Requesting Pervasive Services by Touching RFID Tags

Jukka Riekki[1], *Timo Salminen*[1], *Ismo Alakärppä*[2]

[1] University of Oulu
P.O.Box 4500
90014 Oulu Finland
firstname.surname@ee.oulu.fi

[2] University of Lapland
P.O.Box 122
96101 Rovaniemi
firstname.surname@ulapland.fi

Abstract

We suggest a general framework for requesting pervasive services by touching RFID tags. The tags connect the physical and digital environments. Visual symbols communicate to users the objects that can be touched and the services that can be activated. When a user touches such a symbol with a mobile phone, the data stored in the tag and other contextual information related to the situation trigger the requested service. We have designed a set of visual symbols and implemented the required functionality as component-based middleware. We have studied the usability and user experience of this novel system. The results indicate that touching visual symbols with a mobile device is an easy way to activate services. Based on our findings, we list security, controllability and social acceptance as the main challenges in deploying this interaction method into everyday use.

1 Introduction

As the vision of pervasive computing is gradually becoming a reality, more and more services become available in our everyday environment. These services are no longer used at the desktop computer, but everywhere where our everyday activities lead us – and they are accessed using mobile terminals and technology built into the environment. Although this is a positive phenomenon, it introduces considerable challenges to discovering and selecting services. The traditional user interface is too cumbersome, and fully autonomous mechanisms are not reasonable, as the users need to have control over the digital environment's behavior.

In this paper, we present a general framework for requesting services by touching Radio Frequency Identification (RFID) tags. We focus on using a mobile phone as a mediator between the user and the services available in the local environment. Natural, calm user interfaces can be obtained if the tags to be touched are intuitively associated with the services. Furthermore, the requirements for the system to recognize the user's situation (i.e. context) and to reason out the proper services can be relaxed. This is because the information related to the tag and the mobile phone (e.g. location) set major constraints to the situation. The constraints are especially strong when the reading distance is short – the user has to (nearly) touch the tag with the phone and reading a tag can hence be interpreted as an intentional action. An important advantage is that the user is in control of the system. Finally, compared to completely manual operation, the user does not need to know nor enter the service parameters that can be set automatically when a tag is touched

RFID tags act as a connection between the physical and digital worlds. The physical side of the tag presents information to the user as a visual symbol and the digital side stores corresponding data that is delivered to the system when the tag is touched with a phone. This is a tangible interface; objects and visual symbols attached to them form physical representations of digital services. Furthermore, the phone is used as a physical object rather than as a traditional input/output device. In Brygg Ullmer's and Hiroshi Ishii's categorization this is a relational interface: logical relationships between physical objects are mapped to computational representations [1]. Tangible interfaces have been suggested by many researchers. Ullmer and Ishii [1] described several interfaces. Jun Rekimoto et al. [2] presented a system for manipulating digital data as physical tiles. Roy Want et al. [3] linked physical documents with digital ones. Colin Swindells et al. [4] identified objects by pointing at them. Heikki Ailisto et al. [5]

defined a physical selection user interface paradigm that covers interaction by touching RFID tags – and used a mobile phone as a mediator between the user and the services.

Our contribution is in a general framework for requesting pervasive services by touching tags, in representations for both the data stored in the tags and visual symbols shown to the users, in a concrete middleware implementation, and in usability and user experience studies. The framework defines how the actions of touching RFID tags are transformed into context information and how that information triggers the requested services. The pervasive middleware implements this framework. It offers the general functionality that is needed in building pervasive services, including the delivery of RFID data as context events. Usability and user experience was studied to find out the challenges in deploying this interaction method into everyday use.

2 Requesting services by touching

If a user can request services from a pervasive system by touching tags in the environment, how does the right service get activated? The key to a general solution is to realize that the data read from a tag can be interpreted as contextual information. For example, the context description "User A has requested a calendar view by touching object B", where A and B are identifiers, can be created when the user touches a calendar symbol attached to an object. Hence, the services that are activated by touching are like any other context-aware services. When a tag is touched, a pervasive system has to select the service that is the most suitable for the user in his or her current situation, where the situation is described by the data read from the tag and other contextual information collected by the system.

