If Objects Could Talk: Semantic-enhanced Radio-frequency IDentification

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Abstract. We propose to extend basic RFID usage by storing semantically annotated data within RFID tags memory, so that objects may actually "describe themselves" in a variety of scenarios. In particular here we exploit our approach to carry out an advanced discovery process using annotations stored in RFIDs. A –fully backward compatible– modification to the original RFID data exchange protocol is presented, integrated in a semantic-enabled Bluetooth resource discovery framework. Motivations and benefits of the approach are outlined in a u–commerce context.

1 Introduction

Radio-Frequency IDentification (RFID) is an emerging technology interconnecting via radio two main components: **(1)** a transponder carrying data (*tag*) located on the object to be identified; **(2)** an interrogator (*reader*) able to receive the transmitted data. Traditional RFID applications have been focused on supply chain management and asset tracking [1]. Nowadays tags with higher memory capacity and on-board sensors disclose new scenarios and enable further applications. We present a semantic-based environment where tagged objects become resources exposing to a reader not simply an identification code but a semantically annotated description. It may enable objects equipped with RFID tags describe themselves in a variety of scenarios *e.g.*, during supply chain management, shipment, storing, sell and post-sell, without depending on a centralized database. In particular in this paper we focus on an innovative, semantic-based discovery mechanism. Current identification methods are largely inefficient for advanced applications. Hence we adapt both ideas and technologies from the Semantic Web in a *u–marketplace*[1], where objects endowed with RFID tags have been dipped into Bluetooth mobile ad-hoc networks. Building on previous works that enhanced the basic discovery features of Bluetooth with semantic-based discovery capabilities [2], in this paper we propose an extension of EPCglobal specifications for RFID tag data

[1] Here we intend a u–marketplace as an ad-hoc environment where mobile peer users –both buyers and sellers– can submit their advertisements, browse through available ads and be assisted in finding the best available counterparts to meet their needs and initiate a commercial transaction.

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standards, providing semantic-based value-added services, and present its deployment in an advanced u–commerce setting.

The remaining of the paper is structured as follows. In the next section we comment on related work. Section 3 outlines the proposed framework. In Section 4 we sketch proposed enhancements. A case study clarifies our approach in Section 5. Section 6 closes the paper.

2 Related Work

U–commerce is based on the ubiquity, universality, uniqueness, and unison network characteristics as pointed out in [3]. There, authors forecast that when network devices and infrastructures will become more ubiquitous, they will be powerful and useful marketing instruments. Nowadays RFID is envisioned as one of the most promising technologies to build u–commerce infrastructures. Nevertheless, currently it is trivially used as a link between physical objects and a "virtual counterpart" in the digital world [4]. Most of literature focuses on innovative RFID applications.

In [5] a pervasive architecture for tracking mobile objects in real-time is presented. Proposed solutions are aimed at supply chain and B2B transaction management. A global and persistent IT infrastructure is necessary in order to interface RFID systems through the Internet. These requirements make the approach less suitable for B2C and C2C scenarios especially in mobile ad-hoc contexts.

Römer *et al.* [4] present a Java and a .NET frameworks for ubiquitous computing applications using smart identification technologies. Core design abstractions such as object location, neighborhood, composition, history and context enhance flexibility. Nevertheless, as admitted by the authors, scalability issues are present. They may be related to a virtual counterpart approach, which seems to be unsuitable to really mobile applications. A further limitation is in use of Jini and UDDI as discovery protocols because they only support exact service matches. Semantics of object properties and capabilities is not explicit, but it is encapsulated in either Java classes or Web Services.

Several efforts have been put on exploiting RF technologies to enhance *Human-Computer Interaction* (HCI) *e.g.*, in wearable computer architectures. Hum [6] early introduced an OSI-like protocol stack he called *Fabric Area Network* (FAN), supporting a dynamic data routing between RFID tags deployed on garments and a single wearable base station. Schmidt *et al.* focused on implicit HCI, taking user activity in the real world as input to computers. In [7] the authors introduce a wearable RFID solution enabling operations over an information system simply by picking up or using an operation-related tagged object. The proposed system has been also integrated with SAP R/3 in a case study. Since no semantic information are associated to tags, a virtual counterpart is anyway needed.

