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Simplifying Human to Environment Interaction through Touch Computing

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Abstract. This work analyses the use of NFC technology to simplify the interactions of users with context-aware services offered by intelligent environments. Touch Computing is a novel explicit user interaction mechanism in which users accompanied by their NFC-enabled mobile devices request services from the environment by touching tags or other NFC-enabled devices. This paper describes the deployment of three NFC-aware services within SmartLab, our AmI-dedicated lab, and the user experience derived from them. Moreover, it analyses the possibilities offered by the current state of the art on NFC and suggests some future lines of work, which may revert into its more widespread deployment in the near future.

Keywords. AmI, human-environment interaction, NFC, Internet-of-Thing.

1. Introduction

The promotion of natural user interaction to access surrounding intelligent services is one of the main goals of Ambient Intelligence. Using the current context of a user (location, identity or current action) as implicit input and voice commands or movement (i.e. natural interaction) as explicit input, an AmI environment adapts to the user preferences and habits. As a result of these implicit or explicit inputs, the environment reconfigures and changes its behaviour by triggering and activating services which aid users in their daily activities. Besides, AmI environments undertake these adaptations without the users being aware of the underlying sensing and computing infrastructure which makes it possible.

An interesting technology which has emerged in the last year and which seems as an ideal candidate to help on providing a more natural way of interaction between the user and the environment is Near-Field-Communication (NFC). This technology is a combination of contact-less identification and interconnection technologies that enables wireless short-range communication between mobile devices, consumer electronics, PCs and smart objects. NFC offers a simple, touch-based solution that allows consumers to exchange information and to access content and services in an intuitive way.

Thus, the emergence of NFC should simplify human to environment interaction, giving place to the Touch Computing paradigm, where users have only to wave their representing mobile devices in front of everyday objects augmented with RFID tags and visual markers or other NFC-aware devices in order to trigger the intelligent services offered by them. In fact, the combination of RFID and visual tagging of everyday physical objects and NFC-enabled devices will foster the Internet-of-Things [1][6] where every resource that surrounds us and its associated services are available through some kind of networking (Bluetooh, Wi-Fi, GPRS/UMTS) and programming infrastructure (web service, semantic web service, RSS feed and so forth). In order to progress towards the upcoming Internet-of-Things and the realisation of AmI is important to start experiencing with the application of NFC technology in the provision of the intelligent services within our environment that they provide. Undoubtedly, the consumption and triggering of such services will be improved by the Touch Computing provision enabled through NFC.

In order to study the interest of applying NFC technology and its associated Touch Computing paradigm to AmI, three NFC-aware services have been developed and deployed within SmartLab (www.smarlab.deusto.es), our research laboratory dedicated to AmI. The selection of these three services has been based on the current NFC application domain taxonomy published by the NFC Forum [5] and summarised in the following three types: a) service initiation and configuration, b) P2P data sharing and communication and c) payment and ticketing. Three services corresponding to the first and second application domain, less commercially oriented than the third one, but more suitable for the interaction with environment services through Touch Computing, have been chosen. In the service initiation and configuration domain, the following two services are analysed:

- *Touch2Open*, an NFC-aware service to enable a user to open the door of his office by simply approaching a mobile device to an RFID tag on the door.
- *Touch2Launch*, a service which complements our Internet-of-Things enabling platform, namely Sentient Graffiti (www.smartlab.deusto.es/dsg), by enabling the automatic activation and configuration of its mobile client by pointing an NFC device to an RFID tag.

On the other hand, belonging to the P2P category the following service is proposed:

- *Touch2Print*, a service to enable users to print files by simply approaching an NFC-enabled mobile device bound to a PC to a printer.

The structure of this paper is as follows. Section 2 offers an overview of work developed by other researchers on human to environment interaction through mobile phones, NFC and middleware for the Internet-of-Things. Section 3 describes the Touch2Open service and discusses some user experience issues with it. Section 4 does the same with the Touch2Launch service, whilst section 5 describes our most innovative service Touch2Print, which attempts to put in practice the pairing of two devices in a simple manner through an NFC mobile. Finally, section 6 draws some conclusions and discusses some further work.

