

Alternative RFID based Architectures for Mobile HCI with Physical Objects

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ABSTRACT

High Frequency (HF) passive Radio Frequency IDentification (RFID) is currently a widely adopted technology for mobile HCI with physical objects. Prototypes, pilot projects and industrial systems have been developed in a number of areas mostly following an approach in which RFID tags are either attached to mobile real world entities or carried by mobile users, whilst RFID readers are static and fully integrated into back-end information systems. With RFID readers increasingly embedded on mobile devices, another approach where readers are mobile and tags are static can be followed, depending on conditions and context of use. In this paper we propose an initial simple classification of alternative RFID based architectures following these two interaction approaches and we discuss a generalisation of relevant factors affecting the choice of an RFID based architecture fitting well with a specific domain. Finally, we assess the impact of these alternative RFID architectures on a set of recently proposed usability heuristics for mobile computing.

1. INTRODUCTION

High Frequency (HF) passive Radio Frequency IDentification (RFID) [5] is currently the worldwide most popular and largely adopted radio frequency technology used to interact with real world physical objects. Among the factors contributing to HF passive RFID¹ success, there are a progressive emergence of widely employed standard protocols (e.g ISO and EPCglobal), a complete deregulation in the use of the HF spectrum and the availability of systems (tags and readers) at increasingly lower prices. RFID based prototypes, pilot projects and industrial systems have been conceived, developed and also deployed to the market mainly in areas such as supply-chain tracking of inventory, access control, luggage tracking, electronic payment systems, homeland security, livestock history, library tracking of books and reshelving assistance (see also [9], [10]). Most of the above solutions follow a *Static Reader - SR* approach in which tags are supposed to be either attached to mobile real world entities they identify or carried by users, whilst readers are meant to be static and fully integrated into back-end information systems. New solutions following a *Mobile Reader - MR* approach, where readers are mobile (e.g. on Nokia 3220) and tags are static (cf. [7]), are also currently being devised.

¹hereafter referred to only as RFID

In this work we investigate the most suitable contexts (and related issues) in which to use SR and MR approaches and their specific interaction patterns. In particular, we consider scenarios in which mobile users exploit RFID based systems to receive customised information (triggered by tags) either directly on their own mobile devices or by means of some presentation mechanism provided by back-end systems (e.g. LCDs in a shopping centre, printed out maps at a point-of-interest, spoken messages at an access control area). We present some initial steps to help designers and developers focus more clearly on relevant issues, while devising RFID based systems to interact with real world physical objects. The paper is organised as follows: in Section 2 we propose an initial, simplified classification of alternative RFID based system architectures with respect to an SR or MR approach. In Section 3, we show by examples (including one we are currently working on) how real systems can be mapped to these architectures and in Section 4, on the basis of these examples, we provide a generalisation of factors influencing the choice of RFID system architectures. In Section 5 and 6, we respectively discuss how these architectures may impact on a set of heuristics recently introduced to evaluate mobile systems and we conclude with directions for future work.

2. A CLASSIFICATION OF RFID BASED ARCHITECTURES

At a very abstract level, in both the aforementioned SR and MR approaches the information managed by RFID based systems flows through the following functional blocks: initial reading of tags, information customisation on the basis of read input and final presentation of results. For the sake of simplicity, we will restrict our attention to the reading of RFID tags, namely writing of tags is not considered. The reading of tags also includes here possible communication feature with remote systems and the customisation includes both profiling and data management features. Depending on the deployment of the above mentioned functional blocks, it is possible to imagine the following alternative RFID based architectures (see Figure 1):

- *Back End based Architecture (BEA)*. This is an SR based architecture in which all functional blocks belong to the back-end system.
- *Full Mobile Device based Architecture (FMDA)*. This

is an MR based architecture in which all functional blocks belong to the mobile device. In other words, all the information presented to the user is read from a tag and possibly combined with additional information previously read and already available on the device.

- *Partial Mobile Device based Architecture (PMDA)*. This is an MR based architecture in which the mobile device is used to read a tag and send the information to the back-end which customises the received information and sends it back to the mobile device for final presentation.