In [8], interaction patterns between users endowed with GSM phones and common objects are investigated. Objects are endowed with active RFID transponders equipped with on-board sensors and Bluetooth connectivity. An infrastructure enabling a hybrid implicit-explicit HCI model is implemented. Interaction is mediated by typical mobile phone patterns (called *interaction stubs*), such as SMS templates and reminder alarms.

Proposed approach alters normal relationships between people and things. The need for a costly communication link such as GSM is an open issue.

In [9] a support system aimed at enhancing information exchange in conferences is presented. A location and time aware middleware tracks participants while entering or exiting meetings by means of RFID badges and a reader deployed in each room. Access to a shared chat session and to a remote file system folder is then granted dynamically, as long as users stay in a room to attend an event. Context-awareness relies on preliminary explicit profiling of both users and events of interest. Nevertheless, user experience is enhanced without modifying people habits or their interactions with the environment.

3 Framework: Motivation and Explanation

Novel ubiquitous paradigms call for efficient and effective discovery of resources and services available in an area. To discover resources and services, basic mechanisms currently used are often ineffective, as they are usually based on unique IDs to identify items and simple string matching for discovery. More powerful discovery infrastructures are desirable, able to cope with rich descriptions associated to resources in advanced scenarios. To this aim, in [2] a semantic-enhanced Bluetooth discovery protocol was introduced, which allows a semantic-enabled discovery mechanism of resources and services. Unused classes of service identifiers of the original standard (UUIDs) were exploited as ontology markers, naming these values *OUUIDs* (Ontology Universally Unique IDentifiers). Currently, RFID technology is trivially used to unambiguously identify physical objects and to retrieve related attributes by way of a fixed server. Nevertheless, we believe there is room for more advanced and useful applications of RFIDs extended with structured descriptions, so that a good equipped with an RFID can semantically describe itself along its life-cycle. We conceived a unified framework where an RFID-based infrastructure and advanced Bluetooth service discovery are virtually “interconnected” at the application layer permitting advanced services in u–environments. In particular, here, we present an extension of EPCglobal standard [10] allowing a semantic-based object discovery in a u–marketplace framework. Protocols to read/write tags have been preserved maintaining original code-based access (so keeping a backward compatibility with legacy applications practically without any modification). A good can be easily and thoroughly described by means of a semantic annotated description stored within the tag it is associated with. Hence a RFID reader, scanning characteristics of a selected product, enables a further discovery phase identifying resources similar to the chosen one or to be combined with it. Via the semantic based Bluetooth SDP and exploiting non standard inference services devised in [11] best matching resources of the marketplace will be discovered and returned to the user.

Such an approach provides several benefits. Information about a product is structured and complete; it accurately follows the product history within the supply chain being progressively built or updated during the good life cycle. This improves traceability of production and distribution, facilitates sales and post-sale services thanks to an advanced and selective discovery infrastructure. Traditional approaches, differently from the one we propose here, do not consider items potentially matching with a user request as well as they do not contemplate the possibility of suggesting combinations

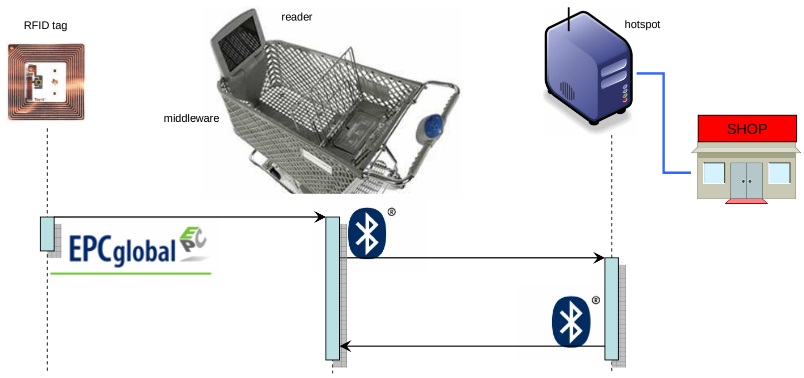

Fig. 1. Allowed interaction sequence diagram.

