Sm@rtLibrary – An Infrastructure for Ubiquitous Technologies and Applications

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Abstract

This paper presents our ongoing research on the potentials of ubiquitous technologies for future workspaces. The Sm@rtLibrary serves as a test and demonstration environment for ubiquitous technologies and their application. In this area we are currently concentrating on localization and location management technologies, context-dependent services, platform and device independent access to the services and information provided in such environments.

1 Introduction

Cooperative Rooms (COR) stand for flexible and dynamic future workspaces, in which real and virtual work environments are seamlessly integrated [1]. Cooperative Rooms is also the title of an interdisciplinary research and development program of GMD-SIT in collaboration with partners from research and industry. It is located at the intersection of information technology, work organization and architecture and takes an integrated and interdisciplinary approach to developing future work environments. Its objective is to design, develop and investigate future workspaces by bringing together information and communication technology, architecture, design and management of buildings, and new flexible forms of individual and joint work.

COR proposes the paradigm of a boundary-less office space, where physical and virtual offices seamlessly blend together, where a transparent infrastructure for both wireless/mobile and wired communications is provided and where resources of real and virtual offices are managed and utilized concurrently and efficiently. It dynamically links people, their tools, and physical workplaces, wherever they happen to be (on company premises, on the move, or at home), while keeping the focus on the context of collective work.

Project team members are working as individuals and from time to time as (sub)groups in physical workplaces with a set of stationary or mobile physical objects. Since physical workplaces tend to be non-territorial, which means that they are used as common resources at different times by different people, they have to provide simple means for locating and controlling their physical objects and adjusting their services to a given work context.

On this behalf, we are equipping physical rooms with the necessary intelligence to give access to the full set of their services. The central component is a so-called RoomComputer [2].

In COR, innovative work environments are not only developed but also used and evaluated in everyday work situations. The field trial area to test and use in practice both COR results and related third-party results is called ScienceClub (SCLUB). It also serves for demonstration purposes and to generate feedback to the research activities. The SCLUB is typically designed as an advanced Business Club in order to increase the productivity of highly skilled and qualified researchers and R&D project teams, and to save cost through an optimized use of physical space and resources. It offers non-territorial workplaces and re-configurable work areas, which can be tailored to different needs and kinds of activities, such as zones and rooms.

This paper presents our ongoing research on the potential of ubiquitous technologies for future workspaces. The Sm@rtLibrary represents a section of the SCLUB and serves as a test and demonstration environment for ubiquitous technologies and their application. In this area we are currently concentrating on localization and location management technologies, context-dependent services, platform and device independent access to the services and information provided in such environments.

2 Sm@rtLibrary

An employee or visitor enters the library. This is automatically sensed by the room. The library user takes one of the freely available Sm@rtAssistants, which is a flexible

webpad with an integrated radio based identification device (so-called RFID-reader) and has wireless access to the local network (by using wireless LAN or Bluetooth). By approaching the Sm@rtAssistant with his/her digital office ID card, the webpad's user interface is personalized automatically to the needs and preferences of the user and his possibilities based on his current location. Within the Sm@rtLibrary, the user might want the library to meet one of the following requirements.

New Arrivals

The user might be interested in the books, CDs, and videos that are new to the library since his/her last visit. Of course only items of personal interest should be shown to keep the complexity as low as possible for the user. To meet this requirement the Sm@rtAssistant can be personalized (see section 3).

Reservation of books

Often it is more comfortable to browse the inventory of the library online from an arbitrary location. If the user finds some interesting books, he/she would like to reserve these books from the library to pick them up later. Again personalization of the library access is necessary in order to simplify the handling. To assist the user in picking up the reserved books in the library itself, a schematic overview of the library is shown and the position of the book is marked.

Figure 1: Position of a Book

Browsing the library

Sometimes it is convenient to go to the library and browse through the shelves. Finding a book, the user might be interested in books with similar topics, other books from the same author, reviews done on that book by colleagues or even from the internet (e.g. from amazon.de), or the common topic of the books in that particular compartment of the shelf. To get access to this kind of information the book's Sm@rt-Label (see section 4.3) can be scanned with the Sm@rt-Assistant. Of course only information that meet the needs of the user are shown, since the Sm@rtAssistant is personalized as already mentioned.