An obvious objective is that the service activated as a response to a user touching a tag is the service that the user intended to activate. This matching can be facilitated by using the RFID tag as a connection between the physical and digital worlds – as an index placed in the physical world that points to the right digital service. The visual symbol on the physical side of the tag communicates to the user the service to be activated when the tag is touched. The digital side stores data that triggers the corresponding service when delivered to the system.

The system generates context events from the data produced by the tag reader and other available data. System components implementing the services subscribe to the context events they are interested in and can process. These components are located in the mobile terminal and in the network. They can fetch additional information using contextual information as a search key. They can request services from other components and interact with the user through the mobile terminal's and other devices' user interfaces. When there are alternatives for performing the requested service (e.g. what to print), additional context information can be used to narrow down the choices, for example, the application on top on the phone's display can be favored. One option is to present the list of alternatives to the user.

We classify the tags as general and special tags. A general tag is used to identify the object the tag is attached to. The visual symbol (general symbol) shown at the top left corner in Figure 1 is used to indicate general tags in the environent. Special tags identify objects as well, but in addition they represent some additional information related to the object: an action to be performed, a location, URL, etc. The rest of the symbols shown in Figure 1 are special symbols. These visual symbols have the appearance of the general symbol augmented by an action symbol.

For example, a printer might have three special tags: *Print*, *Contact maintenance* and *Info*. This would result in a maximum of four tags attached to a printer. Only an object identifier identifying the printer is stored in the general tag. The data stored in a special tag corresponds with its symbol – in this case each special tag contains data identifying an action. The parameters, e.g. the telephone number of the maintenance personnel, can also be stored in the tag; or they can be fetched from the network using the data read from the tag as a search key.

We selected the NFC (Near Field Communication) format for storing data into RFID tags, as it supports storing several records into a tag. Our aim is to store each data item (object identifier, action, URL, location, etc) as a separate record. We selected the Electronic Product Code (EPC) for identifying objects. The EPC contains an organization prefix, an object class and a serial number. The organization prefix defines the organization responsible for maintaining object classes and serial numbers. The object class determines the type of the object the tag is associated with, for example, *Printer*, *Poster*, *Room* and *Doorway*. Finally, serial numbers enumerate all the different instances of each object class.

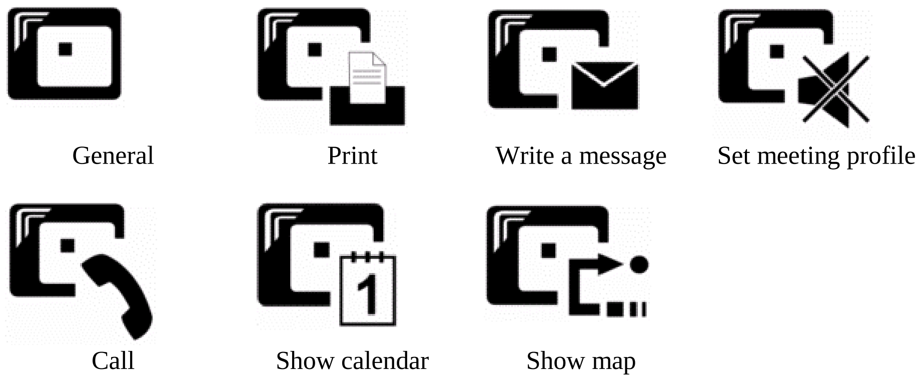

Figure 1. Visual symbols.

So far, we have specified the EPC representation for object identifiers (actions are currently represented as part of the EPC). Other data items can be added flexibly as new NFC records. For example, a globally unique tag identifier might be used instead of an object identifier, but then more information would need to be fetched from the network.