of items in order to satisfy a user need. The above logical framework will be illustrated and motivated in a virtual consumer electronics store case study. Figure 1 shows the main elements of our prototype and a high-level view of the interaction pattern enabled by the proposed approach. In our case study, a "smart shopping cart" is equipped with a sensor and a tablet computer, which integrates a RFID reader and Bluetooth connectivity. When customer picks up a product, the system assists her in discovering additional items, either similar or to be combined with the selected one. A zone resource provider (*hotspot*) keeps track of resources within the marketplace. It interacts with the shopping cart through semantic-enhanced Bluetooth, replying to its requests at SDP layer.

In the rest of the paper we will assume the reader be familiar with basic syntax and semantics of Semantic Web languages –in particular OWL [12] and DIG [13]– and of Description Logics (DLs) [14] which is the formal language we adopt. Here we formalize examples by adopting DL syntax for the sake of compactness.

4 Semantic-enhanced EPC Standard

We refer to the EPCglobal standard for class I Generation-2 UHF RFID tags [10]. Memory is organized in four logical banks [15]: **(1)** *Reserved*, storing –if present– kill and access passwords; **(2)** *Electronic Product Code (EPC)*; **(3)** *Tag IDentification (TID)*, storing tag manufacturer and model identification codes; **(4)** *User*, storing –if present– data defined by the user application. We exploit two bits in the EPC tag memory area now reserved for future purposes. The first one –at 15_h address– is exploited to indicate whether the tag has a user memory (bit set) or not (bit reset). The second one –at 16_h address– is set to mark semantic enabled tags. In this way, a *Select* command[2] (see Table

[2] By means of it a reader imposes to each tag in range to perform a comparison between a bit mask (*Mask* parameter) and the content of a tag memory area identified by the triple *MemBank* (one of the four tag memory banks), *Pointer* (initial address within the specified bank) and *Length*. Then the tag will set/reset one of its status flags according both to the comparison outcome (match/no-match) and to *Target* and *Action* parameters. Target indicates the flag to be

Table 1. SELECT command able to detect only semantic enabled tags.

PARAMETER	Target	Action	MemBank	Pointer	Length	Mask
VALUE	100_2	000_2	01_2	00010101_2	00000010_2	11_2
DESCRIPTION	SL flag	set in case of match, reset otherwise	EPC memory bank	initial address	number of bit to compare	bit mask

Table 2. READ command able to extract OUUID from the TID memory bank.

PARAMETER	MemBank	WordPtr	WordCount
VALUE	10_2	000000010_2	00001000_2
DESCRIPTION	TID memory bank	starting address	read up to 8 words (128 bit)

1) allows a reader to easily distinguish semantic based tags. *MemBank* value identifies the EPC memory bank (bank 01_2); *Pointer* is the starting address of the bit pair (since $00010101_2 = 15_h$); *Length* is 2. *Mask* is 11_2 since semantic-enabled tags are identified by having both bits asserted. *Target* and *Action* parameters have the effect to assert the *SL* tag status flag only for semantic-enabled tags and deassert it for remaining ones. The following inventory step will skip tags having SL flag deasserted, thus allowing a reader to identify only semantic-enabled tags (protocol commands belonging to the inventory step have not been described, because they are used in the standard fashion).

The EPC standard for UHF - class I tags impose the content of TID memory up to $1F_h$ bit is fixed. As said above, optional information could be stored in additional TID memory; it generally consists in serial numbers or manufacturer data. We use the TID memory area starting from 100000_2 address. There we store the identifier of the ontology w.r.t. the description contained within the tag is expressed. Recall that each semantically annotated resource description is referred to a specific ontology which is universally labeled by means of the OUUID identifier. That is the OUUID in the TID bank marks the reference ontology w.r.t. is expressed the description of the good. In order to make RFID systems compliant with the ontology support system proposed in [2], we define a bidirectional correspondence among OUUIDs stored in RFID transponders and those managed by Bluetooth devices. To retrieve the OUUID value stored within a tag, a reader will exploit a *Read* command with parameters as in Table 2.