Figure 2: Additional Information

Borrow and return books

A book can be borrowed or returned on the spot directly by the user unless there is a reservation for that particular book. All the necessary steps can be done with the personalized Sm@rtAssistant. Because the location of the device is available, the application can distinguish between borrowing/returning a book (within the library) and passing on the book and offer the appropriate user interface.

Favorites

Users tend to borrow books from the library sometimes just to forget about them. Piles of books can be found on their desks while others need those books and are looking for them in the library in vain. To tackle that phenomenon users can keep a list of their favorite books while browsing the library either remotely or physically using a desktop PC or the Sm@rtAssistant.

Notes and reviews

While browsing the library or working with a book the user might want to take notes on a book or write a review, either just for himself/herself or also for colleagues. This can be done remotely or while being in the library.

Passing on a book

Library users might want to pass on books directly to a colleague without prior return to the library. A Sm@rtAssistant can be used to identify the book and to change the person currently borrowing it anywhere in the networked building. Because the location of the device is available, the application can distinguish between borrowing/returning a book (within the library) and passing on the book (outside the library).

3 Context Awareness

The description of the scenarios above shows that the Sm@rtAssistant uses a lot of context-sensitive information. The applications are adapted using location, object, and user specific context information. These are described in detail below.

Personalization

The Sm@rtAssistant can be used by anyone in the library. To be able to adapt the application to the needs of the user, personalization is necessary. In contrast to location information the identity of the user has to be determined only once during a session. This is achieved reading information from the user's office ID card (OIC, see section 4.2).

Location information for devices

To adapt the user interface of the Sm@rtAssistant and the information shown on its screen according to its current location, the location of the device has to be accessible by the applications. This information is made available by the RoomComputer's infrastructure (see section 4.1)

Because the device is personalized, it would be possible to detect the location of a particular user while using that device. Due to privacy and security reasons this information can only be accessed by trusted applications (see section 5).

Location information for books

To find a book it is necessary to locate it within the library's shelves. This information is provided by the Sm@rtLibrary infrastructure using the sensors integrated into the shelves (see section 4.4).

Object identification

To be able to deliver arbitrary information on some object it is necessary to identify it. To achieve a sure identification every item in the library has to be equipped with a Sm@rtLabel, which can be identified using the RFID readers attached to the Sm@rtAssistant and the shelves (see section 4.4).

4 Sm@rtLibrary Components

The Sm@rtLibrary project with its Sm@rtAssistant is supposed not only to simplify the routine work in a library. It also serves as a living research and development environment within which we are investigating which infrastructure is necessary for ubiquitous applications in order to guarantee the necessary security and privacy of the user. The Sm@rtAssistent is a context-dependent, ubiquitous application, that is based on the Sm@rtLibrary infrastructure, which itself is based on the RoomComputer (see section 4.1).

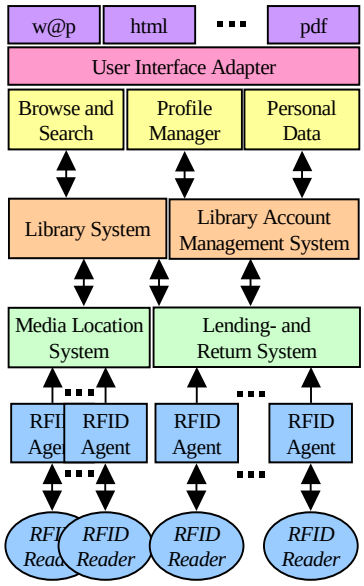

Figure 3: Sm@rtLibrary Components

The Sm@rtLibrary consists of different components (see fig. 3), one of that is a traditional library application with a Web-Browser interface for the management of the stock of books. The borrowing and return processes are managed by the Library Account Management System.

