Near Field Communication (NFC) in an Automotive Environment

Use Cases, Architecture and Realization

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Abstract— **Near Field Communication (NFC) offers intuitive interactions between humans and vehicles. In this paper we explore different NFC based use cases in an automotive context. Nearly all described use cases have been implemented in a BMW vehicle to get experiences of NFC in a real in-car environment. We describe the underlying soft- and hardware architecture and our experiences in setting up the prototype.**

Keywords: Near Field Communication (NFC), NFC Use Cases, NFC Service Platform, NFC System Architecture

I. Introduction

Near Field Communication (NFC) [1], as a subset of RFID, is a bidirectional short range communication technology. NFC allows an interaction distance of approximately 5-10 cm and a maximum data rate of 424kb/s. It works via electromagnetic field induction, thus it is designed for simple and safe data exchange directly between two devices. NFC offers three different operation modes: passive tag (card emulation), active devices for reading and writing of passive tags and peer to peer communication (both devices are active). NFC allows both, convenient and intuitive interactions. It enables users to exchange data, connect and configure devices or use services like contactless payment and e-ticketing in a very easy way.

In this paper we focus on new and innovative NFC based use cases and applications in an automotive environment. BMW Group Research and Technology therefore is driving research activities to show the wide range of functionality NFC can offer within cars. We realized a multitude of NFC based use cases within a BMW to evaluate the advantages of NFC and to get practical experiences with that technology.

II. Related Work

A. Automotive Context

Since car sharing is intended to become more and more attractive, there are already NFC and RFID based solutions on the market to grant access to dedicated cars [2]. To open the car, the driver either uses a specific smart card or some kind of key fob based on a passive tag. Disabling the immobilizer and starting a car is typically not addressed in such a scenario.

Another feature, which is based on passive RFID technology, is the backup key recognition. Some newer cars don't have a key slot any more. When starting the car, the presence of the correct key is checked by a wireless link between the key and the immobilizer. If the key detection fails, the customer can hold the key to a specific area at the steering column where a RFID reader is located to identify the key.

Apart from that, there are a lot of RFID based applications outside the car, like payment and access scenarios for public parking and toll stations. A widespread solution is a RFID sticker behind the windshield. This technology is not based on passive NFC or RFID technology but uses active RFID devices to communicate over longer distances.

B. Non-Automotive Context

Touch and Connect is an intuitive concept for setting up connections. For example, an URL stored on a passive tag can be transmitted by NFC to a mobile device that directly opens the corresponding website. Also configuration of devices (e.g. WIFI parameters or Bluetooth pairing) can be simplified with the concept of touch and connect.

A very common use-case that is very often based on passive NFC/RFID tags or smart cards are access and authentication systems. Thus, access authorization to hotels, stadiums or other secured areas is based on information stored on such a wireless device.

Further there is the fast growing market of contactless payment. The so called micropayment solutions, which are limited to a certain amount of money, are in the process to substitute cash. PayPass, PayWave and ExpressPay [3] are the most common NFC based standards for contactless payment in the world of credit cards.

Another application domain of NFC and RFID is e-ticketing [4]. There are already some large systems successfully in place and established, like the Octopus Card in Hong Kong, Suica Card in Tokio, Oyster Card in London or Touch & Travel in Germany. Most of these systems are using smart cards. Systems that are based on NFC mobile phones are still rare due to the limited penetration of that kind of phones. In some places there is also the possibility to use the same

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smart card not only for e-ticketing but also for authorizing micro payments.

In summary it can be stated that many different use cases and fields of applications can be realized and supported by NFC. In the automotive environment currently only very few applications are known.

III. NFC Use Cases in an Automotive Environment

NFC can be seen an enabler for a multitude of new valuable in-car functions for the customer. On the one side NFC allows the integration of totally new functions into the car and on the other side NFC can simplify the utilization of already existing in-car functions.

The use cases given below are classified into the following groups

- Communication support
- Interaction between the customer and the car
- Information retrieval
- Car key with NFC interface

The following list only shows a selection out of the most important use cases and cannot be considered as complete.