2. Related Work

Several researchers [8][10][12][13] have studied the prominent role that mobiles devices which accompany their owners everywhere at anytime are going to play as intermediaries between them and their environment. Those devices equipped with the latest communication (Bluetooth, Wi-Fi, GPRS/UMTS), sensing (GPS, RFID readers, NFC [4] or cameras) and computation (Java ME, Compact .NET, Symbian) infrastructure are most suitable than ever to act on behalf of the user and discover, negotiate, activate or offer intelligent services to them. In essence, if the web browser has been the agent that has fostered Internet usage, the mobile phone with its accompanying sensing and computation facilities will be the main interaction agent in the upcoming Internet-of-Things [6].

NFC [3][9] is a short-range wireless connectivity standard that has evolved from a combination of contactless, identification, and networking technologies. The NFC range extends to approximately 20 cm and it is complementary to existing longer range wireless technologies, such as Bluetooth and Wi-Fi. NFC operates in the unregulated radio-frequency band of 13.56 MHz and is interoperable with existing contactless smartcard and RFID standards. A typical exchange using NFC involves an initiator device that initiates and controls the exchange of data and a target device that answers the request from the initiator. The data acquired is usually very precise and structured. It is an open interface platform that allows fast and automatic set-up of wireless networks, which also works as a virtual connector for existing cellular, Bluetooth and wireless 802.11 devices.

NFC is compatible with Sony's FeliCa card and the broadly established contactless smart card infrastructure based on ISO 14443 A, which is used in Philips' MIFARE technology. To drive development and adoption of NFC, Philips, Sony and Nokia established the NFC Forum, a non-profit industry association which promotes implementation and standardization of NFC technology to ensure interoperability between devices and services. The NFC Forum [9] has currently more than 70 members around the globe including MasterCard International, Panasonic, Microsoft, Motorola, NEC Corporation, Nokia, Samsung, Sony, Philips, Texas Instruments and Visa International. The following three categories of services may be available according to a NFC Forum whitepaper [5]:

a) *Service initiation and configuration* – The user touches an NFC-enabled device, e.g. a mobile phone, against a specially located NFC tag on everyday objects, such as posters, bus stop signs, street signs, medicines, certificates, and food packaging, which then typically provides a small amount of information to the device. This could be some lines of text, a web address (URL), phone number or other simple piece of data, which the user can then use to obtain information about such object or connect to its representing computing service. This application type is based on existing tag and card technologies, thus minimizing start-up costs, and being the most adopted application form.
b) *P2P (peer to peer) data sharing and communication* – NFC is used to enable communication between two devices so that data can be transmitted locally between the two. If the amount of information is relatively small (up to one kilobyte), it is possible to use NFC to transmit the data itself. However, a more common peer-to-peer scenario is likely to be when NFC is used to establish another wireless connection method (such as Bluetooth or WiFi) to carry the information to be shared. This type of application is together with the previous form the best candidate for being applied to Ubiquitous Computing scenarios.
c) *Payment and ticketing* – NFC enables smartcard payment and smart ticketing scenarios to be developed further by enabling any NFC-enabled device to be used as a payment and ticketing device – i.e. as an ‘electronic wallet’.

> Ultimately this would replace the myriad credit, debit, loyalty, pre-paid and other cards that people carry around in their wallets today. NFC phones also offer enhanced security, enabling the user to protect the secure applications through the phone's user interface features. Contactless-payment and contactless-ticketing infrastructures through NFC has an important business push behind and several organisations such as VISA, MasterCard or mobile operators are very keen their widely adoption. There are already some commercial deployments such as the payment of public transport in the German city of Hanau through NFC mobiles.

The Nokia 6131 NFC SDK [4] allows developers to create and emulate Java applications (MIDlets) for the Nokia 6131 NFC mobile phone. The SDK includes the Contactless Communication API (JSR 257), which enables the use of the Near Field Communication (NFC) features of the Nokia 6131 NFC phone. In addition to the standard JSR 257 API, the SDK includes extensions for several tag technologies, peer-to-peer connections, and branding configuration. The Nokia 6131 NFC SDK contains a Nokia 6131 NFC phone emulator, Java APIs, example MIDlets, and documentation. This is the tool that we have used to implement the three NFC-aware services described in this work.