For the optimization of the processes and workflows in a small, internal library the library was equipped with modern technologies. All books have a Sm@rtLabel, which contains a reference number to support the identification of the corresponding book in addition to a traditional signature on paper-basis. The bookshelves are equipped with RFID-antenna and reader comprehensively so that it is possible for the Media Location System to localize books in the shelves. Books can both be borrowed and returned at specific terminals (Lending and Return System) or by using the Sm@rtAssistant. These contain an RFID reader, which can read both the Sm@rtLabels and the digital OIC (see section 4.2), by which the library user is identified and authenticated. When a book is returned, the identity of the person returning it is irrelevant, so user authentication is not necessary and is not performed.

4.1 The RoomComputer

One of the objectives within COR is to make it possible to monitor, control, and manage both old and new buildings on a unified worldwide platform, irrespective of any particular local technology. The RoomComputer creates the preconditions for locating, adjusting and administering physical objects such as rooms, equipment, and other resources in a given work context. It implements a distributed application, which provides services like Control of light, heating, ventilation, air and climate, Reservation of rooms and required resources, and Localization of persons and objects within rooms and buildings [2].

The RoomComputer is an autonomous installation unit (typically located in the doorframe of the room), which is connected to the Intranet/Internet. It is based on an embedded PC and can be equipped with a touch sensitive LCD display as local interface. A smartcard reader, and RFID-readers are being attached to it.

It provides a flexible distributed framework architecture implemented by means of JAVA and Web technology, which can easily be tailored to the needs of its users. Through a standard Web-browser any RoomComputer can be accessed remotely in the same way as locally.

4.2 The digital office ID card

The digital office ID card (OIC) used within our project was developed as a prototype of an ID card for members of German ministries and public service and is based on smartcard technology. It has been specified in [3].

The OIC was developed to replace traditional paper/plastic ID cards. Therefore it contains data about its bearer, such as name, first name, date of birth, citizenship, ID number, and validity period. Another important feature of the OIC is that it implements the German/European law for issuing digital signatures. Other security-related functions like authentication and encryption are as well included. Additional information about the bearer includes access rights and roles he/she has within the organization.

Our implementation of the OIC prototype is based on Philips' Mifare Pro smartcards with a file based smartcard operating system according to ISO 7816-4 and has two interfaces: contact and contactless. This dual interface

technology enables secure operations via the contact interface, such as digital signatures, and comfortable operations like identification and micro payment via the contactless interface.

4.3 Sm@rtLabels

In the Sm@rtLibrary a Sm@rtLabel is being attached to every book and every magazine, usually on its cover. Sm@rtLabels are based on I-Code tags from Philips with a 512 bit read/write memory operating at 13,56 MHz [4][5]. The maximum operating distance from the antenna to the smart label is 1.2m. The I-code label itself is 80x50mm^2 in size and self-adhesive. The labels do not need a battery, as they are powered by the electromagnetic field of the antenna [13].

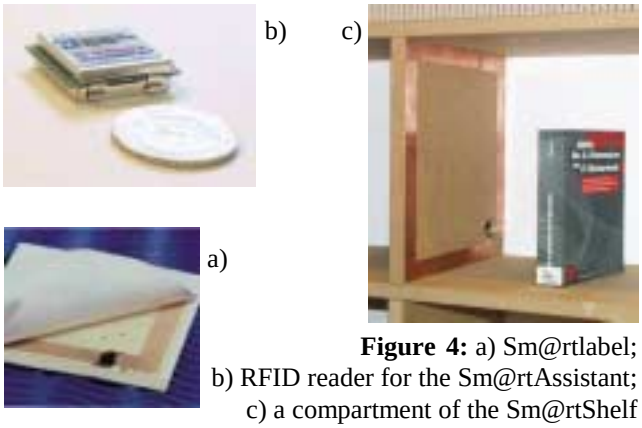

Figure 4: a) Sm@rtlabel; b) RFID reader for the Sm@rtAssistant; c) a compartment of the Sm@rtShelf with integrated antenna

4.4 RFID readers

The Sm@rtLibrary project uses three types of readers for the Sm@rtLabels: one that is attached to the Sm@rtAssistent, an antenna and reader especially designed and developed to fit into a bookshelf, and an antenna and reader that fits into a door frame capable of identifying persons and objects entering or leaving the corresponding room.