A. Communication Support

A very important use case is **Bluetooth Pairing**. The idea is to simplify the pairing process between the mobile phone and the car's hands-free equipment. Without NFC we need more than 8 different user interactions to establish a first connection between the car and the mobile phone (e.g. activate Bluetooth, search for the hands-free equipment, type in PIN on both sides, etc.). With NFC these interactions can be substituted by *one* intuitive interaction: just hold the NFC-enabled phone to the dashboard where the car's NFC-device is located (e.g. marked by a NFC-logo) and confirm the pairing. In the background, the automatic pairing process works as follows: the car transmits the necessary pairing information like the internal Bluetooth Address, the PIN, the name of the device etc. via NFC to the mobile phone. The car activates its Bluetooth interface and the mobile phone will then establish a secure link to the car using the Bluetooth interface and completes the pairing process. Typically the new NFC-based and intuitive pairing process only needs 1-2 seconds to be fully executed.

Another similar use case is **WiFi Configuration**. Acting on the assumption that we might have a WIFI interface in future cars, NFC can also be used to configure the WIFI interface on the consumer electronic side. Instead of searching for the right access point (in this case the car) and configuring the consumer electronic device (CE device) by choosing a crypto method and typing in a long cryptographic key, the customer just has to hold the CE device to the dashboard and the configuration works automatically. Thus, the CE device will be connected to the car's access point in just some seconds without any other user interaction.

The **Electronic Business Card (vCard)** use case can be applied to interchange business card information between the customer and the car. Imagine a standard business card that is complemented by a passive NFC tag. The tag holds electronic data about the name, address, phone numbers, mail-address and webpage. For example, if a customer wants to set up a call to the person written on the business card he just wipes the card over the dashboard and the menu on the car's display shows the phones number(s) and asks for confirmation to dial the number. If a location is stored, the customer can of course also select the address to navigate to the destination.

Further, NFC can simplify **Internet Access**. For example, if the vCard contains an URL, the corresponding webpage can automatically be loaded and shown on the car's display. The same URL can be read by a PDA or mobile phone to access the webpage. This use case is not restricted to vCards but also works with NDEF smart poster tags defined by the NFC-Forum.
Another function is the transfer of a webpage from one device to the other one. If a user views a webpage on his smart phone and he wants to use the larger display in his car, he just holds the smart phone to the dashboard and the webpage will be transmitted to the car's computer and display.

B. Interaction between the Customer and the Car

A modern car has many options for **Personalization**. Examples are infotainment settings (sound and display settings), setting of air-condition, side mirrors, seats, lights, chassis configuration, last destinations etc. All these information can easily be stored on a NFC tag (e.g. a key fob) and thus can be portable. This allows the customer to always carry his personal settings with him and use them in his own as well as in other cars just by simply wiping the personalization tag over the dashboard where the NFC reader is located. The personalization is not restricted to the driver but can also be used by the passengers to personalize their environment like setting of the air condition or the rear seat entertainment system.

NFC can be utilized for **Software Activation** of optional software modules. For example "prepaid" NFC tags can be sold for (temporary) activation of additional navigation maps. Or a customer who already subscribed for a specific (online) service can use that same service within another car by simply holding the NFC tag to the dashboard. The information of the subscribed service can be stored inside the NFC tag or the NFC tag is just used for **User Authentication** and the backend is checking user rights and subscriptions.

The in-car NFC interface can also be applied to realize **E-Payment** applications. It is possible to pay online services, music downloads, road charges etc. by simply wiping the NFC based credit card (micropayment) over the dashboard. A secure online connection to the backend will then be used to transmit the credit card data to the clearing company.

It is also possible to use NFC for **Car Access** if a reader is installed in a way that it is accessible from outside the car (e.g. located in the side mirror). Particularly this is helpful for car sharing communities or other cases where different people have access to a number of cars (e.g. car fleet of the company).

C. *Information Retrieval*

NFC can be used to retrieve information from the car. One example is a **User Guide.** In this case different NFC tags (e.g. on a "user guide flyer" that is illustrated by pictograms) can be read by the car. After reading a specific tag the corresponding electronic manual can be shown on the car's display. The same information can be read by a mobile phone or a PDA if the user is outside the car e.g. at the motor compartment and doesn't see the in-car display. In this case the CE device can establish a connection to the car to load the related manual pages.
Another option is to install passive NFC tags directly at different locations within the car. When the user touches the tag with his CE device he gets information about the tagged device like the nominal tire pressure or how to fill up water for the wiper.

Also internal **Car Information** can be retrieved using NFC. This information can be dynamic and generated by the car like internal control messages, trip information, temperature etc. Instead of browsing through the different menus of the board computer it's just necessary to hold the respective NFC tag to the dashboard where the NFC reader is located and the corresponding menu will then pop-up automatically.