Together with the semantically annotated object description expressed in DIG, within the user memory bank will be stored contextual parameters (*i.e.*, numerical values whose meaning depends on the specific application). Due to verbosity of DIG format and limitations of tag memory, the use of a compression algorithm is needed. For the sake of conciseness, here we omit characteristics of the encoding tool. To store a semantically annotated description containing up to 50 concept and roles we estimate a memory occupancy not exceeding 8 kbit. A reader can perform extraction and insertion of a description on a tag, by means of one or more *Read* or *Write* commands respectively. Both commands are compliant with the RFID air interface protocol. In Table 3, parameters of the *Read* command[3] for extracting a compressed description are reported.

updated, while Action tells to the tag how to update it (*i.e.*, whether to assert, deassert or leave the flag unmodified).

[3] It allows to read one or more 16-bit memory words from one of the four tag memory banks. *MemBank* parameter identifies the memory bank to be read (as in *Select command*). *WordPtr*

Table 3. READ command able to extract the semantic annotations from the user memory bank.

PARAMETER	MemBank	WordPtr	WordCount
VALUE	11_2	000000000_2	00000000_2
DESCRIPTION	user memory bank	starting address	read up to the end

Table 4. Mapping of product categories to values of contextual resource parameter.

Value	1	2	3	4	5
Product category	telephony	computers	photography	audio and video	hobbies

4.1 Semantic-based Object Discovery and Matchmaking

In [11] algorithms were proposed to semantically classify and rank matches between a request and available resources based on their logical descriptions. In a nutshell, *rankPotential* algorithm allows to rank resources according to the degree of potential satisfaction of a user request w.r.t. a resource when their descriptions are logically compatible, while *rankPartial* allows to obtain a ranking also when the resource and the request are logically disjoint. Without delving into details we just mention that the original framework has been adapted to our mobile ad-hoc scenarios based on semantically-enhanced SDP. In our RFID setting a user request is built from the initial interest in a specific resource; the system can suggest similar goods but also goods to be used in combination with the picked up one. To this aim, a two-step discovery is performed, exploiting two related ontologies. In the first step *rankPotential* algorithm cited above is exploited to retrieve correspondences with the request and to identify similar resources. Not compatible ones are ranked in the second step by means of *rankPartial* . The hotspot will thus provide two different lists of records, respectively for resources in a potential correspondence with the request and in a partial one. In advanced mobile environments, the match between a request and a provided resource involves not only the description of the resource itself, but also data-oriented contextual properties. An overall utility function has to combine these values with matchmaking results, in order to give a global match measure. In the proposed framework the utility function is based on price (in US dollars), estimated delivery time (in days) and specific product categories, as shown in Table 4. The utility function has a two-fold expression, for potential and partial matches (similar resources and to be combined ones, respectively). In both formulas the leading term is represented by the semantic match. A higher utility function value corresponds to a better match.

4.2 Leveraging ONS for Ontology Support

The *Object Naming Service (ONS)* [16] mechanism is a supplementary system to grant the so-called ontology support. Note that the whole proposed system is basically structured as a MANET. Hence, in case the reader does not manage the ontology w.r.t. the tag annotation is expressed, it needs to retrieve the related DIG file via the Internet.

and *WordCount* respectively are the starting address and the number of memory words to be read; if *WordCount* is 0, the tag will send all the memory words up to the end of the selected bank.

Hence we use the ONS service planning to register within the *EPCglobal Network Protocol Parameter Registry* the new *dig* service suffix. It will indicate a service able to retrieve ontologies with a specified OUUID value. Of course the same could be done for OWL. In case of EPC derived from the GS1 standard [17], we reasonably assume that the pair of fields used for ONS requests and referred to the manufacturer and to the merchandise class of the good, will correspond to a specific ontology. In fact that pair identifies exactly the product category. Two goods with the same values for that field parameters will be surely homogeneous or even equal.