The reader attached to the Sm@rtAssistant is low in power consumption and small in size. The reading range of this reader is approx. 0.1m and does not provide collision detection. The RFID readers integrated into the shelf do support fast collision detection and have a reading range of approx. 0.5m to cover the size of one shelf compartment. The antenna and reader integrated into the doorframe have a reading range of approx. 1.0m to cover the width of a door. Collision detection as well as the support of both protocols, Mifare Pro and I-Code, is integrated.

5 Software Architecture

The main objective for the development of the Sm@rtLibrary was to implement a flexible and scalable software architecture which allows for the easy integration of different types of context-based information and would be able to represent that information in a manner, which is independent of the particular end-user. For this reason a layered context architecture has been implemented (see fig. 6). Independence from end-user devices has been achieved by use of JAVA and XML technology.

A Sm@rtAssistant consists of an RFID agent that collects and processes the sensor data and transmits it to the User Agent. The User Agent controls the Presentation Agent, which consists of a standard component, for example a Web-browser. Via the User Agent the Presentation Agent requests information about the identified object from the Information Server and supplies the necessary information about the particular end-user device being used.

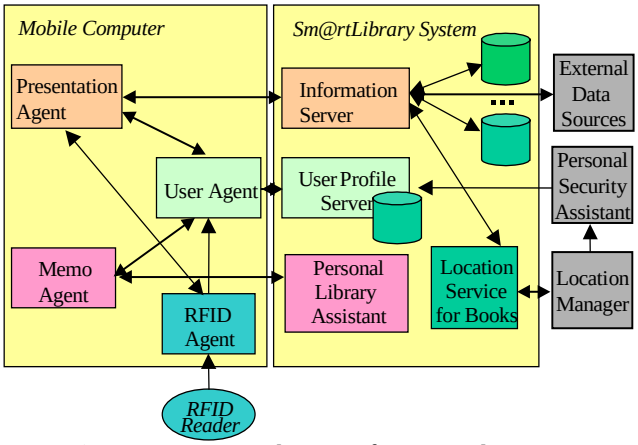

Figure 5: Sm@rtLibrary Software Architecture

On the basis of the present context the Information Server determines information, which was requested and returns this to the requesting client in a format which is suitable for the particular end-user device. The requested information can originate from different databases, the Location Services or from any external information sources.

Layered Context Architecture

Every sensor has its own agent that collects the sensor data, processes it and transmits the extracted information to the next higher layer. Dependent on the kind of sensor, the sensed data can either be reported continuously to the agents or requested by the agent when needed.

The next higher layer is the Context Manager. It collects the data from the different sensors, that are either be transmitted by the sensor agents or by processing layers between. The different data are processed, combined and provided to the context-dependent applications by a standardized interface. In this way, they are freed of the necessity for compiling and aggregating detailed context information.

Processing layers are necessary for the location data. For reasons of privacy protection the location data of persons are not being transmitted directly but stored in a protected manner and only be passed to authorized applications. For example, if a person enters the library, the corresponding agent passes this information, together with the information that "objects" carrying Sm@rt-Labels are "entering" or "leaving" a room to the Location Manager. By the identification of the corresponding ID's and depending on whether it is a person or an object, the Location Manager performs an action. The Location Manager stores location information about persons in a secure way, i.e. protected by means of cryptography. This encryption means that the information can only be decoded under specific circumstances, e.g. theft, fraud suspicion, according to the 4-eye-principle. However, in order to be able to provide the information about the location of a person to specific applications, this information is passed to a person's Personal Security Assistant (PSA). The PSA is an application, which runs in a protected environment and is exclusively under control of the respective person. A person can configure their PSA and decide which sensitive data will be passed under which circumstances to which persons or applications.

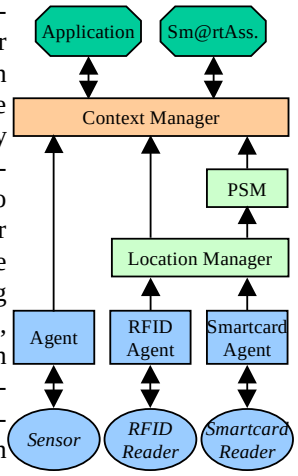

Figure 6: Context Architecture

This layered architecture for context information has the advantage that the collection, processing and aggregation can be separated from each other. This allows a high degree of flexibility to be achieved. The addition of further sensor data or processing steps is always possible without problems, not affecting existing parts.