Spare Part Information increases the transparency for the customer. The packing of spare parts can be equipped with passive NFC tags storing product information. After installing the parts into the car, the information can be transferred by just holding the packing material to the dashboard to register the spare part. The information about replaced parts is available to the customer. Further, the concrete spare part properties can be used to adapt internal car functionality.

D. *Car Key with NFC Interface*

In the groups *A, B* and *C* it was supposed to have a NFC reader located within the car, e.g. behind the dashboard, at the back of the front seats, the doors or the mirrors. In this group *D* the NFC interface is located inside the car's key (connected to the key electronics). Thus, the NFC interface is portable and can also be used outside the car.

One exemplary use case is the **Car Status**. When a user turns off the car, the car transmits status information to the key via the internal radio interface. When the user is outside the car, he can use a NFC mobile phone to read this information from the key like the status of the locks, the position of the car, the tank level etc.

The same key can also be used for **E-Ticketing**. For example the user can buy an electronic ticket for a soccer match within the car. While driving to the stadium the ticket is transferred onto the key that grants access at the RFID based entrance of the stadium. Also electronic tickets for public transport systems can be stored onto the key and be used with the already existing RFID infrastructure in many cities.

The key can also be utilized as a NFC based **Credit Card**. It is possible to pay with that key at every acceptance point for contactless payment like shops, gas stations, toll stations etc.

All these use cases show the huge potential of NFC within the car. Some of the use cases can be realized in short-term and some of them more in a long-term perspective. Some use cases need NFC-based CE devices (e.g. mobile phones, PDA, etc.) and some use cases rely on a public NFC/RFID infrastructure (e.g. for public transport, payment, ticketing, etc.). Thus the future use of NFC within the car directly depends on the future market penetration of NFC devices and the infrastructure which could vary much in the different regions of the world.

IV. ARCHITECTURE

In the following we provide details on the system architecture for the implementation of the NFC use cases. Because of the diverse nature of the use cases and different hardware requirements, the architecture focuses on offering abstract interfaces to facilitate and speed up the development of the different applications. First, we describe the NFC/RFID Service Platform which is a device-independent abstraction layer offering web services to the applications. After that, we show the overall architecture of the complete system including different hardware devices and use cases.

A. *NFC/RFID Service Platform*

The **NFC/RFID Service Platform** is an abstraction layer between the NFC devices and the applications, offering a transparent access to different NFC devices of different manufacturers with different hardware interfaces via simple web services. The NFC/RFID Service Platform offers an abstract, user friendly interface and a convenient notification service, for example when devices are added or removed. Currently the following tag types are supported: Mifare Ultralight, Mifare 1K, ISO14443-A tags (Smart Cards, DESFire).

Figure 1 illustrates the architecture of the NFC/RFID service platform. It contains three modules: Web Services, Messaging and Core. The NFC/RFID Service Platform runs inside the Microsoft Internet Information Services (IIS). For the messaging component, we use Active MQ as a language-independent, open-source message broker.

The **NFC/RFID Core** is an internal library implementing the basic functionality of all NFC devices such as reading from and writing to tags or peer-to-peer (P2P) functionalities. It provides a common interface for several kinds of NFC devices and thus forms an abstraction layer between the different device interfaces and the web services module.

The notification mechanism of the NFC/RFID Service Platform is provided by the **NFC/RFID Messaging** component. This library uses the Active MQ message broker to broadcast messages to all registered processes. Via this mechanism, applications can be notified when devices are detected or removed, when tags appear or disappear in the field or when a message from a P2P device has been received. For receiving notifications of a specific service the client applications need to register at the Active MQ message broker.