There have been already some earlier research experiences analysing the role NFC will play in AmI. Broll et al. [1] have applied NFC and Semantic Web technology to automatically generate mobile user interfaces from objects tagged with RFID or visual markers. Their goal is to offer a middleware platform to enable the Internet-of-Things. Bravo et al. [2] have used RFID and RFID-readers to extract activity identification context with mobile phones and so activate services by touching or proximity in classroom and conference sites. Krisnamurthy et al. [7] have used near-field-communication to automatically adapt the profile mode (silent, meeting, normal) of mobile phones based on their current context, so that the disturbances associated to mobile phones in sensible settings such as hospitals, conference halls or lectures, are avoided. The Touch Project [14] aims to promote the Touch Computing interaction paradigm as a mechanism to link mobile phones and physical things. Their interdisciplinary team is developing applications and services that enable people to interact with everyday objects and situations through their mobile devices. Their main goal is to achieve real deployments of NFC technology and analyse the social effects that such technology can have in our everyday life.

3. Touch2Open Service

As has been reviewed, NFC-enabled devices are meant to turn a mobile device into an electronic wallet and why not also into an electronic key that gives us access to our work premises, car or home. In order to assess the usability of such scenario, the Touch2Open service has been developed and deployed within SmartLab. So far we could enter into our research lab by swapping an RFID identification card in front of an RFID reader by the door. Unfortunately, every time a user forgot the card, they had to ring the bell of the lab so that another member inside could open the door or instead use a standard key to open the door.

The Touch2Open service aims to solve this problem by allowing users equipped with an NFC-enabled mobile phone (in our case Nokia NFC 6131 mobiles) to enter the lab when they simply place their phone in front of an RFID tag attached to the front-door. In order to prevent misuses of this service and to enhance security the user is required to enter once a day, the first time in the day when he tries to open the door, his user password which is memorised for the following interactions of the day in the Touch2Open Mobile Client application. This password is transmitted by the NFC-enabled device to a door opening service in order to be granted permission to enter the office. The architecture of the Touch2Open service consists of two main components:

- *Door Controller Web and Bluetooth Service* – this service hosted in a Bluetooth-enabled machine next to the front-door offers both a web and a Bluetooth interface front-end and has been implemented on top of the API supplied by the provider of our lab access front-door (www.dorlet.es). The web service provided offers an open() method to which the userName and password of a previously authorized user must be supplied as parameters.
- *Touch2Open Mobile Client* – this application is launched automatically every time the user places his mobile nearby the front-door RFID tag. This is possible thanks to the MIDP 2.0 Push Registry [11] specification which in the Nokia NFC 6131 enables the activation of a MIDlet (programmed with the Nokia NFC 6131 SDK), in this case the Touch2Open Mobile Client, whenever an RFID is read. The contents of the card read are processed by the MIDlet, which extracts from it the connection details to communicate the mobile device with the Door Controller Bluetooth server. Once the server connection details are processed, the Touch2Open mobile client sends the user login and password to the server that checks with the Dorlet web service whether the user has access to the office or not. If so the door is opened, otherwise it ignores the command.

Figure 1. Touch2Open Service in Operation.

Figure 1 shows how a user equipped with a Nokia NFC 6131 where the Touch2Open Mobile Client has been previously installed accesses our lab by simply approaching his mobile device to an RFID tag. Note that the screen that requests the password details of the user only appears the first time in the day that the user utilises the mobile to enter the lab. Thereafter it is remembered, as if a web session key was considered.

In essence, the Touch2Open service simplifies the access of people to their work or living environments by simply requiring them to carry a device which is always with them, i.e. their mobile phone. Moreover, the NFC technology, assisted by the Push Registry MIDP 2.0 technology, simplifies enormously the required user interaction with their mobile in order to activate an environment service. In this occasion, a touching gesture is enough to, under the hook, establish a Bluetooth connection between the mobile and a Bluetooth service and issue a door opening password-authorised request.

