

Augmenting Offices with Ubiquitous Sensing

Jean-Marc Andreoli, Stefania Castellani, Antonietta Grasso, Jean-Luc Meunier,
Martin Muehlenbrock, Jacki O'Neill, Francois Ragnet, Frederic Roulland, Dave Snowdon

Xerox Research Centre Europe

Firstname.Lastname@xrce.xerox.com

Abstract

The advent of the ubiquitous computing era was predicted and outlined a decade ago, however it is only with the recent developments of an affordable enabling infrastructure, that its potential to transform daily life is starting to be understood. In this paper we present a day in the office of the future, in a not too distant future, and we then outline a sensing infrastructure and services that we are implementing at XRCE to enable it.

1. Introduction

Mark Weiser developed the concept of Ubiquitous Computing for the first time a few years ago: he envisioned a new computing era where computational and communication power was available in devices and objects of every size and purpose [1]. Since then many projects have been studying some of the potential of such ubiquitous infrastructure in the work environment. For example, analyzing what could be done with devices that were able to locate themselves and to make available this information to provide office services, such as contacting people outside the office; or having the infrastructure record every activity carried out, either on the desktop or away from it, in order to be able to retrieve documents by recalling the specific context in which the document was used, be it an email or a chat in the corridor [3]. Since these research projects two main things have happened: the technology has improved in terms of costs and reliability, and application designers have started some reflection around how such technology should support the everyday work of its users.

As in many emerging fields, there is the risk of being technology driven and forgetting issues like privacy, complexity of the infrastructure and services, and smooth integration with work practices [12]. In the work that we are doing at XRCE we are developing scenarios that are used as a design base with the work practices experts and we are building in parallel the required sensing infrastructure on technology that is easy, cheap and preferably already in place as basic office computing set-up.

In this paper we present the scenario that has driven our work, and we then outline the sensing infrastructure and services that we are assembling at XRCE to enable it.

2. A long day in the augmented office

John is an IT consultant in a fast growing company; he is working on an offer for a customer to create a new version of their external web site, which should be based on Xerox DocuShare™. In the preparation phase he would like to collect as much information as possible on similar offers, in order to benefit from the work done by colleagues on similar cases and keep his offer consistent with the company strategy. However,

he and his team work under very tight constraints and have no time to actively look for background information on previous offers.

He starts to work on the proposal by reviewing the existing products that could be used for the construction of the web site. While doing this he needs to print some of the technical information, in order to read it carefully and annotate it. When he goes to the printer several documents are sitting around the printer from people on the same floor, but *he can instantaneously find his one*, because it contains a RFID tag that is recognized by his PDA and it is used to provide services related to the document even though it is not digital. He picks up his document and waves it in front of the printer's RFID reader to check if any similar documents have been recently printed on that topic. The large screen attached to the printer then displays information about other activity in the group that is relevant to the current topic. In particular *the screen highlights that a colleague in the same unit was printing the same technical documentation; the screen also shows a map of the office, highlighting where the colleague is located and if he is in*. Given that is not too far, John decides to take a slightly longer way back, to have the possibility to have a chat with the colleague. As he approaches the office, the door display starts blinking, *showing that the colleague is in the office and might be interruptible*, because the agenda does not show imminent meetings, and his currently sensed activity is not critical. John puts his head in his colleagues' office and starts a quick chat, discovering that the colleague not only has plenty of technical knowledge about the latest version of DocuShare, but has been recently working on a similar proposal for another company.

A few hours later, John is working on the latest version of the highly confidential contract he is going to submit to the customer. Apparently the initial proposal has been well received and he is busy finalizing it. He prints it for a review and approval meeting with his manager and some time later he walks to the printer on his way to the meeting.