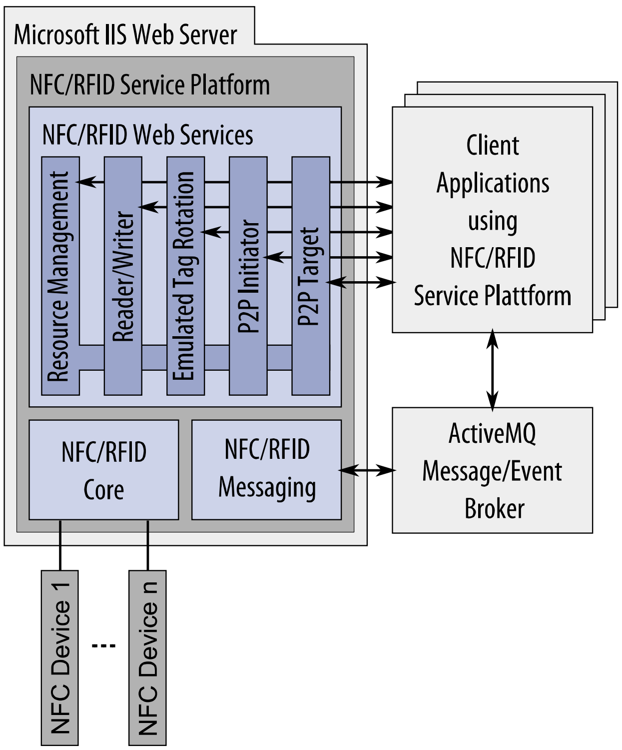

Figure 1: Architecture of the NFC/RFID Service Platform.

The interface to the external applications is provided by the **NFC/RFID Web Services** module. It supports all modes of NFC devices via dedicated web services: Reader/Writer, Emulated Tag Rotation (a combination of card emulation and reader/writer mode) and P2P functionality, both in initiator and target mode. The management and initiation of these services is controlled by the **Resource Management** service. In particular, it can retrieve a list of all connected devices, provide status information and details about connected devices, as well as start and stop services for a selected device. The Resource Management service broadcasts messages via the NFC/RFID Messaging component whenever a new device is detected or a device has been removed.

The **Reader/Writer** service allows using devices in the corresponding mode and offers status information about currently available tags. It sends notifications when new tags are found or tags are removed from the field. The Reader/Writer service supports the access schemes of Mifare 1K and Mifare UL tags as well as the APDU command scheme of ISO14443-A tags. For the Mifare tags the service offers read and write methods to access a specified block in a specified sector. For Mifare 1K tags the access conditions of each sector of a tag can be read or written. Accessing ISO14443-A tags (like DESFire) is possible by sending APDU commands. The web service method call returns the APDU response.

NFC devices optionally offer a card emulation mode, where the emulated card behaves like a passive tag and can be detected and used by other NFC devices. Our use cases usually use the same NFC devices in parallel and require the NFC devices to be in reader/writer and card emulation mode at the same time. For example, if the application has stored WIFI configuration information on the emulated tag of the NFC device, this information must be accessible whenever the user tries to read it. In this case, the NFC device must be in card emulation mode. But at the same time, the user might rather hold a vCard tag to the device and expect it to read the information. This would require the device to be in reader/writer mode. Because the user can require both applications using the same NFC device at any time, we introduced the **Emulated Tag Rotation** service. This service periodically switches the NFC device between reader/writer and card emulation mode to emulate a behavior in which the NFC device is in both modes at the same time.

The methods offered by the Emulated Tag Rotation service correspond to those of the Reader/Writer service. In fact, when the device is in reader/writer mode, the methods of the Reader/Writer service are used. In addition, it offers reader/writer functionality for the emulated Mifare1K tag. Beside the notifications issued by the Reader/Writer service, the Emulated Tag Rotation service provides additional information for card emulation mode: a broadcast is sent whenever the device (i.e. the emulated tag) enters the field of a reader or is removed from a field.

Finally, the NFC/RFID Service Platform offers services for peer-to-peer mode. The **P2P Initiator** service offers a method for sending messages and receiving the response from P2P devices operating in target mode. The notification service signals newly detected or removed P2P target devices. In contrast, the **P2P Target** service notifies applications about the reception of new messages from another device. Besides, it offers a method for issuing a response to the P2P initiator device.

In sum, the NFC/RFID Service Platform offers a convenient network interface via web services to independent applications. It supports all three NFC modes, reader/writer, card emulation as well as peer-to-peer. The methods offer a transparent abstraction of the hardware devices, while the event notification mechanism enables quick inter process communication.

B. System Architecture

The overall system architecture is designed to facilitate the development and integration of new use cases via a plug-in mechanism. By abstracting the hardware functionality, all applications have transparent access to all available hardware components. Because of its generality and transparency, this architecture is also well suited for further projects.