4. Touch2Launch Service

A second service initiation and configuration NFC-aware service has been developed, namely Touch2Launch. In this case, the goal has been to simplify the way that our Internet-of-Things platform, Sentient Graffiti (http://www.smartlab.deusto.es/dsg) [8], enables a user to retrieve public and private virtual graffitis associated to surrounding resources, i.e. smart objects, in their environments. In Sentient Graffiti, a virtual graffiti is defined as a virtual post-it note in the form of an XML document which combines some content (multimedia presentation or web service front-end) with some keywords summarising the content, and some contextual attributes (profile of creator, location, time interval and so on) which restrict who, when and where can those annotations be seen.

Sentient Graffiti is a Web 2.0-based platform designed to make the development and deployment of AmI scenarios in global (both indoor and outdoor) environments much simpler. Both mobile and web-based clients enable a user to publish, browse, search and discover based on their current context and topics interest (keywords) virtual post-it notes published by other users in the Sentient Graffiti back-end. The most interesting contribution of Sentient Graffiti is that enables augmenting everyday objects (posters, doors, locations, sculptures and so on) with software services by simply placing them in a specific geodesic location range, nearby a Bluetooth server or sticking to them visual or RFID tags. The Sentient Graffiti Mobile Client enhances user to environment interaction by enabling the following interaction mechanisms:

- *Pointing* – the user can point his camera phone to a bi-dimensional visual marker and obtain as result all the graffitis associated to such marker which are relevant and can be seen by him.
- *Touching* – the user can use a mobile RFID reader bound to a mobile through Bluetooth to touch an RFID tag and obtain all the relevant graffitis associated to that tag.
- *Location-aware* – mobiles equipped with a GPS in outdoor environments can obtain all the relevant nearby graffitis in a certain location range which are relevant to the user.
- *Proximity-aware* – the Sentient Graffiti mobile client can retrieve all the graffitis published in nearby accessible Bluetooth servers when the device is in Bluetooth range from the server.

Figure 2. Sentient Graffiti project.

Figure 2 shows a scenario where a user by means of proximity interaction scans for nearby Sentient Graffiti Bluetooth servers, finds one installed in a near digital information booth and browses through the private and public notes available for him in that context.

Our previous incarnation of Sentient Graffiti had been implemented on the following non NFC-aware Nokia series 60 devices: 6330, N90, N91 and N95. The adoption of NFC technology and the incorporation of the Touch2Launch service in our latest implementation, available for the Nokia NFC 6131 device through its NFC SDK, has provided the following improvements for the touching and proximity aware interaction modes:

- *Touching interaction through NFC.* So far, enabling touching interaction required the complicated scenario of pairing a Bluetooth RFID reader such as the ID Blue (http://www.cathexis.com/) with a mobile device, and then force the user to carry both the mobile and the RFID reader, to be able of touching the RFID tags identifying intelligent service enhanced surrounding objects. This cumbersome scenario is now simplified for users with a Nokia NFC 6131, since the device itself is able of reading smart object identifying RFID tags. Again, the combination of Push Registry MIDP 2.0 and NFC technology prevents a user from even having to have the Sentient Graffiti mobile client started in their device. As soon as the user approaches his device to an RFID tag, the Sentient Graffiti Mobile Client is started and configured to retrieve all the virtual graffitis associated to the read RFID tag.
- *Proximity-aware interaction through NFC.* An important drawback of the scenario described in Figure 2, is that the user had to wait until the Bluetooth discovery process concluded (about 10 seconds) to figure out whether that information point contained a SG server providing virtual graffitis of his interest. The use of NFC-tecnology has simplified this scenario considerably. Now, the binding between an NFC-enabled device (Nokia NFC 6131) and the

Bluetooth server is carried out by simply touching with the mobile an RFID tag attached to the information point. Such tags offer Bluetooth connection details such as the Bluetooth MAC address of the server and the port where a service is waiting for mobile client requests. Moreover, thanks again to the combination of the Push Registry capacity of MIDP 2.0 and NFC, it is not even necessary that the user has the mobile Sentient Graffiti application started. By pointing his device to the information point tag, the application is automatically initiated, and most importantly, correctly configured so that it automatically retrieves virtual graffitis for the user from the nearest Bluetooth Sentient Graffiti Server.

In conclusion, the Touch2Lounch service incorporated into the Sentient Graffiti Mobile Client has enhanced the capacities of this platform to enable both touch and proximity-aware interaction with nearby smart objects providing services. Thus, NFC makes Sentient Graffiti even more suitable as a platform to enable the discovery and consumption of services within the Internet-of-Things.