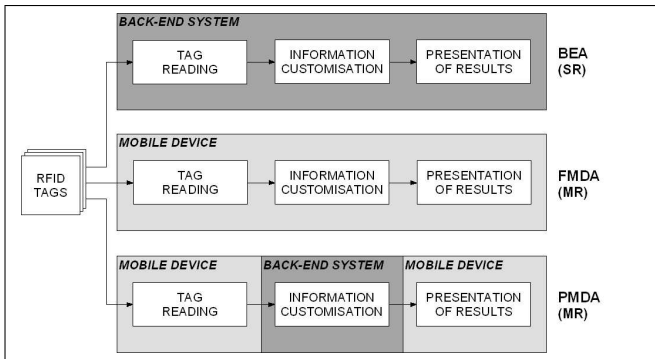


Figure 1: Alternative architectures

3. MAPPING SYSTEMS TO ALTERNATIVE RFID BASED ARCHITECTURES

In this section, we show how real world RFID based systems can be related to our classification and mapped to the SR and MR approaches. In particular, we begin by presenting specific examples which are fitting well only with one of the proposed architectures. Then, we introduce a work-in-progress prototype that we are currently developing following both the SR and MR approaches.

Typical BEA example

Consider the example of a library that uses RFID technologies to support the tracking of books borrowed by readers (as in [2] for instance) and to suggest possible related items when choices are made. In this scenario a few things can be observed: people who borrow books are usually regular visitors to a library and may want to let the library know about their preferences and interests; books are entities which need necessarily to be moved; information about books and their location on the shelves as well as on readers who borrow books are usually already available on back-end systems under the library's control; mechanisms to provide a matching of books and readers' interests can be easily implemented on back-end systems and can be already available; people are mostly interested in receiving suggestions and further information about books when they are in the library; the borrowing operation is usually performed at an established library's checkpoint (e.g. the till) and its overall completion time is expected to be low (e.g. to avoid queues).

It seems natural to augment such a scenario by using RFID tags on books and users in a "barcode-like" fashion. The quick reading of tags (there is no further information in addition to an id) can be easily integrated into the back-end

which already provides both the information customisation and the presentation of results.

Typical FMDA example

RFID technologies can be employed to provide extra information about wine assisting users when they have to choose a bottle. In this scenario, users may want to be advised about wines matching their drinking preferences and taste before buying or ordering a bottle. In this case, the interaction experience is typically not restricted to a single place, but users may need assistance in different sites (e.g. supermarkets, restaurants, cafes, pubs) which usually have no previous records about them and cannot perform any matching operation and customisation. Moreover, users may be interested in changing their preferences at runtime before making their choice. Extra information about wines can be assumed to be available locally (e.g. through specific encodings). Finally, customised information on found matches are expected to be sent privately to users and possibly presented on different channels according to their preferences and specific needs (e.g. sight or hearing problems).

The most straightforward way to augment such a scenario is by RFID tagging labels on bottles with all the additional encoded information (as also discussed in [6]) and by keeping all functional blocks on users' mobile devices. Depending on adopted encoding techniques, information on tags can be used directly on mobile devices and no further communication with remote systems is needed. Configuration of profiles and presentation channels can be managed on mobile devices via a specific application.

Typical PMDA example

Imagine a directory service used to retrieve information on real world's objects (cf. [3] and its examples). While on the move, users can be informed of specific details regarding objects and possibly related services (as also in [11], [4]). Information can be filtered and provided on a number of channels depending on mobile users' preferences and context. This is an inherent mobile scenario where users keep going from one object to another and possibly search for information in different spots (there is not a unique checkpoint). Extra information provided on objects and possible associated services can be large. Context is frequently changing and so are conditions of use (e.g. stopping by an object or just passing by it). Users' preferences need to be easily configurable depending on these conditions (e.g. the maximum number of details about objects, the favourite presentation channels). Users do not want to impact too much on mobile devices' resources (e.g. batteries, processing power).

In this scenario, it seems useful to provide users with a mobile device capable of reading RFID tags associated with real world objects. These tags contain indirect information about objects (e.g. an index, a link, a url) which is used on the mobile device to connect to a back-end and trigger a content customisation according to specific profiles. Based on the requested information and on these preferences, the back-end can prepare the retrieved information accordingly and send it back to the mobile device for the appropriate presentation.

An example supporting alternative architectures

There is a possible need for the food industry, public health educators and policy makers to imagine new ways to in-

fluence and perhaps drive improved people's decision making and behaviours related to food consumption (cf. [8]). We are developing an RFID based automatic personal assistant to food choice during out-of-home eating. With such a tool menus in food assets (e.g. restaurants, cafes, pubs) can be customised according to personal nutritional profiles (allergies, intolerances, diets, calories intake) and also budget information. In the current scenario, users go to a food and drinking asset to stay there. They are accustomed to making a decision about their meal after reading available courses on paper made menus or boards (i.e. physical objects). Decision time is usually not a relevant issue (i.e. people can take their time). Moreover, food and drinking establishments can already have in place back-end systems handling information on menus and courses. On the other hand, customers may want to keep their nutritional profiles and budget information private and may need to change this information to receive different customisations presented on a number of alternative channels.

