Ambient Functionality – Use Cases

Eija Kaasinen, Timo Tuomisto & Pasi Välkkynen

VTT Information Technology, Sinitaival 6 (P.O.Box 1206), FI-33101 Tampere, Finland
{firstname.lastname}@vtt.fi

Abstract

In this paper we describe use cases and user requirements for ambient intelligence applications on personal mobile devices. Wireless connections to tags and sensors provide mobile applications with different identification, measurement and context data. Mobile applications that utilise local connectivity share many common patterns. We have identified these common patterns and describe them as use cases related to physical selection, activating applications, sensing and context-awareness. Based on user and expert evaluations of usage scenarios we also present user requirements for the use cases.

1. Introduction

Mobile devices are increasingly evolving into tools to orientate in and interact with the environment, thus introducing a mobile-device-based approach to ambient intelligence. As mobile devices are equipped with tag and sensor readers, they provide platforms for different applications that make use of local connectivity. These applications share many common features related to collecting measurement data, communicating with objects in the environment, identifying contexts, activating applications and so on. These features include common usage patterns that can be illustrated as use cases.

In this paper we describe common use cases that we have identified for mobile applications that utilise local connectivity. We also describe initial user requirements regarding these use cases, based on scenario evaluations with users. We start with an overview of related research in section 2 and then describe our mobile-device-based ambient intelligence architecture in section 3. In section 4 we introduce our design approach and present excerpts of usage scenarios to illustrate what kinds of applications our design targets at. In section 5 we describe the identified use cases and the user requirements related to them.

2. Related research

A lot of research on ambient intelligence is going on but the results still cover only dedicated services and specific applications [1]. Different basic component technologies such as mobile devices, sensors, ad-hoc networks and computing technologies are already available, but advancements are needed in their integration, scalability and heterogeneity [2].

In the following we will give an overview of research related to local connectivity, especially research related to using tag data for identification, collecting sensor data wirelessly, and using these two to identify the context of use.

2.1. Physical selection

Want, Weiser and Mynatt have identified the coordination of real and virtual objects as a key research problem in ambient intelligence [3]. Kindberg [4] has introduced the term “physical browsing” as “the users obtain information pages about physical items that they find and scan”. Physical selection can be seen as the phase in physical browsing by which the user selects with a mobile terminal a physical or a virtual object for interaction. As a result of physical selection, the content of the tag is interpreted and an action is launched.

Want et al. have carried out interesting work regarding the association of physical objects with virtual ones [5]. They have built several prototypes, some of which were implemented with RFID (radio frequency identification) tags read with an RFID reader connected to a PC. Generally their selection method was touching, that is, reading from a short range.

Kindberg et al. [6] have created Cooltown, in which people, places and physical objects are connected to corresponding web sites. The user interaction theme of Cooltown is based on physical hyperlinks, which the users can collect using a mobile terminal to easily access services related to people, places and things. Cooltown utilises IR (infrared) and RFID technologies to transmit these links to the users' mobile terminals.

Holmquist, Redström and Ljungstrand [7] have built WebStickers, a desktop-based system to help the users better manage their desktop computer bookmarks. Their system illustrates well the association between digital and physical worlds by using tags. The idea of WebStickers is to make physical objects act as bookmarks by coupling digital information (URLs, uniform resource locators) to them.

The above-mentioned research projects have used mainly static information or dynamic information composed of different sources in their applications. Measurement data from local sensors has typically not been part of the applications.

2.2. Wireless connections to sensors

In mobile applications that utilise sensor data, sensors can be embedded within a mobile terminal or connected wirelessly to the terminal as separate sensor units via local connectivity.

Sensors can measure environmental information such as location, altitude, illumination, temperature, pressure or surrounding sounds. Personal sensor data on physiological activity and mental state can be measured using electrocardiography [8], accelerometers, galvanic skin resistance [9] etc. Current application areas for personal data monitoring include fitness, sports, wellness and ambulatory monitoring in healthcare.