5 Case Study

An agent-based middleware integrating RFID and Bluetooth environments at the application layer has been developed upon *IBM WebSphere RFID Tracking Kit* [18] to verify the approach in a mobile marketplace setting. As mentioned above, a virtual consumer electronics store was selected as case study. Annotations of products in the marketplace is referred to a consumer electronics ontology, marked with a specific identifier we indicate $OUUID_E$. The store hotspot performs semantic matchmaking of resource annotations, exploiting a reasoner that executes *rankPotential* and *rankPartial* algorithms. In the proposed approach we adopted *MAMAS-tng* [11]. Let us suppose Claire is looking for a new laptop computer. She notices a quite cheap notebook model, bundled with an office productivity suite. She puts it into the smart shopping cart. Sensor detects the customer took a product. The RFID reader is triggered and reads data stored within the tag attached to the laptop package, as described in Section 4. Then it is deactivated again. Tag data consists of product EPC, ontology identifier $OUUID_E$, annotated semantic description (stored as a DIG expression in a compressed encoding) and contextual parameters. Let us suppose that tagged description corresponds to a notebook with Intel Centrino Core Duo CPU, 1 GB RAM, 80 GB hard disk drive, DVD writer and wireless LAN connectivity; it has Windows XP Home Edition OS and an office software suite. The equivalent expression in DL formalism is:

– $notebook \sqcap \forall has\_CPU.Intel\_centrino\_core\_duo \sqcap \forall has\_HDD.hard\_disk\_80\_GB \sqcap \forall has\_disc\_recorder.DVD\_rec\_16X\_6X \sqcap \forall has\_ram.ram\_1\_GB \sqcap \forall has\_cards.wireless\_802\_11\_card \sqcap \forall has\_OS.Windows\_XP\_Home\_edition \sqcap \forall has\_software.suite\_office$

w.r.t. $OUUID_E$ reference ontology. Price is \$550, delivery time is 0 days and product category is 3.

The tablet touchscreen shows the received product details for building further semantic based requests. Let us suppose Claire likes her choice. Now she would like to find some basic accessories. She confirms the system-recommended request, which is submitted via the semantic-enhanced Bluetooth SDP from the smart shopping cart to the hotspot. Let us suppose the following products are available in the consumer electronics store knowledge base:

– **S1:** notebook with AMD Athlon XP-M CPU, 1 GB RAM, 80 GB hard disk drive, DVD writer and wireless LAN connectivity. It is bundled with Windows XP Professional and antivirus software. Price is \$599; delivery time is 0 days; product category is 2:

Table 5. Matchmaking results.

Supply	Compatibility (Y/N)	*rankPotential* score	*rankPartial* score	$f(\cdot)$
S1: notebook with antivirus	Y	6	-	0.001
S2: notebook with office suite	Y	3	-	0.236
S3: desktop computer	N	-	79	0.166
S4: notebook bag	N	-	26	0.502
S5: UMTS phone	N	-	23	0.443

$notebook \sqcap \forall\ has\_CPU.AMD\_Athlon\_XP\_M \sqcap \forall\ has\_HDD.hard\_disk\_80\_GB \sqcap \forall\ has\_disc\_recorder.DVD\_rec\_16X\_6X \sqcap \forall\ has\_ram.ram\_1\_GB \sqcap \forall\ has\_cards.wireless\_802\_11\_card \sqcap \forall\ has\_OS.Windows\_XP\_Professional \sqcap \forall\ has\_software.antivirus$