5. Touch2Print Service

The third NFC-aware service developed and deployed in SmartLab is termed Touch2Print. This service aims to make more natural the way people print their documents within an organisation. Traditionally, whenever a user wants to use a printer, he needs to configure a driver for such new printer in their system. Moreover, oftentimes, consultants and customers visiting our offices require printing some documents. Normally, due to access rights and the need for login details such guest users are not allowed to use our printers. Finally, we often have in our systems access configuration for only the printer closest to our location and not necessarily that one which is in the meeting room where we meet with customers. As we can see, all these facts demand for a more natural way of pairing with and accessing nearby printers. For printers available in public spaces such as meetings rooms, it would be very convenient that the user could "print his documents in that printer next to him", without having to know the domain name, IP address or login details required for accessing it. In order to address this issue, the "Touch2Print" service has been devised.

The Touch2Print service enables a user to obtain a printout of his selected documents by simply approaching his laptop to the printer where those documents want to be printed. In order to use the current implementation of the system the following software installation requirements are needed:

1. *Users must install in their laptops the Touch2Print PC Client.* This service makes available to the user a print queue where new documents can be imported or removed whenever they want to be printed. Figure 3 shows the user interface of such client. As can be seen, the user can easily add, remove and order the documents he wants to print out whenever a printer is made available. Note that this service does not only offer a user friendly interface, but it is also composed of a Bluetooth server which enables nearby Bluetooth devices to connect and browse the list of files in the queue and command which specific files should be sent to the printer.
2. *Users must be equipped with an NFC-aware device where the Touch2Print Mobile Client is installed.* This mobile application enables the user to bind his

mobile to his laptop though a Bluetooth channel, select the files to be printed, recognise the RFID tag attached to a printer where its connection details are encoded, and command the Touch2Print PC Client through the Bluetooth channel to connect to the printer and print the selected files. The mobile user interface which allows the user to bind his mobile to a Touch2Print PC Client, browse through the available files and select them for printing is shown in Figure 4. This binding process between the mobile and the laptop can be carried out in two forms: a) using Bluetooth service discovery, or b) the user places the mobile on an RFID tag on the laptop providing the Bluetooth connection details of the Touch2Print PC Client.

3. *The organisation offering the Touch2Print service needs to install the Touch2Print Printer Client in a Bluetooth-enabled server attached to the printer where the documents will be printed.* This application makes use of the attached printer HTTP interface or SDK (in our case a Ricoh Aficio MP C2500 has been used) to print the documents. This client is also a Bluetooth service which is used by the laptop when the files to print out are sent.

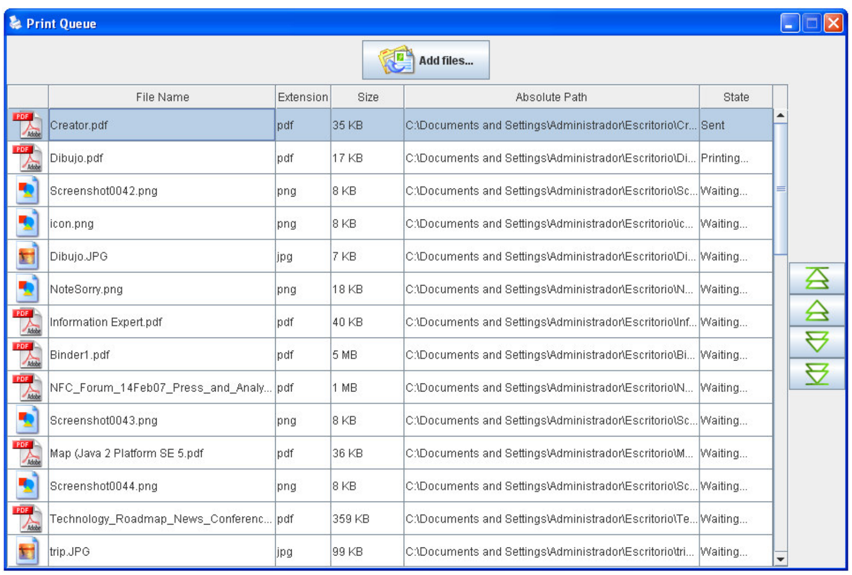

Figure 3. Touch2Print PC Client.