3 Middleware

We have identified the fundamental requirements for generic-use pervasive middleware by examining the existing pervasive systems (e.g. Gaia [8], One.world [9], and Aura [10]) and requirement specifications. The requirements are: interoperability, discoverability, location transparency, adaptability, and context-awareness. *Interoperability* is the ability of two or more systems or components to exchange information and to use the information that has been exchanged. The requirement for *discoverability* states that the system components need to discover the surrounding entities and, conversely, the system components need to be discovered by the other entities in the system. *Location transparency* means the locations of the system components are transparent to the other components, the programmer, and the user. *Adaptability* is the ability of a software entity to adapt to the changing environment. Finally, the requirement of *context-awareness* states that a pervasive system needs to be aware of the user's context in order to provide relevant information and services to the user.

We have utilized the five identified requirements as the basis for our pervasive middleware development. The main difference between our work and the other types of middleware that offer similar functionality is that we have targeted the middleware for mobile devices; technologies that would hinder its usage in resource-limited mobile devices are avoided.

Our middleware architecture divides functionality into components, each of which is specialized in some task or domain area and provides corresponding functionality to the other entities in the system. This CAPNET (Context-Aware Pervasive Networking) middleware masks the complexity of networks and distributed systems and thereby allows developers to focus on application-specific issues. Furthermore, it factors out the commonly used functions into independent components, so they can be shared across platforms and software environments. This component framework is illustrated in Figure 2.

A component can represent a service in the user's environment, such as a printer or a projector, which provides an analogy between the digital and physical worlds. The components live inside a container called an engine. The engine core fulfills the five fundamental requirements. It handles interoperability with the other engines and components in the system. It provides location transparency to the components and mechanisms for discovering resources, services, and other components in the system. Context-awareness is provided to the system by context components, and adaptability is supported by dynamically reconfigurable stub objects. The engine can also contain an unspecified number of other components that bring added value to the system.

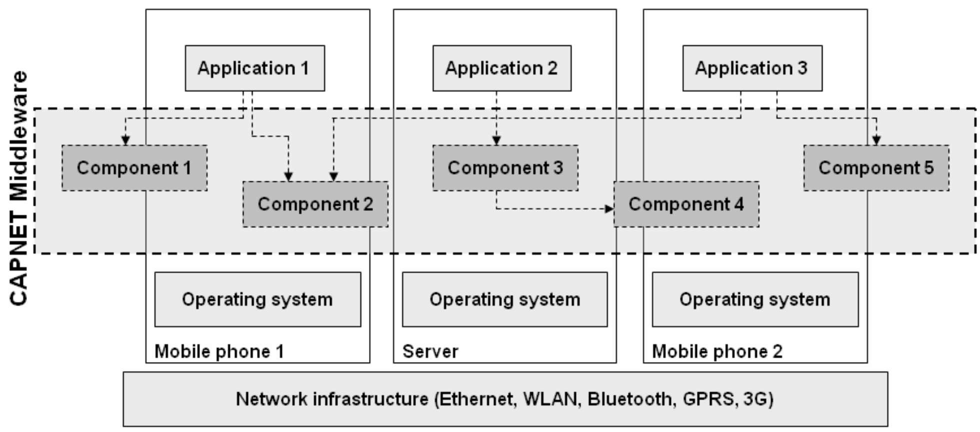

Figure 2. CAPNET architecture overview.

The applications (i.e. the services the user interacts with) are components as well. They can utilize other components in the system, regardless of where the application or components are physically located. Figure 3 illustrates a system that consists of a mobile phone and two network servers. The application, running on the mobile phone, utilizes keyboard and projector services, represented by corresponding components.