- **S2:** notebook with Intel Centrino Core Duo CPU, 1 GB RAM, 80 GB hard disk drive, DVD writer and wireless LAN connectivity. It is bundled with Linux and an office suite. Price is \$529; estimated delivery time is 1 day; product category is 2:
  $notebook \sqcap \forall\ has\_CPU.Intel\_centrino\_core\_duo \sqcap \forall\ has\_HDD.hard\_disk\_80\_GB \sqcap \forall\ has\_disc\_recorder.DVD\_rec\_16X\_6X \sqcap \forall\ has\_ram.ram\_1\_GB \sqcap \forall\ has\_cards.wireless\_802\_11\_card \sqcap \forall\ has\_OS.Linux \sqcap \forall\ has\_software.suite\_office$
- **S3:** a desktop computer with Intel Pentium 4 CPU, 1 GB RAM, 250 GB hard disk drive, DVD writer, wireless LAN connectivity and a LCD display. It is bundled with Windows XP Home Edition and an office suite. Price is \$499; delivery time is 0 days; product category is 2:
  $desktop\_computer \sqcap \forall\ has\_CPU.Intel\_Pentium\_4 \sqcap \forall\ has\_HDD.hard\_disk\_250\_GB \sqcap \forall\ has\_display.LCD\_display \sqcap \forall\ has\_disc\_recorder.DVD\_rec\_16X\_6X \sqcap \forall\ has\_ram.ram\_1\_GB \sqcap \forall\ has\_cards.wireless\_802\_11\_card \sqcap \forall\ has\_OS.Windows\_XP\_Home\_edition \sqcap \forall\ has\_software.suite\_office$
- **S4:** a blue notebook bag. Price is \$19; delivery time is 0 days; product category is 2:
  $notebook\_bag \sqcap \forall\ has\_color.blue$
- **S5:** a silver-colored UMTS mobile phone with dual display and miniSD memory card support. Price is \$169; delivery time is 0 days; product category is 1:
  $mobile\_phone \sqcap \forall\ has\_connectivity.UMTS \sqcap \geq 2\ has\_display \sqcap \leq 2\ has\_display \sqcap \forall\ has\_display.LCD\_display \sqcap \forall\ has\_memory\_card.mini\_sd$

The hotspot performs the discovery and matchmaking processes as described in Section 4.1 and returns results via Bluetooth SDP. Matchmaking results for this example are presented in Table 5. The second column shows whether each retrieved resource is compatible or not with request R. If yes, the *rankPotential* computed result is shown, otherwise the *rankPartial* computed result is presented. In the last column results of the overall utility function are reported.

Note that $S2$ is ranked as the best supply for similarity match, despite a longer delivery time than $S1$. This is due to a better *rankPotential* outcome. Among candidate resources for combination, category affinity favors $S4$ over $S5$, while $S3$ has a clearly poorer match. For each retrieved resource a picture is provided along with matchmaking score, price and description, as displayed in Figure 2. After finalizing her purchase, Claire leaves the shopping cart in the store cart rack. This event is detected and the tablet touchscreen returns to a quiescent state, waiting for another customer.

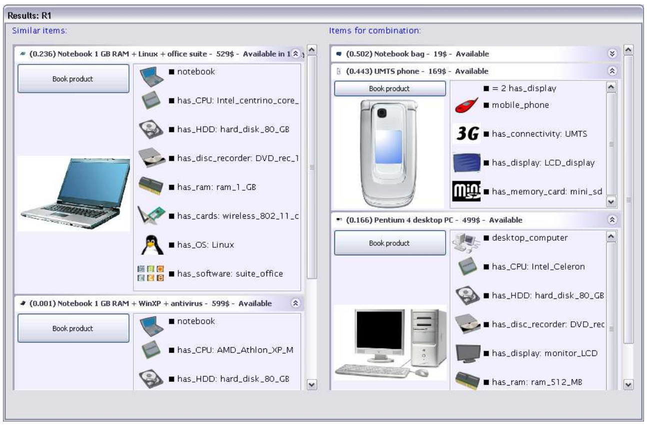

Fig. 2. Retrieved resources are shown to the user.