The architecture is depicted in Figure 2. It integrates different **Hardware Components** such as NFC devices, displays, embedded control units as well as WIFI and Bluetooth components. All of these devices are controlled via newly created or already available specific interfaces in the **Hardware Abstraction Layer**. We have described in detail the NFC/RFID Service Platform in chapter IV.B. Similar abstractions are provided by the human machine interface (HMI) for the front and rear displays of the car, by the abstract CAN module to communicate with different CAN busses, and by WIFI and Bluetooth components. All of these components offer their own most appropriate way of communication:

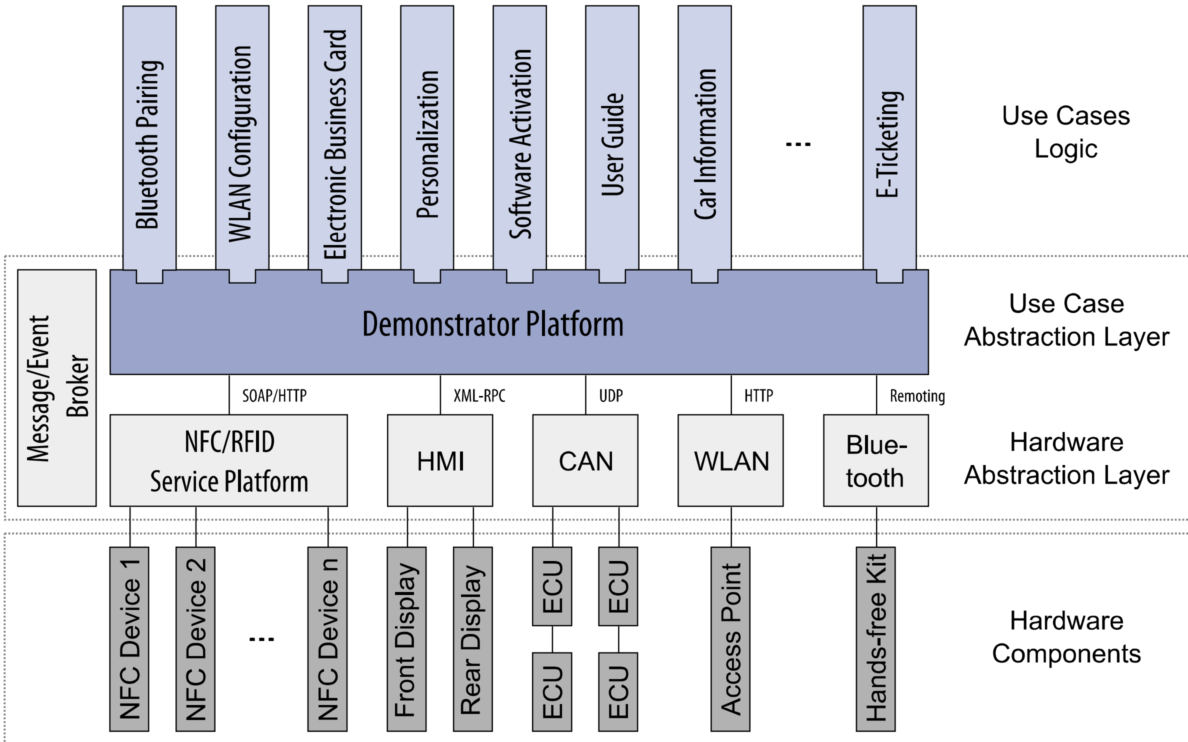

Figure 2: System architecture overview.

SOAP, XML-RPC, UDP, HTTP or Remoting. Only the Active MQ message broker is a common service over all hardware components.

When implementing use case applications, the programmer shouldn't be bothered with these different protocols and access modalities. In the **Use Case Abstraction Layer** the Demonstrator Platform integrates the different modules of the Hardware Abstraction Layer to provide a unified access to all of the connected devices. Similar to the Resource Management service of the NFC/RFID Service Platform, the Demonstrator Platform provides information on available hardware components. In addition, it implements error handling and logging interfaces.

Use case applications are integrated with a convenient plug-in mechanism. After connecting to the Demonstrator Platform, all applications can transparently access the hardware components in a simple and abstracted way and profit from the notification service of the message broker. In this way, only the specific functionality of each use case needs to be implemented, because the hardware-specific functionality is encapsulated in the Demonstrator Platform. This speeds up the development time enormously.