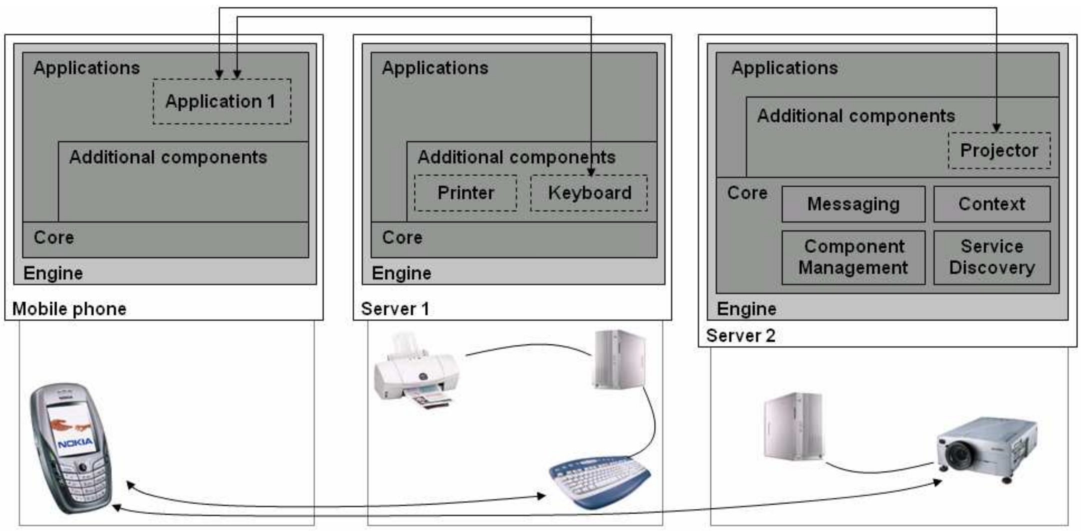

Figure 3. CAPNET engines and services.

The engine core consists of service discovery, messaging, context and component management components. The main controlling unit of an engine is called component management. It controls all components by loading them into the system, initializing, starting, and terminating them. It also processes requests from the other components concerning component access. The messaging component provides synchronous and asynchronous communication mechanisms to the other components. Furthermore, messaging provides distribution and interoperability mechanisms between the components. All communication between components in different engines flows through the messaging component.

The service discovery component is used to discover and locate services, resources, and other components in the environment. When a component (client) needs the services of another component, it selects a component from a list of alternatives provided by the service discovery and asks component management to provide a reference to the selected component. The context component provides context information, both synchronously and asynchronously, as context events. It utilizes the available sensors for acquiring contextual data from the environment.

Dynamically reconfigurable stubs provide location transparency to the CAPNET system. When an application requests a component, component management returns a stub object, which represents the requested component. If the requested component is located outside the local engine, the stub utilizes messaging to redirect component calls to the actual component in a remote engine. If the execution environment of an application changes due to the user's mobility, component management can adapt the system to the new situation by reconfiguring the stubs and associating them with the corresponding services in the new environment.

We have built applications utilizing RFID tags on top of this middleware. The middleware generates context events when users touch RFID tags. The applications react to these events either by offering the requested service themselves or by requesting from the middleware the component offering the service and redirecting the service request to that component.

4 Usability and user experience tests

We made the first usability tests with a prototype that consisted of applications running on mobile phone and a number of services in the environment. The middleware for Symbian mobile phones included component management, messaging, and context components. Complete middleware was implemented on network servers in Java language. The mobile phone was provided with an external RFID reader module that communicated with the mobile phone via Bluetooth. The visual tags presented in Figure 1 were used to label the services. The data representation described in the earlier section was not fully implemented, but this deficiency was hidden by the middleware.

The main goal of this test was to study how well users do understand the meaning of the visual symbols. We also wanted to compare the general and special tags. Furthermore, we were interested in the user experience, acceptability, and first impressions of this new technology. The test users were students and staff members of the university. Eight individuals formed four pairs. The average age was 28 and all the participants were men. The participants evaluated themselves to have good skills in using this kind of technology. The phone model used in the tests (Nokia 6600) was familiar to almost everyone. Also, technology played an important part in their everyday life. The participants were interested in using new technology and they had a positive attitude toward new technology in general. In spite of that, their attitude toward using RFID tags was initially quite reserved.