Bluetooth is currently the most commonly available wireless personal area network (WPAN) for local connectivity. Other low power technologies used for local connectivity are ZigBee and ANT[10] used e.g. in Suunto T6 wristop [11] computer for communicating with a heart rate belt and with an accelerometer installed in the shoe.

Commercial Bluetooth equipped sensor units are still rare [12]. Commercial wearable sensor units typically act as data loggers whose content needs to be uploaded daily or weekly into a user terminal with USB (Universal Serial Bus), infra red, or a proprietary radio link. Common wellness monitors – weighing scale and blood pressure meter – still lack wireless connections or even wired connections to digital infrastructures.

A major challenge with wireless sensor units is how sensors should be introduced and connected to the mobile device. In Bluetooth pairing any two Bluetooth devices form a trusted pair: whenever the other is detected, the paired devices automatically accept communication, bypassing authentication. The Near Field Communication (NFC) Protocol [13] proposes using NFC devices to establish a Bluetooth connection by touch and connect. Hall et al. [14] point out the advantages of linking RFID tags to Bluetooth enabled devices. As the tag contains connection parameters, the system may bypass the discovery process - which otherwise may take even 10 seconds. If the tag performs wakeup for the sensor unit, also power consumption is reduced. The idea of bypassing the Bluetooth device discovery by physically selecting and reading the Bluetooth address has also been utilised in reading visual tags with camera phone [15] or pointing by IrDA (Infrared Data Association) [16].

2.3. Context-awareness

An efficient way to improve the usability of mobile services and applications is adapting the content and presentation of the service to each individual user and his/her current context of use. In this way, the amount of user interaction will be minimised: the user has quick access to the information or services that (s)he needs in his/her current context of use. The services can even be invoked and the information provided to the user automatically.

A system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task [17]. The main challenge with context adaptation is the reliable measurement or identification of the context that may include physical, technical, social and emotional elements.

In previous research, context-awareness has mainly been studied in restricted application areas, such as tourist guidance [18], museum guide [19], e-mail [20], mobile network administration, medical care and office visitor information [21]. In these studies, the location of the user is the main attribute used in the context-adaptation. Designing applications for wider contexts of use will require more measurement data.

3. MIMOSA application platform

According to the vision of the MIMOSA project (Microsystems Platform for Mobile Services and Applications) [22], a personal mobile phone is the trusted intelligent user interface to the ambient intelligence environment and a gateway between the tags, sensors, networks of sensors, the public network and the Internet. For realising such a vision, MIMOSA develops and implements an open architecture based on novel low-power microsystems devices integrated on a common technology platform. The approach is based on short-range connectivity that can be set up with relatively modest investments in the infrastructure. At the same time, however, a wide range of consumer applications is covered.

Local connectivity to tags provides access to data and functions related to the environment and different objects in it. Local connectivity to sensors can be utilised to monitor the environment or the user. Tag data and different measurements can be analysed and processed to identify the current context of use.

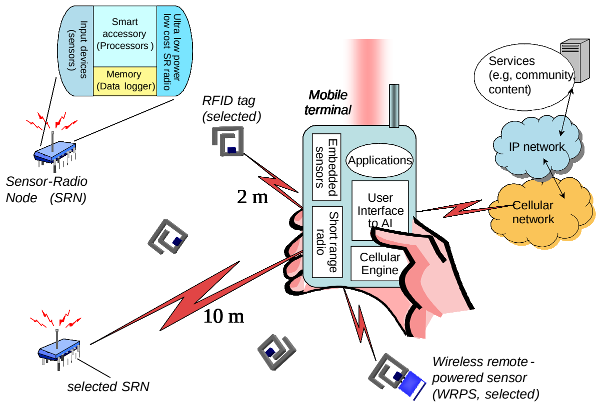

Figure 1. MIMOSA applications can utilise local connectivity to tags and sensors

At the top level the MIMOSA architecture can be divided into four physical entities: mobile terminal, remote application server, sensor radio node (SRN) and wireless remote-powered sensor (WPRS) that have local connectivity capability so that they can communicate with each other (Figure 1). Wireless remote powered sensor includes a sensor and a tag for identification. Sensor radio node is a more versatile unit that may include several sensors, memory and micro-controller that enable the pre-processing of sensor data.