But a surprise awaits him! Arriving at the printer, he finds it busy printing a very large document from Margot. Also, several other jobs are in the print queue. He can't tell how important all these jobs are, but it is clearly going to be quite a while before they are all done. However *the system offers him the opportunity to negotiate with Margot and possibly with the other users whose jobs are in the queue*. He presses the interrupt button on the printing device, thus initiating the negotiation. Margot's smartphone rings. John and Margot are immediately connected and he quickly explains his problem. Margot checks the current status of her own job and figures that she cannot suspend the job and print the rest later, after the other users in the queue. The printer then starts negotiations with other printers in order to find a suitable solution. *It proposes to Margot to split her job into two parts,*

one performed on the current printer and the other part to be performed on an idle printer, which is close to the room where Margot is going to go to attend a presentation, according to her agenda. Margot agrees to the proposed solution and then John gets his document and leaves to go to his meeting. After he leaves the printer resumes processing the normal print queue, while the second part of Margot’s job is printed on the other printer identified earlier.

John is now out of his meeting where the latest changes to the contract have been approved. The day has been long, but fruitful, and he can sit on the lounge sofa, equipped with the latest issues of technical and financial magazines, as well as with a large screen showing the latest news and some information about what the other teams in his unit are doing. The screen also shows images from another location where his colleagues work. That area is a service room, where there is also a multi-functional printer and many people pass there during the day. Someone is now approaching on the other location to collect a job. It is Mary.

In the meanwhile John is busy reading, however, his PDA reminds him that he wanted to ask an administrative question to Mary, about the new contract. He can walk to the screen and initiate the conversation straightaway, because he knows from the system that she usually does not feel disturbed when someone asks her a videoconference while at the service area. As they start talking, the printer suggests relevant documents that Mary can select to display on the large screen or print on either side, in support of the current discussion.

3. What to sense

A context-aware scenario like the one above, requires the capability to “sense” the context of usage, in order to provide timely information about the environment and support the users in making decisions and to act on the basis of the current situation. The notion of “sensing” denotes any means used to obtain information about the user’s current situation including sensing the actual physical environment and, accessing on-line information about users and devices.

If we look back at the scenario, the main classes of entities that can be dynamically characterized are people and objects (mobile as well as static devices, but also other objects like documents). Moreover information can come from the physical environment, but also from the digital one, e.g. sensing by software that a person is busy typing on his laptop. A list of what is sensed to support our scenario is presented in the following:

1. People
 - a. Instantaneous information like the location, and the current activity;
 - b. Demographic information, including identity;
 - c. Historical information including preferences, records of previous actions, content of the agenda.
2. Objects
 - a. Mobile devices
 - b. Static devices, including printers and large screens
 - c. Documents

In the following table we present the details of what is required to be sensed, for each relevant functionality highlighted in the scenario.

Scenario Functionality	Required capability
Locating a document at the printer	<ul style="list-style-type: none"> ▪ Identifier on object ▪ Reader of identifier on PDA
Recommending work from colleagues in relation to the current document	<ul style="list-style-type: none"> ▪ Identification of presence and identity of users nearby the printer ▪ Tracing of document activity of colleagues
Showing presence and availability of people	<ul style="list-style-type: none"> ▪ Identification of location of users ▪ Sensing of planned diary information ▪ Sensing of actual user context
Negotiating printing services	<ul style="list-style-type: none"> ▪ Exploration of negotiation alternatives ▪ Coordination of negotiation decisions among users and objects ▪ Sensing of planned diary information ▪ Identification of presence and identity of users around the printer
Provision of news about activities going on in the organization	<ul style="list-style-type: none"> ▪ Identification of presence and identity of users nearby the large screen ▪ Tracing of document and communication activity of colleagues
Support for intended short interactions across sites	<ul style="list-style-type: none"> ▪ Detection of intention to interact ▪ Identification of presence and identity of users nearby the large screen ▪ Discovery of surrounding communication means

Table 1: Mapping functionality to requirements from the sensing infrastructure

4. The Enabling Sensing Technology

Information in the physical world is gathered by dedicated sensors, which can be embedded in the environment, on the user’s clothes or in the user’s PDA. We believe it is important to combine multiple sensor outputs in order to increase the accuracy and the reliability of the whole sensing infrastructure. The combination of an infrared sensor, a keyboard sensor and sound sensor determines more reliably people’s presence than each separately.