The material for this study was collected using thinking aloud methods. Observing, forms, and discussing were also used as tools. Tasks were carried out by the pairs on two days. The tasks were observed. After finishing a task, the test users were asked to fill out question forms. Each pair filled out two forms: one for background information and one for feelings and comments about the test session. Discussions were recorded during the test and form filling. In all the tasks the users had two alternatives. First, they were able to proceed by touching a general symbol (i.e. a general tag) and then selecting an action from the phone's user interface. In these tests, touching a general symbol always triggered a service that listed on the terminal's display the other services available for this object. The second alternative was to touch a special symbol (i.e. a special tag associated with an action) that offered direct access to the service. During the first day the test users were allowed to choose which symbol they wanted to use; either the general symbol or one of the special symbols. The next day they were at the beginning allowed to select the symbol. After that they were asked to try out the one they had not yet selected. In the tests, the participants performed as Kari in the following scenario:

“Kari is a new employee in a company and has been invited to a meeting with his manager Janne. However, Kari finds out that Janne is not in his office at the appointed time. Kari has been told that the building is equipped with services which can be accessed by touching tags with a mobile phone. Tags are indicated with visual symbols that can be easily recognized from the environment and that suggest the offered service. Kari notices some tags next to the door of Janne’s office, and one of them looks like a calendar. Intuitively, Kari associates the calendar tag with Janne’s schedule and touches it with his phone. This action opens a calendar application with Janne’s calendar appointments on Kari’s phone’s display. It appears that Janne has scheduled the meeting in a meeting room instead of his office.

Kari notices a map tag next to the calendar tag. As Kari touches it with his phone, the phone opens an application which shows a route to Janne’s location which is the meeting room. As Kari starts walking towards the meeting room, he notices a printer in the corridor. Kari finds out that the printer is labeled with two tags; the first one is a general tag. Kari associates the second tag to a printing action and touches it with his phone. Since the map application is on top on the phone’s display, the map is printed. As a curiosity, Kari also touches the first tag. This causes a list of available services to be shown on his phone: *Print*, *Info* and *Call maintenance*. Thus, Kari finds out that, with a general tag, he can access all the available services related to the printer. Finally, Kari finds the meeting room. When he is about to enter the room, he discovers some tags next to the door of the meeting room. He associates one tag with the meeting profile and touches it with his phone. As a consequence, the phone changes the profile into the meeting mode, and no phone calls disturb him during the meeting.

When the meeting is over, Kari needs to make a reservation for a cocktail party for the evening. He finds some tags from the brochure of the company organizing the party. One tag is next to a contact number. Kari associates this tag with a phone call and touches it. As a consequence, a phone call is initialized, and Kari makes the reservation. Finally, before going back home, Kari finds out he has to enroll in a weekend course. While he is writing an SMS to the course assistant, he notices a computer with a tag attached to it. Touching the tag enhances the mobile phone with advanced input and output capabilities: the display of the SMS application is transferred to the computer’s larger screen, and the text can be typed using the computer’s keyboard.”

Some stages of the test are illustrated in Figure 4. In the pictures, the user is holding the tag reader that communicates via Bluetooth with the mobile phone. In the situation shown on the left, the printer service is used. Next, the user locates another employee in the building. In the third situation, the user is at the office doorway and uses the services he has found. In the situation shown on the right, the user interface of the SMS application has been transferred onto the computer’s screen.

Figure 4. Experiments.

The middleware and the applications worked as expected during the test sessions. The GPRS connection used in communication with the server side components introduced latency, which was easy to notice especially with the keyboard service. However, the perceived problems were negligible and did not have any noticeable effect on the tests.

The results can be roughly categorized under the following five topics: usability, control, security, utility, and social acceptability. We will discuss usability first. The users learned to use the special tags already during the first usage situation. Special tags were preferred to general tags because they present their meaning in a concrete way. They were judged as logical, fast and easy to use. However, the users noticed that it might be difficult to find the correct symbol for a certain task among several adjacent special tags. Furthermore, the users valued the simplicity resulting from a single general tag. The users valued the colors and simple symbols as well. They wanted to have symbol features which were familiar from earlier usage contexts; it is clear that familiar features facilitate recognition in new usage situations. Finally, symbol placement was found important in terms of usability. Consistent placement helps in recognizing and interpreting symbols.