The mobile terminal can collect information from the sensors automatically or by user initiation. The terminal can also read different RFID tags. Optional remote connectivity allows connections to remote application servers on the Internet.

4. The design approach

In our vision, the user feels and really is in control of ambient intelligence applications that are accessible through his/her personal mobile device. These applications help people in their everyday lives: they are useful, usable, reliable, and ethical issues have been taken into account in the design. We are developing demonstrator applications on the platform parallel to designing the MIMOSA platform itself. We are focusing on four representative consumer application fields where user mobility can be combined with measurements of the user and his/her environment: sports, fitness, health care and housing. In addition, we are studying general everyday applications.

Our project team has defined together a common vision of the future and illustrated the vision in the form of usage scenarios. These scenarios (36 short stories) have been used as the basis for user requirements. During the first phases of our project we analysed the scenarios in order to identify common patterns as use cases and related functional requirements. We evaluated the scenarios with end users and application field experts (94 people in total) in focus groups to identify user requirements regarding individual applications, common patterns and the architecture. The following excerpts of our usage scenarios illustrate the kinds of applications that we are targeting at:

1. Lisa notices an interesting poster of a new movie at the bus stop. She points her phone at the poster and presses a button to download a sample video clip for viewing on her bus trip. As the bus has not yet arrived, Lisa points to a tag at the bus stop to check how late the bus will be and to get guidance in redesigning her travel route.
2. John has heard from his doctor that many of his health problems are related to his overweight. Now he has started to use a mobile application that motivates his efforts to eat less and exercise more. As he steps on the scale, his weight is transferred into his mobile phone, where he can see his progress day by day. The scale also measures his fat rate and dehydration level. This morning the welfare application on his phone recommends that he should have two glasses of water to balance his dehydration level. As John starts his daily jogging exercise, his motions are monitored in order to give him feedback of the energy consumption. A lactate sensor indicates if he should slow down in order to keep the right aerobic level for fat-burning.
3. Matthew is quite serious with his golf practise. As he comes to the golf course, his golf application on his wristop is activated. All of Matthew's golf clubs are equipped with tags and sensors. His wristop computer runs a golf application that helps him to keep track of the clubs he has used and the courses he has played at. During the game, the golf clubs send measurement data of each swing to the wristop computer. At home Matthew compares his results to those of Tiger Woods.

Scenario 1 illustrates how physical objects can include links to further information and functions. Scenario 2 illustrates how health measurements can support self-care. Scenario 3 illustrates how an application is activated as the mobile device identifies a certain context as well as more versatile local connectivity to tags and sensors.

5. Use cases and user requirements

MIMOSA use cases are related to communicating with nearby objects, monitoring measurement data as well as identifying contexts and reacting accordingly. In the following we will describe four categories of use cases in detail: the user interface paradigm of physical selection, activating applications, collecting sensor data and context-awareness.

For each category, we will describe a collection of typical use cases with related user requirements. We illustrate the use cases as UML (Unified Modeling Language) style sequence diagrams where the interacting objects are users, mobile terminals, tags, and sensors. User requirements are based on user evaluations of the scenarios as well as analysis of the use cases by usability experts.

5.1. Physical selection

Physical selection is a user interaction paradigm that allows the user to select a link embedded in a physical object. The technical devices providing the links in MIMOSA are RFID tags and sensor radio nodes. The content of the link may be any digital information related to the physical object, for example a link to a web page or a sensor reading. Additionally, physical selection can be used to intuitively connect devices to each other in order to activate communication between them. The use cases for physical selection are the three methods for selecting the tag with the mobile terminal: touching, pointing and scanning.

5.1.1. Use cases

Touching means selecting the link by bringing the terminal close to the tag. The tags may be read by using continuous polling to detect when the terminal is near a tag, or only when the user also presses a button in the terminal.