We briefly review in the following sections a setup that we are currently putting in place at XRCE and that fits the needs of the proposed scenarios. In this set-up, we provide the users with a PDA with wireless network access. Computer-user interactions are detected with several granularities (from typing to classifying actions on documents and other information structures like agendas) as they occur on the desktop computer or on the PDA, either in connected or disconnected mode. The PDA also provides Bluetooth services and RFID reading.

4.1. The wireless LAN

Wireless LANs are becoming more and more widespread, despite their current security weaknesses. A wireless LAN

requires installing one or more access points, which act as a bridge between the wired and the wireless networks. With additional redundant access points, a location system can be obtained as a by-product of the wireless LAN, by triangulating the radio signal [4][5]. Places are then identified by their radio characteristics in a so-called calibration phase. Later on a device can locate itself by measuring the current radio characteristics and comparing them with calibration data. Both locating and tracking are possible with this technique, depending if it is the device that computes its location or some server part of the infrastructure. Figure 1 shows the position of the network access points in a floor of our lab, where the accuracy is at the room level with a reliability of about 80%. The network card increases the PDA power consumption but the adaptor provides an additional battery to compensate.

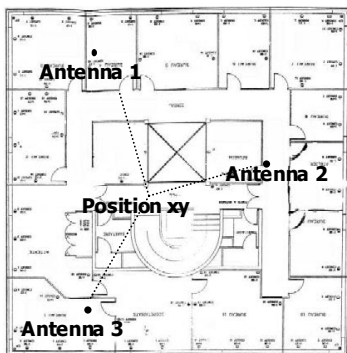


Figure 1 - The wireless location system

4.2. BlueTooth technology

Many devices now have built-in BlueTooth support, i.e. device discovery and short range low-power wireless connectivity. A printer can for instance use it to monitor people's presence in its surroundings, assuming they have their PDA with them. Conversely, a PDA may discover nearby devices and deduce its own probable location from a database of the positions of fixed devices in the building. Complementing the wireless LAN location system is important either for increasing accuracy on the WLAN-covered area or for determining PDA's location other areas, where by the way BlueTooth can also provide network connection thanks to BlueTooth network gateways.

4.3. Active RF technology

The Radio Frequency Identification (RFID) technology provides the ability to read/write to/from small cheap tags in a contact-less way. These tags come in different shapes, color, capacity and, are small enough to be embedded into paper or even under the skin of your forearm. Tag readers can be attached to handheld devices as well as embedded in a table or a door frame.

In our case, we equip the user's PDA with a RFID reader and attach tags to various objects, including printers, desks, displays, doors, and documents. Moreover, documents can be printed on tagged paper, allowing the printer to associate on the fly the document, or its reference, with the tag of the paper sheet.

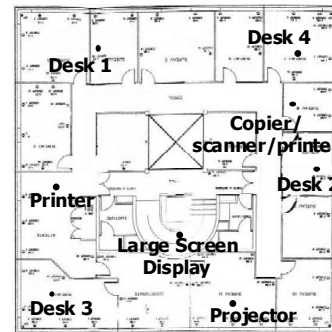


Figure 2 – The RF infrastructure

4.4. Digital sensing

Sensing the user activity on a personal computer is an important and easy source of information. Keyboard typing, mouse movement, stylus uses are for instance good indicators of presence or activity, as demonstrated by communication tools like ICQ [7]. Phone usage can similarly be sensed by software connecting to the phone exchange.

However sensing spans several levels of abstraction. The one about immediate level of activity is the basic one. Other forms of sensing required in our scenario include the activities a person is involved in at a specific moment and more in general the activities that are planned in a given temporal range. In our set-up we sense the current activity in the case of the printing, by capturing the document and analyzing its content as described in [8]. On the other side, having a global picture of the user activities, the agenda content is exploited. It should be noted that this sensing relies on data which are punctual, i.e. the current manipulated document, the current content of the agenda. In our set-up we collect as well the information about the digital activity, in order to learn about the user and be able to make inferences.