Related user trials of selecting mobile services indicate that the physical pointing method can be significantly faster than the conventional method [6]. Usability studies concerning a mobile device's menu structures suggest that a hierarchical menu suits novice users well. An expert user may wish for short-cut codes which bypass the navigation structure and allow direct access to the desired task [7]. Such results, together with our observations of a fast learning rate, indicate that the special tags are suitable for expert users – providing that the visual symbols are unambiguous. In other words, the perceived affordances [11] of the visual symbols (together with the objects they are attached to) have to match with the services that are activated when the symbols are touched. Perceived affordance refers here to the user's perception of what can be done with a visual symbol, what kind of service can be requested. Lars Erik Holmquist et al. [12] also emphasize the importance of affordance. A further challenge is introduced by the fact that users can give different meanings to a symbol depending on the usage situation and personal background. For example, the test users noted that they interpret an envelope symbol on a computer display as a symbol for e-mail, but on a mobile phone's display as a symbol for SMS.

Automated service activation was discussed during the tests – services could be activated when a user enters the tag's proximity. The users preferred clear manual user interaction because it gives a better feeling of controllability. A related finding was that a feeling of controllability requires clear feedback to the user. Feedback was not required if the service started immediately after touching a tag. Lauri Pohjanheimo et al. [6] also mention feedback as one of the key usability issues. Although special tags were preferred, general tags produced a better feeling of controllability, as the users could select a service from the menu.

The users found the special tags more secure to use than the general tags because they give more information about the expected system behavior. The mobile phone was important for everyone and it was mentioned as a natural, familiar and secure terminal for the tested services. However, to assess security, the users wanted to know who is behind the services. They did not want to risk their personal mobile phones if they doubted that a service is not secure. New technology was found to be secure when used in a familiar environment – but touching tags with one's own mobile phone in public places was considered risky. Eija Kaasinen [13] has found similar results regarding control and security.

The users clearly evaluated the utility of the services through their personal needs. The tested services were mentioned to be useful. The special symbols were found to result in higher utility because they were faster and easier to use. However, it seemed utility is not enough for everyday use – acceptance is required as well. The mobile phone was said to be an acceptable terminal for the tested services. The test users were ready to use these services immediately or within one year in their home environment if the required facilities and a positive atmosphere exist. They were not ready to use the services elsewhere, because they considered the security risk to be too high – and because they were embarrassed about touching RFID tags in public places. It seems that although touching is a natural action as such, it is not necessarily considered as a socially acceptable way to use new technology.

5 Conclusions

We presented a general framework for requesting services by touching RFID tags. The prototype implementing this framework worked well. The first usability tests suggest that touching is a natural and easy way to request services.

The test users adopted a positive attitude towards RFID tags during the test. The special tags triggering services with one touch were preferred to the general tags that caused a list of alternatives to be shown on the phone's display. The feeling of controllability seems to have a considerable effect in adopting new technology like RFID tags. Designing unambiguous symbols is challenging, as interpretation is linked to the usage situation and personal background. On the other hand, this characteristic could be used to promote the acceptance of new technology – by bringing well known local symbols into the user interface.

We found social acceptability and security to be key factors in deploying RFID tags in our everyday environment. The environment seems to have an important effect on the feeling of security – the tested technology was considered to be more secure in the familiar home environment than in public environments. Social acceptability can even be the deciding factor when people consider whether to start using RFID tags. Acting under the watchful eyes of strangers or in an otherwise negative atmosphere might be a barrier for some users. These findings suggest that the first RFID applications should be developed in familiar environments (e.g. homes) – the applications would be trusted and users would not be ashamed of touching tags with a mobile phone. After getting accustomed to RFID tags, public usage might have a lower threshold. Alternative physical selection methods might also promote wide-scale usage, for example, some users might prefer to request services by pointing to the visual symbols instead of touching them.

Our findings are inline with the results reported by others. However, pervasive applications are characterized by variability in usage situations and this introduces new challenges that need further research before good usability and positive user experience can be guaranteed. We will continue the research. The tests reported here were quite modest, and hence these results are only preliminary. The development of the middleware and the representations continues. We have obtained RFID readers that are integrated into mobile phones and hence can start studying how users regard touching tags with a phone instead of a separate reader. We are creating a wider set of visual symbols and are going to conduct more usability and user experience studies to verify and further elaborate the findings. We are keen on finding new tools for designing visual symbols through the concept of affordance. Also, further work is needed to clarify factors affecting acceptability in different environments and contexts.