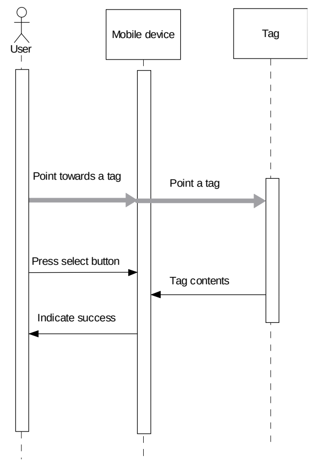

Figure 2. Physical selection by pointing.

In *pointing* the tag is selected by aiming a beam at the tag. The beam may be either visible light, for example laser, or invisible, for example infra red, possibly assisted with a visible beam for easier aiming. To detect the pointing beam the tag has to be equipped with a sensor.

Scanning reads all the tags in the environment and presents them in the mobile terminal’s display. The user can then select the tags (s)he needs to interact with.

Figure 2 depicts how pointing works. Grey arrows are used to describe changes in the spatial relations of physical objects, e.g. moving the mobile terminal to point at a tag.

5.1.2. User requirements

The tags and nodes should support all three physical selection methods: touching, pointing and scanning, and they should behave consistently in the interaction. Consistency supports users in adopting this novel user interface paradigm.

As our user evaluations were based on written and illustrated scenarios, the interviewees based their conception of the look and feel of tags to familiar concepts such as bar codes or infra red controllers. Key user requirements include marking the tags in a consistent way so that the user can identify them on different objects and in the environment. The appearance of the tag could indicate the functions that are included in it. The reading should be easy; the user should not have to wave his/her mobile device back and forth. Fluent reading of tags is a central requirement that becomes especially important in tasks where the reading should take place unnoticed (e.g. while jogging and running pass a check point) or when the user reads a collection of tags. Application-specific requirements for physical selection include for example properties of the pointing beam and required reading ranges for the tags.

The users emphasised the difference between personal tags and public tags. Public tags that can be read by anyone are useful in public places such as the poster in scenario 1. When tags are connected to personal items such as medicine packages, tags that can be read anywhere by anyone were seen as a privacy threat – anyone can unnoticeably read any tags that you are carrying or wearing. Long reading distance is also a threat for privacy. There seems to be trade-off to solve between easy reading and privacy protection.

5.2. Activation of applications

Many applications are bound to a limited space and activity, or are available only locally. Activating contextually relevant applications was a repeated action in our scenarios.

5.2.1. Use cases

A *context tag* is a tag that holds enough information to start an application that is already installed on the mobile device, or to install a new application in the mobile device. For example, in scenario 3, the user comes to a golf course and touches a context tag at the entrance to start the golf software.

After the installation the application can be associated with the ID of the tag so that next time the already installed application can be activated based on reading the tag. Figure 3 illustrates starting an application by reading a context tag.

5.2.2. User requirements

In the user evaluations, the requirements for ease of taking the applications into use were obvious. Although our scenarios described ready made installations, the interviewees often referred to problems that they expected to face in installing and configuring the systems.

Especially in relation to sports and fitness scenarios, the interviewees pointed out that they would not have time for complex set-up operations. The interviewees also saw that if each single sensor has to be activated separately, they easily would forget some of them. In the middle of the exercise it will be too late to start the application or measurements. The system should get started "with a single button". As for the jogging scenario, the interviewees proposed that measuring should start automatically "as the running speed grows”.

The users are expected to use their personal mobile device for several different purposes, e.g., when playing golf, for fitness control, home control etc. The coexistence and fluent activation of situationally relevant applications will be a major challenge for taking the services into use. Context-based activation of applications is a promising concept to ease taking the applications into use.