Given the nature of this scenario, it is possible to imagine a typical BEA in which information on menus and courses in back-end systems are enhanced with further details about ingredients and calories. This can have in general a low impact on back-end business processes. Users carry an RFID tag containing their encoded profiles and scan this tag on a reader which needs to be integrated into the back-end and conveniently located in the asset. The back-end performs the profile reading and customises the responses accordingly presenting suitable results and suggestions on a nearby screen with a printing option to preserve a traditional interaction pattern with a physical menu. At the same time, in an alternative FMDA, menus are augmented with RFID tags containing encoded extra information on courses' ingredients and calories. Users can scan the menus with their mobile device which reads the tags and customises the response on the basis of personal profiles configured and managed only by an ad hoc personal application. If on one side both the generation of tags and the provisioning of the mobile application can have a significant impact on back-end business processes, on the other side this last alternative makes the assistance a more private experience and lets users have higher control on their profile configuration.

4. RELEVANT FACTORS IN THE CHOICE OF AN RFID BASED ARCHITECTURE

Based on the given examples, it seems possible to provide a generalisation of items affecting and guiding the choice of possible alternative architectures for RFID based solutions:

- I1-User runtime configuration of applications
- I2-System context of use
- I3-Size and type of information (direct vs. indirect) exchanged between tags and readers
- I4-Information management and customisation
- I5-Information presentation
- I6-Information privacy, security and system trust

Intuitively, an increasing importance of I1 should favour an MR approach (where users can have runtime applications at

their disposal) and is therefore an obstacle to a BEA adoption. As about I2, contexts which are tightly integrated into a back-end can clearly justify an SR approach as can inherently nomadic contexts in which users go to different sites and are resolved to make a stop there. In these sites checkpoints are expected to be located in precise and static spots where users can even accept to queue to interact. On the other hand, mobile contexts with a very high frequency of movements and with no easy integration into the back-end prompt to MR approaches and are therefore a driver to FMDA or PMDA. In I3, an increasing size of tags and the availability on them of direct information (immediately usable on the mobile device) can be a driver to FMDA. In fact, more concurrent and independent mobile readers can access in parallel the information on a tag, whereas in BEA only one static reader is used and in PMDA a further latency in final response time can be expected due to communication with the back-end and to the back-end completing the information customisation. Indirect information (e.g. links, urls) are instead a driver to either BEA or PMDA where remote processing is involved to use the information coming from tags. An increasing importance of I4 and I5 are both an obstacle to FMDA, as they can be highly demanding in terms of processing power, whereas when item I6 becomes an issue an MR approach should be favoured either via FMDA or PMDA, where users are more directly in control of critical information and system behaviour.

5. RFID BASED ARCHITECTURES AND MOBILE USABILITY HEURISTICS

In [1] the authors describe a new heuristic-based evaluation methodology for mobile computing and propose a set of usability heuristics that are relevant to mobile human computer interaction. In the following we complement the discussion presented in the previous section by assessing the impact of the identified alternative RFID system architectures on this set of eight heuristics.

H1 - Visibility of system status and losability/ findability of the mobile device. In BEA the system status is invisible to end users as the back-end fully controls the information flow by hosting all functional blocks. If mobile tags (the only mobile devices in such case) get lost, only a relatively small amount of information (depending on tags memory size) is lost and, in any case, the back-end may prevent a malicious use of this information through ad hoc policies (e.g. black list mechanisms). On the other hand, FMDA relies on local personal profiles which might result in a more serious risk for users in case of theft or loss of mobile devices. Finally, with respect to other contextual issues affecting losability and findability of mobile devices hosting RFID readers (increasing energy consumption), battery status is relevant in both FMDA and PMDA and an adequate network coverage is also required in the latter.