5. The enabling services

The scenarios in the first section presented a number of services that smoothly interleave with the main activities of John, to enhance and facilitate his daily work. This functionality mainly acknowledges that plenty of the activity in a work office is based on activities that cannot be planned in advance in their detail. John did not know in advance that someone else would be printing when he was in a hurry, John did not know in advance that a colleague would be giving him suggestions for his proposal; John could not have planned in advance that Mary was crossing him (even if at distance) precisely when he needed her. All of these unplanned events are either opportunities or problems, and the ubiquitous system is in the background to exploit or address them. What really matters is that they have to be interleaved with the daily activities, and a sensing system is required to support them at the moment of need. These services are presented in the rest of the section in more detail.

5.1. Historical Information and notification of activities at awareness points

Historical information permits the system to personalize its service, for instance learning that someone doesn't refuse impromptu video interactions when in the service area.

It also permits the building of a profile of a person, for instance recording what technical documentation was printed by a person may tell about her expertise or center of interest [8].

5.2. Collaboration driven use of shared resources via negotiation

Negotiation mechanisms permit the handling of situations where a consensus has to be reached across a number of possibly distributed decision-makers, with different goals, on how to perform a given task with a limited number of resources. For example, in our scenario, changing the order of print jobs order in a printer queue requires a number of interactions among the involved users and printers in order to have them reach an agreement on how to print the users' jobs given their deadlines.

The involved users should be provided with the ability to explore concurrent alternatives for reaching their goal, e.g. should the job be printed as a block on a given printer or split it into two parts. Users should be able to make informed decisions providing them with contextual information, e.g. the agenda of the meeting. Once a decision is made, the corresponding actions should be performed in a coordinated way among the participants, e.g. if a job is reallocated to another printer, the users and printers involved should be notified and the job transferred. These features are provided by a middleware framework we are developing for modeling and supporting negotiation based interactions among users and objects [9].

5.3. Facilitation of unplanned interactions

In an office environment, unplanned interactions play an important role in the exchange of information as well as the social cohesion of a group; one must not neglect their importance as they are often instrumental to the organization [11]. In contrast to simply spontaneous encounters, opportunistic meetings occur because someone had the intention to talk to another person but did not set up a plan to meet [10]. However, there always is the danger that the encounter does not take place and that the issue falls into oblivion. Facilitating them firstly includes facilitating their happening, by alleviating people from the hurdle of finding out an appropriate time and place while taking into account each other's constraints and activities. The difference here with making a rendezvous is the deep interleaving with current ongoing activities so as to support the setting-up of an interaction in near real-time. Secondly, these interactions should be supported in-situ and in an ad-hoc manner as they cannot be logistically pre-arranged either. For instance, by discovering surrounding devices, such as printers or screens, that may support the interaction by providing a convenient access to relevant documents. Finally, putting in perspective series of such interactions helps users to better articulate their work, for instance by reminding them of previous related interactions with the same people or same topic.

6. Summary

In this paper, we have presented our vision of how ubiquitous sensing and computing can concretely support office workers in a foreseen near future. We have then outlined the sensing technology we are currently setting up at XRCE.

The work that is currently going on for the provision of the described services is twofold. Firstly we rely on the STITCH [13] and Xplore [9] middleware to enable our scenario. STITCH allows us to loosely couple small devices and to coordinate all components and services, while Xplore supports negotiation around use of resources. Secondly, we are defining a context model that will be at the heart of each service and will permit to abstract from low-level sensor outputs. Finally, we challenge our scenarios by submitting them to work practice experts that help in making them both usable and innovative. In summary we believe that ubiquitous computing design has to gather contributions from all these fields in parallel: middleware and sensor infrastructure, contextual abstraction and work practice validation.

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