The system architecture of the current implementation of the Touch2Print service is shown in Figure 5. Currently only mobile devices such as the Nokia NFC 6131 or the Samsung SGH-X700 are available which enable us to profit from the advantages brought forward by the NFC technology to the human environment interaction domain. Therefore, although the most natural would be to simply approach a laptop to a printer and thus immediately initiate a required printing, as shown in Figure 6, we still need to make use of an NFC-enable device as intermediary between the printer and the laptop. In fact, most of the currently available printers neither they are NFC-aware nor they provide a Bluetooth interface. Consequently, a second level of indirection is still required in the architecture of Figure 5, including a Bluetooth-enabled PC server attached to the target printer. In conclusion, the actions a user must undertake to be able of printing his documents in the nearest printer are as follows:

1. The user starts-up the Touch2Print PC Client in her Bluetooth-enabled laptop and places in the queue those files she wants to print out.
2. The user starts-up the Touch2Print Mobile Client in her Bluetooth-enabled NFC-aware mobile device and binds it to her laptop through a Bluetooth link or even better points his device to a tag attached to the laptop which launches the mobile client and established a Bluetooth link between the mobile device and the laptop. This binding process is required only every time the user decides to connect her device to a different machine providing the Touch2Print PC Client. Otherwise, the connection details of the last laptop/PC with which the Touch2Print Mobile Client communicated are remembered through Java 2 ME RMS.
3. The user selects the files to be printed through the mobile's user interface.
4. The user approaches her NFC mobile phone to an RFID tag attached to the printer, from which the Bluetooth MAC address and service port of the Bluetooth-enabled server attached to the printer can be obtained. Such connection details are transferred by the mobile device to the bound laptop running the Touch2Print PC Client.
5. The Touch2Print PC Client sends through a Bluetooth channel the files to print to the Touch2Print Printer Client running in the PC attached to the printer. Such client makes use of the Ricoh Java SDK to print out the documents in the printer.

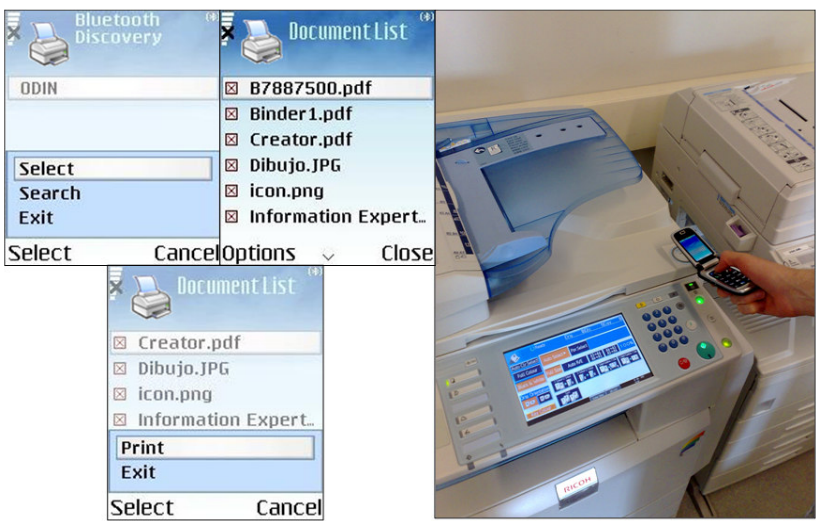

Figure 4. Touch2Print Service in Operation.

The current incarnation of the Touch2Print service, although providing a more natural way of printing documents, is still rather cumbersome due to the fact that 3 pieces of software need to be installed. Every user needs to install the PC and Mobile clients in their respective devices. An organisation offering this service needs to deploy the Printer Client in a PC attached to the printer in question. Ideally a situation like the one depicted in Figure 6 would be much more convenient, where a user would carry out the following simpler process:

1. The user equipped with an NFC-aware laptop opens a document he wants to print out and selects as printer the Touch2Print Virtual Printer. This printer appears in the user's system once the Touch2Print PC Client has been installed in a system.
2. The user approaches his laptop to an NFC-aware printer that automatically exchanges the file to be printed using either NFC, default behaviour, or any other communication channel available with higher bandwidth, such as Wi-Fi or Bluetooth.