Acknowledgments

This work was funded by the National Technology Agency of Finland. The authors would like to thank all the personnel in the Capnet program and the participating companies. Furthermore, Simo Hosio, Marketta Heinonen and Heikki Laaksamo are acknowledged for test environment creation, designing the visual tags and specifying the EPC representation, respectively.

References

[1] B. Ullmer and H. Ishii, "Emerging Frameworks for Tangible User Interfaces," *Human-Computer Interaction in the New Millennium*, J.M. Carroll, ed., Addison-Wesley, 2001, pp. 579-601.

[2] J. Rekimoto, B. Ullmer, and H. Oba, "DataTiles: A Modular Platform for Mixed Physical and Graphical Interactions," *Proc. SIGCHI Conf. Human Factors in Computing Systems*. ACM Press, 2001, pp. 269-276.

[3] R. Want, K.P. Fishkin, A. Gujar, and B.L. Harrison, "Bridging Physical and Virtual Worlds with Electronic Tags," *Proc. SIGCHI Conf. Human Factors in Computing Systems: the CHI is the limit*, ACM Press, 1999, pp. 370-377.

[4] C. Swindells, K.M. Inkpen, J.C. Dill, and M. Tory, "That One There! Pointing to Establish Device Identity," *Symp. User Interface Software and Technology* (UIST'02), ACM Press, 2002, pp. 151-160.

[5] H. Ailisto, J. Plomp, L. Pohjanheimo, and E. Strömmer, "A Physical Selection Paradigm for Ubiquitous Computing," *Ambient Intelligence*, LNCS 2875, G. Goos et al., eds., Springer-Verlag, 2003, pp. 372-383.

[6] L. Pohjanheimo, H. Ailisto, and J. Plomp, “User Experiment with Physical Pointing For Accessing Services with a Mobile Device,” *EUSAI Workshop Ambient Intelligent Technologies for Wellbeing at Home*, November 2004, Netherlands, http://www.eusai.net/MyReview/FILES/WORKSHOP/7369a7036386b928a89ce747bddd4395.pdf

[7] K. Hassanein and M. Head, “Ubiquitous Usability: Exploring Mobile Interfaces within the Context of a Theoretical Model,” *Proc. 15th Conf. on Advanced Information Systems Eng.* (CAiSE 2003.), June 2003, Austria, http://citeseer.ist.psu.edu/675869.html.

[8] M. Roman, C. Hess, R. Cerquiera, A. Ranganathan, R.H. Campbell, and K. Nahrstedt, “A Middleware Infrastructure for Active Spaces,” *IEEE Pervasive Computing*, Oct.-Dec. 2002, vol. 1, no. 4, pp. 74-83.

[9] R. Grimm, “One.world: Experiences with a Pervasive Computing Architecture,” *IEEE Pervasive Computing*, July-Sept. 2004, vol. 3, no. 3, pp. 22-30.

[10] D. Garlan, D.P. Siewiorek, A. Smailagic, and P. Steenkiste, “Project Aura: Toward Distraction-Free Pervasive Computing,” *IEEE Pervasive Computing*, April-June 2002, vol. 1, no. 2, pp. 22-31.

[11] D.A. Norman, *The psychology of everyday things*, Basic Books, 1988, p. 272.

[12] L. Holmquist, J. Redström, and P. Ljungstrand, “Token-Based Access to Digital Information,” *Proc. 1st Int. Symp. Handheld and Ubiquitous Computing*, LNCS 1707, H.-W. Gellersen, ed., Springer-Verlag, 1999, pp. 234-245.

[13] E. Kaasinen, “User Acceptance of Mobile Services – Value, Ease of Use, Trust and Ease of Adoption,” doctoral dissertation, VTT, Espoo, Finland, 2005, VTT Publications 566, http://www.vtt.fi/inf/pdf/publications/2005/P566.pdf.