AN MBSE-APPROACH FOR USING NEAR FIELD COMMUNICATION IN THE AIRCRAFT CABIN

Thorsten Kiehl*, Ralf God

Institute of Aircraft Cabin Systems, Hamburg University of Technology
Nesspriel 5, 21129 Hamburg, Germany

thorsten.kiehl@tuhh.de

Abstract
In air travel a fierce competition for customers forces airlines to keep track with societal developments. A prominent example is the use of Portable Electronic Devices (PEDs) with wireless interfaces onboard aircraft. Due to this demand WiFi, Bluetooth and GSM are already certified for aircraft use. A novel wireless interface used in PEDs and which features secured communications is Near Field Communication (NFC). After a maturation period NFC now seems to reach a breakthrough in PEDs. At airports this technology is already set to be an enabler for future digital travel. An exhaustive integration into the air transport system, or even into the aircraft cabin, still remains a challenge, because a common infrastructure has to support various businesses and uses cases within a distributed and complex technical environment. To cope with those challenges the methodology of Model-based System Engineering (MBSE) is considered to be a suitable and future-oriented approach. Hence, an introduction to NFC technology and the tailoring of an MBSE-approach using the System Modeling Language (SysML) for an integration of NFC into the aircraft cabin are presented.

1 INTRODUCTION

The design of the aircraft cabin is highly influenced by social trends. For an airline this is both a blessing and a curse. There is a great opportunity to differentiate from their competitors when following such trends at an early stage. However implementing technology and novel services into the cabin is complex and expensive as well. Fierce competition forces airlines to keep track with social trends and to offer their passengers more than a sole transport service.

A striking example for following social trends is the use of Portable Electronic Devices (PEDs) onboard aircraft. As today's information society becomes increasingly mobile, so called Transmitting PEDs (T-PEDs), e.g. smart phones and tablet PCs, are common in use and wireless networks (Bluetooth, WiFi, GSM or even LTE) provide seamless connectivity to the digital world. Airlines have recognized that processes in air transport can profit by this trend, because they can be supported and optimized by integrating passengers' T-PEDs. Even In-Flight Entertainment (IFE) is influenced by the use of T-PEDs, as those devices are equipped with outstanding technical capabilities and, even more important, have a personalized user interface and store individual media of their owners. Airlines are targeting for additional revenues by digitally enabled services and a formerly strict intolerance for using T-PEDs in the cabin during flight has been readdressed.

The technical enablers for broadband wireless connectivity aboard aircraft have been developed and implemented by certifying IEEE 802.11- and GSM-standard for in-flight use (cf. Figure 1). Both standards cover successfully different aspects for wireless data transmission. However it is still not fully determined how additional services and ancillary revenue can be generated in the cabin by using these technologies and how the handling aboard can be simplified. Secure transactions during flight, e.g. electronic payment and personalized services based on electronic authentication are still rarely considered in an aircraft and the existing transmission technologies are not offensively featuring them.

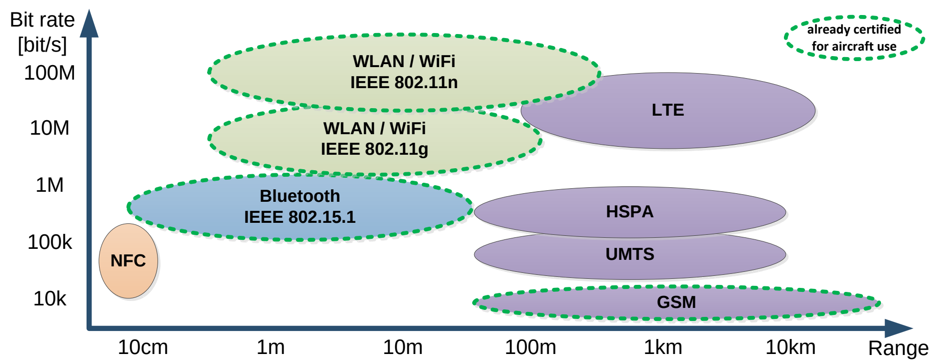

Figure 1: Wireless communication technologies

Near Field Communication (NFC) addresses these latter challenges and is supposed to be a feasible solution. Section 2 introduces to NFC technology and its dissemination in air transport and Section 3 to Model-based Systems Engineering (MBSE). Its role in the development of complex systems in aircraft industry and an MBSE framework together with essential tailoring activities are presented. Initial results and a way forward to integrate NFC in the aircraft cabin are discussed in Section 4.