Independence of End-user Devices

From our point of view, beside personalized services, a major design goal of every ubiquitous application should be an extensive platform independence and an automatic adaptation of the user interface with respect to the end-user device (e.g. PC, Handheld, PDA, mobile phone) being used. Because of the fact that all services should be accessible from different end-user devices based on different hard- and software platforms the user interfaces have to be flexible. This can only be achieved by the use of widespread standards and technologies.

The Internet with HTTP and TCP/IP as the basic protocols, Web-servers providing access to information and services and the Web-browser available on almost every platform provides a widespread infrastructure. In our case XML serves as a description language for user interfaces and contents with the objective to obtain independence from end-user devices. The combination of Web-servers together with XML allows for a device independent preparation of information to be presented to a user. With suitable Stylesheets this information can be adapted easily to the specifics of a particular device or browser.

6 Related Work

The usage of RFID tags as an enabling technology for ubiquitous computing has already been investigated in other research projects. For example, Langheinrich et al. implemented a context-aware recipe finder [21], Barrett et al. have been working on creating so-called "virtual floppies" [11], Minar et al. are using RFID tags to create a virtual jukebox [15]. The coupling of real and virtual objects using barcode labels is being considered by Ljungstrand et al. in their WebStickers project [14]. Want et al. are describing a number of scenarios where RFID tags are used to connect physical objects with virtual representations or computational functionality [12]. The first three projects mentioned do have one thing in common, that the relationship is bi-unique: a virtual object is always assigned to exactly one real object. Only Want et al. describe the possibility of associating more than one URL with one Tag. Our approach goes further. We associate real objects not only with one single virtual object but also with a whole set of virtual counterparts, objects or applications. Any unambiguous assignment is solved at "activation" time, at which the current relationship is determined by the present context. HP's Cooltown project [6] is also related to our system. In Cooltown a Web page can be assigned to arbitrary things. The project uses – like ours - the Web infrastructure as an infrastructure for the ubiquitous presence of things [7].

Context information is often used in order to facilitate the communication and interaction with a user. The Cyberguide Project [8] uses location information and direction information to adapt the displayed information to the actual situation. The Conference Assistant [10] uses target position information, conference schedule and user preferences. Within the Sm@rtLibrary we use context information to select an information subset out of a given set of possibilities. As been described previously in the scenario, we can restrict the set of new entries to those, which are relevant to the user. Basically we are using context-information in order to determine an individual alternative from the different possible assignments of virtual representations to a real object. Much closer to our work is the approach being followed at Georgia Tech [9] that uses an infrastructure to support context-aware applications.

Location services often use technologies like GPS [18]-[19][20] to locate objects and persons outdoors. In the in-

door area Active Badges [16][17] are most frequently used. However, we do prefer the low-cost and unobtrusive RFID technology. Because on the one hand large numbers of everyday objects can be easily tagged and used in multiple locations, using a simple and inexpensive infrastructure. On the other hand it is based on the same kind of principles we are using for the OIC used to identify and locate persons.

7 Conclusion

Cooperative Rooms stand for flexible and dynamic future workspaces, in which real and virtual work environments are seamlessly integrated. COR proposes the paradigm of a boundary-less office space, where physical and virtual offices seamlessly blend together, where a transparent infrastructure for both wireless/mobile and wired communications is provided and where resources of real and virtual offices are managed and utilized concurrently and efficiently. Since physical workplaces tend to be non-territorial, which means that they are used as common resources at different times by different people, they have to provide simple means for locating and controlling their physical objects and adjusting their services to a given working context.

The field trial area to test and use in practice both COR results and related third-party results is called Science-Club. The Sm@rtLibrary represents a section of the SCLUB and serves as a test and demonstration environment for ubiquitous technologies and their application. In this area we are currently concentrating on localization and location management technologies, context-dependent services, platform and device independent access to the services and information provided in such environments.

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