H2 - Match between system and the real world. All the architecture options available in our classification employ RFID tags to enrich the user experience by means of either additional or personalised information. In particular, in a BEA the back-end system can be seen as an invisible system having the capability to sense the surrounding environments and automatically present information and services to nearby users. The underlying transparent match

of these services with real world RFID tagged objects can require only minimal changes to user behaviour during interaction. As about FMDA and PMDA, an additional burden to user interaction patterns is represented by the need of becoming familiar with the RFID reader available on the mobile device. Scanning of real world objects must be swiftly integrated with traditional presentation mechanisms

H3 - Consistency and mapping. Basically, every option in our architecture classification preserves the traditional interaction pattern users are accustomed to. In BEA, as RFID tags and readers interact transparently in the smart environment, it is possible to smoothly keep a consistency with the interaction context. Users may take advantage of specific enhanced features (e.g. automatic profiling, accounting, tracking) implemented on the back-end systems without even having to provide any explicit input interaction. Traditional behaviours may already trigger mobile human computer interactions consistent with the environment (e.g. a user passing a gate, or scanning a wallet containing an RFID tag to receive customised information). In FMDA and PMDA, due to possible physical limitations of mobile devices' interaction functions and to changing conditions of use, automatic mechanisms should be devised to consistently map the scanning of RFID tagged real objects with corresponding tasks on the device (e.g. automatic opening of a visual browser to retrieve and show an object's specific properties, automatic execution of an embedded TTS to speak out messages related to a service associated with a physical object)

H4 - Good ergonomics and minimalist design. In BEA mobile RFID tags are embedded in real world objects and their progressive miniaturisation should provide a good ergonomics and a minimalist design almost by definition. In FMDA and PDMA issues may arise about the use of an integrated RFID reader into mobile devices, although this is more a hardware related problem and manufacturers already benefit from well established studies and knowledge on ergonomics for mobile devices. Furthermore, since applications for every classified RFID architecture are typically well defined and restricted to specific domains, it is possible to imagine a suitable design of interfaces on different and complementary presentation channels.

H5 - Ease of input, screen readability. In all RFID based system architectures, RFID tags are used by definition to input data which are transmitted transparently to nearby RFID readers. As previously discussed, BEA does not need in general any other additional mobile input device since all the computations are triggered by RFID tag readings. Instead, in FMDA and PMDA there is possibly the need of a further interaction on the mobile device with the input read on tags, although this is not strictly required. On the other hand, screen readability is an issue in both FMDA and PMDA, although the former is more likely to provide easy-to-glance presentation mechanisms due to the possibly small amount of information coming from tags.

H6 - Flexibility, efficiency of use and personalization. In general, BEA seems to be the less flexible solution, because it relies on a static ad hoc infrastructure equipped with RFID readers and possibly a number of fully integrated

presentation devices (i.e. LCDs, TTS). Moreover, personalization of system output according to changing contextual needs is tightly bound to the configuration of the back-end applications and possibly the update of information on RFID tags. These can be both inefficient operations. On the other hand, in both FMDA and PMDA, users have a personal and more direct access to information coming from RFID tags and context-dependent suggestions may be provided on mobile devices upon reading of information coming from real world objects. In particular, in FMDA personal profiles and customisation rules can be changed locally at runtime depending on the context.

H7 - Aesthetic, privacy and social conventions. BEA is more tolerant to social conventions and traditional interaction patterns as it is essentially based on a transparent reading of tags which should not affect habits and interaction patterns. Users are hardly requested to change their behaviours if only a simple RFID tag scanning is expected. Instead, privacy issues may arise in BEA and PMDA due to requirements of sending possibly sensitive information to back-end applications for further processing users have no control on. On the other hand, in FMDA user profiles and sensitive information used for customisation of output results are kept private and safe on the mobile device, although this may require novel interaction patterns users have to get used to.

H8 - Realistic error management RFID may fail due to collision problems and/or out-of-range readings. Anti-collision protocols exist and are used to cope with these possible failures and errors which will be managed either on the central back-end systems (in BEA) or locally on each mobile device (in FMDA and PMDA). Furthermore in BEA and PMDA, network disconnections or excessive latencies and delays in the output presentation might produce misbehaviours which need to be dealt with. In both cases, either the back-end system or the mobile device should be able to alert the user and provide alternative ways to safely complete the interaction experience with RFID tagged objects.

6. CONCLUSIONS AND FUTURE WORK

In this paper we have described the initial steps towards the assessment of possible RFID based system architectures which can be used to interact with physical objects. RFID is currently a widely adopted technology employed in mobile HCI with the real world and our first goal is to start describing and discussing relevant issues for designers and developers of RFID based systems and applications. Our main contributions towards achieving this goal have been: an initial classification of RFID based architectures depending on two possible interaction approaches (SR and MR); on the basis of real world examples, a generalisation of relevant factors affecting the choice of an RFID based architecture fitting well with a specific domain; a more in-depth analysis of the impact that RFID based architectures have on a recently proposed and validated set of heuristics for mobile computing.

We intend to further investigate all these aspects in the coming future to possibly verify the feasibility of a more systematic approach or a methodology to follow while devising RFID based solutions to interact with real world physical objects in mobile scenarios.

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