory in order to make more apparent the realization of ubiquitous computing. To this end, we developed our own inexpensive platform prototype for ubiquitous computing, which has been implemented based on commercial off-the-shelf components.

The overall network architecture is based on the cooperation of an edge wireless network and a core wired network. The edge part is based on Bluetooth technology alone. The core network is based on a fixed 100 Mbps Ethernet local area network used to connect the edge infrastructure with the central database.

The system considers four types of entities: hospital patients (BH_Patient), room managers (BH_Room_Manager), clinical personnel (BH_Doctor), and the central database server (BH_Database_Server). Figure 1 shows a pictorial representation of the BlueHospital architecture.

A doctor provided with a Bluetooth-enabled PDA is the basic example of a mobile BH_Doctor entity. BH_Doctors are connected to the central database through the room man-