6 Conclusion

In this paper we proposed a unified framework integrating RFID technologies with enhanced Bluetooth Service Discovery Protocol supporting formal semantics. Objects tagged with RFID transponders carry a semantically annotated description so permitting to implement an advanced object discovery. Some slight modifications to the EPCglobal standards have allowed the support to ontology-based data as well as to non standard inference services, while keeping backward compatibility. The system has been implemented within a message-oriented commercial middleware in order to test the feasibility and the usability of the proposed solution.

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References

1. Weinstein, R.: Rfid: A technical overview and its application to the enterprise. IT Professional **07** (2005) 27–33
2. Ruta, M., Di Noia, T., Di Sciascio, E., Donini, F.: Semantic-Enhanced Bluetooth Discovery Protocol for M-Commerce Applications. International Journal of Web and Grid Services **2** (2006) 424–452
3. Watson, R., Pitt, L., Berthon, P., Zinkhan, G.: U-Commerce: Expanding the Universe of Marketing. Journal of the Academy of Marketing Science **30** (2002) 333–347
4. Römer, K., Schoch, T., Mattern, F., Dübendorfer, T.: Smart Identification Frameworks for Ubiquitous Computing Applications. Wireless Networks **10** (2004) 689–700

5. De, P., Basu, K., Das, S.: An ubiquitous architectural framework and protocol for object tracking using RFID tags. In: The First Annual International Conference on Mobile and Ubiquitous Systems:Networking and Services (MOBIQUITOUS 2004). (2004) 174–182
6. Hum, A.: Fabric area network a new wireless communications infrastructure to enableubiquitous networking and sensing on intelligent clothing. Computer Networks **35** (2001) 391–399
7. Schmidt, A., Gellersen, H., Merz, C.: Enabling implicit human computer interaction: a wearable RFID-tagreader. In: The Fourth International Symposium on Wearable Computers. (2000) 193–194
8. Siegemund, F., Florkemeier, C.: Interaction in Pervasive Computing Settings using Bluetooth-Enabled ActiveTags and Passive RFID Technology together with Mobile Phones. In: Proceedings of the First IEEE International Conference on Pervasive Computingand Communications (PerCom 2003). (2003) 378–387
9. Kawakita, Y., Wakayama, S., Hada, H., Nakamura, O., Murai, J.: Rendezvous enhancement for conference support system based on RFID. In: International Symposium on Applications and the Internet Workshops (SAINT2004). (2004) 280–286
10. Traub, K., Allgair, G., Barthel, H., Bustein, L., Garrett, J., Hogan, B., Rodrigues, B., Sarma, S., Schmidt, J., Schramek, C., Stewart, R., Suen, K.: EPCglobal Architecture Framework. Technical report, EPCglobal (2005)
11. Di Noia, T., Di Sciascio, E., Donini, F., Mongiello, M.: A System for Principled Matchmaking in an Electronic Marketplace. International Journal of Electronic Commerce **8** (2004) 9–37
12. W3C Recommendation: OWL Web Ontology Language. www.w3.org/TR/owl-features/ (2004)
13. Bechhofer, S., Möller, R., Crowther, P.: The DIG Description Logic Interface. In: Proceedings of the 16th International Workshop on Description Logics (DL'03). Volume 81 of CEUR Workshop Proceedings. (2003)
14. Baader, F., Calvanese, D., Mc Guinness, D., Nardi, D., Patel-Schneider, P.: The Description Logic Handbook. Cambridge University Press (2002)
15. Epcglobal Inc.: EPC Radio-Frequency Identity Protocols Class-1 Generation-2 UHF RFID Protocolfor Communications at 860 MHz–960 MHz. Technical report, EPCglobal (2005)
16. EPCglobal Ratified Specification: Object Naming Service (ONS - ver. 1.0). http://www.epcglobalinc.org (October, 4, 2005)
17. EPCglobal: (http://www.epcglobalinc.org)
18. Chamberlain, J., Blanchard, C., Burlingame, S., Chandramohan, S., Forestier, E., Griffith, G., Mazzara, M., Musti, S., S.-Y.Son, Stump, G., Weiss, C.: IBM WebSphere RFID Handbook: A Solution Guide. IBM International Technical Support Organization (2006)