2 NEAR FIELD COMMUNICATION

Near Field Communication (NFC) is based on an international series of standards which define a physical interface and protocol for inductive wireless transfer of data at 13.56 MHz and over distances of up to 10 cm [1]. NFC features secured communication and secure transactions, e.g. for ticketing, payment, authentication or access control and is integrated in smart phones and other mobile devices to establish data transmission with a communication partner via a tangible user interface. Touching devices together or bringing them into close proximity initiates the secured communication. The communication interface is compliant with wireless smart card communication and Radio Frequency Identification (RFID).

NFC was developed in 2002 by Philips (now NXP Semiconductors) and Sony. Together with Nokia they founded in 2004 the NFC-Forum, a non-profit industrial organization to develop specifications and to ensure interoperability among devices and services. Technically based on RFID and associated smart card technology, NFC is compatible to the leading contactless smart cards *MIFARE* by NXP and *FeliCa* by Sony. One of the essential standards of NFC is NFCIP-1 (ISO/IEC 18092), which defines the RF interface and the communication protocol for NFC with a maximum data rate of 424 kbit/s. A further standard is NFCIP-2 (ISO/IEC 21481) specifying the communication mode selection mechanism.

In general NFC offers three different operating modes defined by the NFC Forum (cf. Figure 2). In *Reader/Writer Mode* the NFC devices acts like a standard card reader and thus can read and write smart cards and RFID tags. The device is active and therefore powers the smart card. In *Card Emulation Mode* the NFC device is passive and by emulating a smart card it can be read by any smart card reader. As the NFC device receives its power from the reader, it does not have to be switched on for data exchange. This is advantageous for example for a boarding pass stored in a smart phone as the information can be read even with an empty battery. Finally in *Peer-to-Peer (P2P) Mode* two NFC devices are communicating directly with each other. To do so, the active and passive role of the devices is alternated continuously.

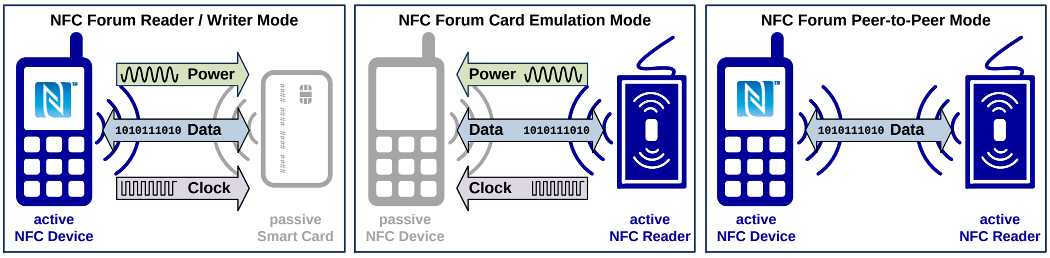

Figure 2: The three different NFC communication modes

2.1 NFC Dissemination

It is already recognized that NFC with a tangible user interface offers a innovative way of contactless user interaction with secured data exchange. Novel services can be offered, but also existing business processes can be significantly improved by using T-PEDs with NFC interface. However the global adoption to NFC technology has to overcome a classical hurdle: The trend-setting T-PED manufacturers still sit on the fence waiting with the integration of novel hardware features until a significant amount of services is using these features. At the same time the service providers hesitate to offer a new business, if only a few customers can use an NFC-based service because of a lack of hardware.

In 2002 MasterCard started a trial with its contactless payment solution *PayPass* based on contactless smart cards which is already a standard today. Initial NFC trials were rolled out in local public transport in 2005 and supported by Nokia with their device *Nokia 3220* [2]. It was Google's announcement of their smart phone *Google Nexus S* in 2010 which brought movement to the NFC and payment market: *Google Wallet* is based on NFC and enables mobile payment via smart phone.

Nowadays many of the Android and most of the Windows 8 based T-PEDs are equipped with NFC. The important trend-setter for PEDs, Apple, still lacks an NFC device, but at the same time they have built a strong patent portfolio and got granted a comprehensive patent for using NFC in air transport [3]. This patent was published in 2005 and claims a so called *iTravel App* which supports and facilitates process chains at the airport by the use of NFC (see Figure 3).