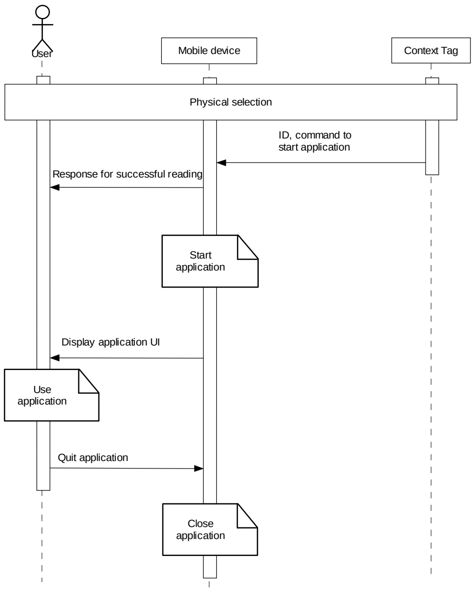

Figure 3. Starting an application by reading a tag.

Additional configuration challenges will be faced when starting applications because each application may require a different set of sensors and tags. When starting an application for the first time, the physical selection paradigm may be used for introducing and registering sensors and tags to the application. The application may then use these registrations or “pairings” (~analogue to Bluetooth pairing) for automatic connectivity to the sensors. Such a sensor may also be registered as a context tag for the application: by physically selecting the sensor, the application is started automatically.

5.3. Collecting sensor data

In our scenarios, we could identify three kinds of use cases where sensor data was collected: a single reading of a sensor, reading sensor data periodically, and establishing a connection between a smart sensor unit and the mobile device, whereby communication is possible in both directions. These use cases are described in the following subsections. In the use cases we presume that the sensors have already been introduced to the application as described in section 5.2.

5.3.1. Select and read

Single sensor measurements can be made just by reading a wireless remote-powered sensor (WRPS) after physical selection. As an example in scenario 2, the scale is equipped with a tag whose contents include the current measured weight. The welfare application may be continuously active on the mobile device. Being already introduced to the application, the scale can be read by just touching or pointing to it. If the application is not active but the scale tag has already been associated as a context tag with the welfare application, the application can be started by reading the tag.

5.3.2. Select and read periodically

Many MIMOSA scenarios include a background application, running continuously and capable of reading tag contents from a distance. If the application is capable of reserving its own time slot in the tag reader, it should be capable of controlling the reading range and reading interval of the reader as well. The application then also should own all the data associated with the time slot.

As an example, a lactate sensor (scenario 2) may be read continuously by the welfare application. The application periodically reserves the tag reader for its own purposes, increases the reading range from touching to some appropriate level, and reads the contents of the tag.

5.3.3. Select and establish connection

Measurement data can be transferred between a sensor radio node and a terminal by establishing a bidirectional connection between these devices (Figure 4).

The physical selection paradigm and the application activation paradigms described in sections 5.1 and 5.2 make measurements easier by reducing the time for discovery, selection and application activation. This requires that the sensor radio node is equipped with a wakeup tag.

Our scenario 3 utilised bidirectional communication between a wristop device and an integrated motion measurement unit (IMU). Figure 5 illustrates that when a golf swing is recognised by the sensor radio node (SRN), the SRN sends the club ID to the wristop computer, which logs the club used and the current position from GPS. After reading the ID – in addition to reading GPS data – the application might query and read the whole swing data for later analysis.

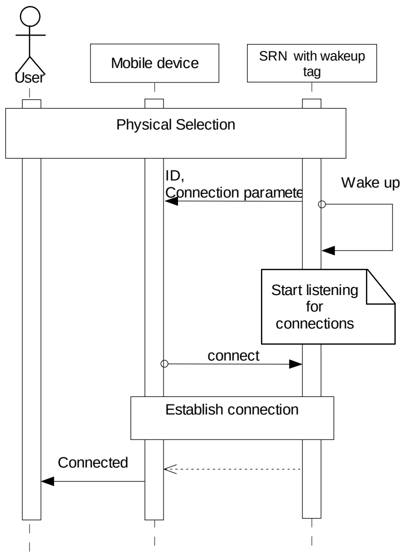

Figure 4. Using sensor radio node with a wakeup tag.

5.3.4. User requirements

In general the users appreciated the possibility to measure things that you "cannot see or feel". These kinds of measurements could be, for instance, health parameters, proper stretching of body before and after physical exercise, environmental conditions or safety-related measurements at home.