V. PROTOTYPE

A series-production BMW has been equipped with additional hard- and software components to proof the technical feasibility as well as to explore the usability of selected use-cases. The use cases have been integrated into the car with focus on characteristically BMW look-and-feel and entire functionality. Requirements of series development and production were not taken into account in the prototypical setup.

The additionally integrated hard- and software components are connected to the ignition in a way that ordinary usability is preserved: Unlock the car, activate the ignition and after a couple of seconds the NFC use-cases are fully available. The system works as long as the ignition is activated – independent if the engine is running or not – and is shut down when the ignition is turned off.

A. Prototype Setup

Four NFC reader-boards with NXP's PN531 highly integrated transmission module [5] and Smart*MX* IC [6] for security support have been installed into the car: one into the driver-side exterior rearview mirror, one into the dashboard within reach for the driver as well as the co-driver as visualized in Figure 3 and one below the rear-seat entertainment system's displays on either side. The boards are connected via USB to an industrial PC that is installed inside the trunk. Several of the cars electronic control units are connected via CAN bus systems, serial line or Ethernet to the PC. Further, a WIFI access point and an UMTS router are integrated into the trunk and connected to the PC as well. The additionally installed electronic systems are energized by the car.

The following NFC devices communicate with the installed PN531 boards: passive ISO 14443-A Mifare 1K and Mifare UL Labels in different sizes, Nokia's 6212 and 6131 NFC-enabled phones and a PDA equipped with an SD-slot NFC-reader module.

Further, the car's key has been equipped with an NFC-interface that is connected to the electronics of the key. Thus, car data can be transferred via the proprietary UHF interface to the key's NFC interface. The developed key can also be used for micropayment in our prototypical setup as shown in Figure 4.

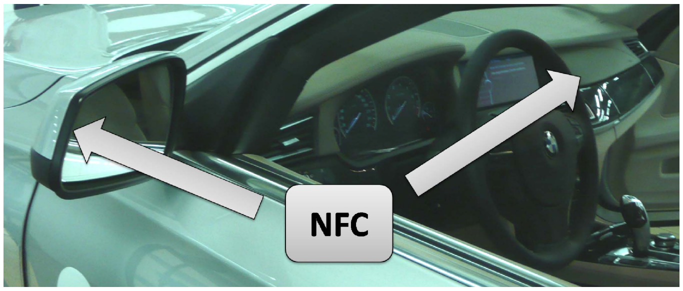

Figure 3: Installation locations of 2 NFC devices.

B. Use-Cases

The following set of the describes use-cases in Chapter III have been implemented and run concurrently in the car: Bluetooth Pairing, WIFI Configuration, Electronic Business Card, Internet Access, Personalization, Software Activation, User Authentication, User Guide, Car Information, Spare Part Information, Car Status, E-Ticketing and Credit Card.

Figure 4: Micropayment with a NFC car key.

The use cases are transparently integrated into the car. With activated ignition the system boots automatically and launches the described software components (Chapter IV). The applications are notified when the driver or passenger interacts with the system, e.g. via a NFC device or the BMW iDrive, and evoke the necessary reaction.

The usability of the system is exemplified by *Bluetooth Pairing*. If one of the NFC-enabled Nokia phones is positioned onto the spot on the dashboard, the phone vibrates and asks the customer to confirm the pairing with the car and, simultaneously, the status information about actually paired phones is shown in the cars central information display. After confirming the operation on the phone, the connection is established immediately and the status information is updated (Figure 5).

VI. Conclusion

In the paper at hand we described the variety of valuable NFC-based functionality in the automotive environment. We presented a flexible layer based system architecture that combines the realization of the use-cases including device-management, communication with external sources, multi-application support and logical abstraction for efficient implementation. Based on that architecture a large set of the described use-cases have been integrated into a prototype car as proof of concept. Our work shows the potential of Near Field Communication in an automotive environment to enable additional functionality and ease the interaction with the car via intuitive handling.

Figure 5: NFC-based Bluetooth Pairing in the car.

Independent studies predict market penetration rates for NFC-enabled CE-Devices in the lower double-digit range for the next few years (compare [7], [7]). A considerable penetration of NFC infrastructure, e.g. mobile phones, contactless point-of-sale terminals, e-ticketing infrastructure or NFC-enabled business cards, is necessary to start discussions about series development.

Future work: Based on the prototype and planned pilot projects we will evaluate the user experience of NFC-based functionality in the automotive context.

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