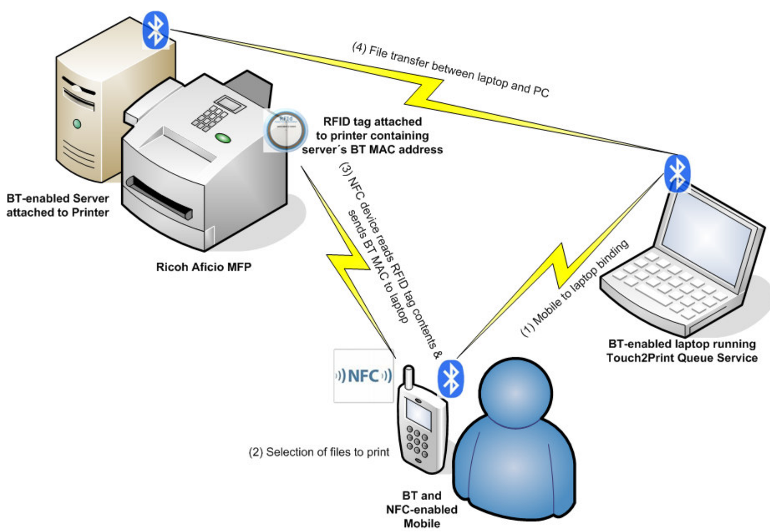

Figure 5. Touch2Print Service Architecture.

Although mobile devices are the ideal devices to incorporate NFC technology, it is foreseeable to expect that other customer electronic devices follow suit soon, such as digital cameras, PDAs, printers and laptops. Thus, Touch Computing scenarios between those types of devices will be soon possible, without the complicated arrangements currently required and shown in Figure 5, if compared with the truly more natural pairing mechanism shown in Figure 6.

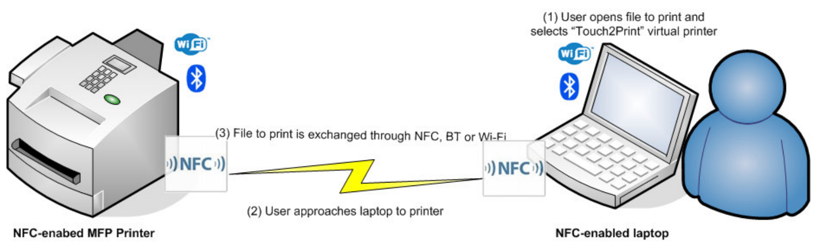

Figure 6. Touch2Print Future Ideal Configuration.

6. Conclusions and Further Work

This paper has described three interesting NFC services deployed within SmartLab which enable us to approach to the Internet-of-Things vision through a more natural interaction mechanism, i.e. Touch Computing. The services described have allowed us to draw the following conclusions about NFC technology:

- NFC-enabled mobile devices not only will serve as our electronic wallets but also as our electronic keys in a near future. We will not have to carry a plethora of keys to open our office, home or car doors any longer, but one single NFC-enabled device to reach the same purpose.
- The adoption of NFC technology through touch interaction, assisted in Java platforms with the MIDP 2.0 Push Registry, will simplify the activation and automatic configuration of sessions with surrounding services. This has been proved by the adoption of the Touch Computing paradigm within our Internet-of-Things enabling platform, namely Sentient Graffiti.
- Pairing devices through NFC, in other words the NFC application domain "P2P sharing and communication", is still in its infancy. However, the development of services such as Touch2Print should motivate manufacturers of electronic devices to cooperate through the NFC Forum to enable seamless pairing of functionalities and data exchanges among their different devices.

In future work we will carry out a user study analysing the experiences of a community of users (about 20) during two months using the three NFC-aware services described, together with our Internet-of-Things enabling platform, Sentient Graffiti, at the University of Deusto. This study should enable us to draw some scientific and social conclusions about the actual value of NFC technology and its application to the Internet-of-Things, in order to enhance user to environment interactions in AmI environments.

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