The interviewees innovated several new kinds of sensors that might be useful. Self-care systems are easy to deploy, as they do not require much infrastructure around. There were needs for both short-term and long-term monitoring (months or even years) of physical condition.

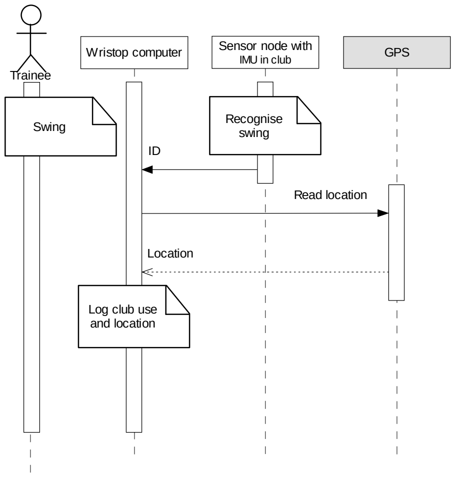

Figure 5. Logging golf club usage.

The running scenario included several measurements. The interviewees pointed out that the user should have the freedom to choose which measurements (s)he wants to include. Situations vary, and the user may want to measure different things on different days.

Motion monitoring that was a central theme in sports-related scenarios, raised some doubts related to the necessity of the information provided. The users also questioned whether measurements could be reliably analysed and synthesised to the kind of feedback that they were expecting. For instance, the motion of the golf club should be analysed to offer the user not only measurement curves but information on what is wrong with his/her swing.

5.4. Context-awareness

From the system's point of view, context-awareness includes three elements: identifying the context, maintaining user profiles, i.e. information on user needs in different contexts and using information about the context with the user profile to provide situationally relevant services, information and functions to the user.

Contexts can be identified by combining and analysing different measurement data. The measurements take place as described in section 5.3, and the system concludes the context based on the measurements of the user and of the environment. As the context includes several physical, social, technical and emotional elements, the measurements need to be very diverse. Still, a reliable identification of the context is often difficult.

Contexts can also be identified by using tags. Tags may indicate nearby objects and thus define the context. The system can read the context tags automatically or the user can actively select a context tag to inform his/her device about the context. Tag-based context-identification was described in section 5.2 in connection to activating applications. In a similar way, an already active application can utilise context tags. For instance, a golf application can identify the clubs that the user has been using as well as his/her location on the course. This information can be used to identify the current phase of the game. The context can be defined in more detail if the tag-based context information is complemented with measurement data of the user and the environment.

In the user evaluations, the users emphasised the need for ease of taking an application into use and using it. This requirement was crucial for applications targeted at sports and fitness. Tag-based context identification was felt acceptable because it was in the user's control and because it supported well the required ease of use. Depending on the application, the context can be identified totally automatically or by user initiative. The latter alternative can utilise physical selection as described in section 5.1.

Automatic identification of the context presents challenges for tag reading. Each application and each context tag may require different reading distance. The reading distance has to be accurate to identify the context reliably. For instance, in health care applications it would be beneficial to identify that the user is taking medicine. How near does the medicine package then have to be to conclude that the user is about to take the medicine? In the golf application, the club has to be next to the wrist long enough before the system can conclude that the player is planning to swing with that club.

6. Conclusions and further work

By defining a variety of usage scenarios and analysing them we revealed use cases that repeat in different applications utilising local connectivity. We have learned a great deal about user requirements for those use cases by analysing the scenarios and evaluating them with users and application field experts. Fulfilling the user requirements related to these basic patterns are crucial to the success of ambient functionality. In addition to the MIMOSA specific application fields, the use cases and related user requirements can presumably be applied in other application fields as well.

To study user interaction in more detail, we will continue our work by building proof of concept prototypes that illustrate key use cases. By evaluating the proof-of-concept prototypes we expect to get more detailed user feedback about viable interaction patterns and user acceptance of local connectivity based applications in general.

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