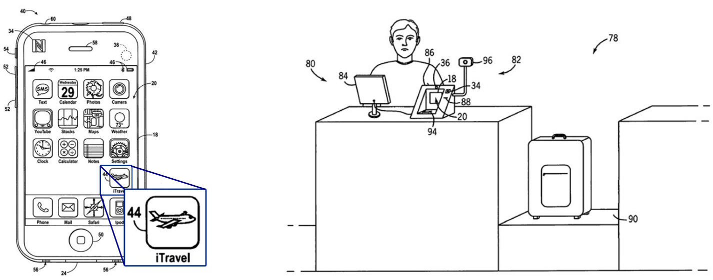

Figure 3: NFC-supported check-in according to a patent by Apple [3]

Air transport kept waiting for a longer time with practical trials using NFC. Although predestinated for NFC-support the air transport system is complex and characterized by a worldwide cross-linking with challenging security requirements. A first trial at the airport of Nice in 2009 [4] highlighted the promising use of NFC at airports. At the same time the International Air Transport Association (IATA) started their *e-Services* project with the Electronic Miscellaneous Document (EMD) to facilitate sales and ancillary revenues for the airlines. IATA has the clear strategy to use NFC and PEDs in the near future to enhance *e-Services* in air transport [5], [6]. In parallel the Société Internationale de Télécommunication Aéronautique (SITA) as a major IT service provider claims a strong demand for the use of NFC at airports. SITA started a large field test in spring 2012 at Toulouse-Blagnac airport to support NFC-enabled boarding passes and services [7]. This recent evolution and the distinct visibility of NFC in air transport prove that NFC technology is designated for use in aeronautics. NFC perfectly fulfills the requirements of secured communication and secure transactions in air transport and is preferably integrated into T-PEDs.

2.2 NFC Aboard Aircraft

In contrast to airports NFC is not yet integrated into the aircraft. This might be related to the fact that aircraft manufacturers and airports do not cooperate in system and process development. However they have recognized that for their direct and indirect customers, i.e. the airlines and the passengers, T-PED-supported door-to-door processes are a must. The safety and security requirements for integrating an NFC system into the aircraft cabin are considerably higher than at the airport. But indeed, more and more passengers carry NFC-enabled T-PEDs aboard and up to now there is no project which aligns the challenge for a comprehensive and consistent NFC-integration.

The integration of NFC into the IFE, which is separated from other aircraft systems would definitely limit the use aboard aircraft. A comprehensive use of NFC aboard aircraft requires an integration into the Cabin Management System, which is the central communication backbone within the cabin. This system interfaces various stakeholders, i.e. the cabin crew, the passengers and the maintenance staff and provides them individual use cases where authentication, secured communication or secure transactions are prerequisite. To achieve an overall benefit from NFC use in air transport a consistently harmonized security and service concept has to be accomplished [8]. This concept has to consider the aircraft cabin to be an integral part of the overall system and an MBSE-approach is expected to accomplish these challenges.

3 AN MBSE-APPROACH

Today the aeronautical systems engineering process is following the so called V-model, which was introduced by Boehm in 1979 [9]. The basic concept of the V-model is to split a large project into sequential but interacting development phases (cf. Figure 4a). Requirements acquisition on top level is systematically elaborated and refined to detailed design. Subsequently the implementation of components or software code is followed by an integration phase to end up with the initially defined product. Permanent validation and verification activities assure consistency between requirements and product.

Documentation of the aeronautical systems engineering process is traditionally done in textual form. Nowadays systems are getting more complex and massively interlaced with other systems. The scope and importance of the software part of systems has considerably enlarged and thus the classical way of working with textual documents reaches its limits. A novel approach to cope with such challenges is using methods and tools of Model-based Systems Engineering (MBSE). MBSE is characterized by using formal and standardized modeling languages, an unambiguous semantic and finally a model-based proceeding in the development process [10]. System properties and relations can be illustrated and recognized more easily due to the graphical description. In large projects the communication with the stakeholders and requirements capture can be improved which again results in a better visibility of system challenges. Possible design flaws can be detected at an early development phase [11].

Due to the vast scope of NFC integration in air transport the methodology of MBSE for a seamless use of NFC is suggested. A common infrastructure has to support various businesses and use cases within a distributed, complex and technical challenging environment. Moreover the many potential stakeholders of the interlaced system cannot determine and express a joint benefit, because they do not have a comprehensive understanding of each other's businesses and applications. MBSE is supposed to cope with these issues.

3.1 Formal Languages in Model-based Design

The Origin of MBSE was in software engineering. The emergence of object oriented high-level programming languages, such as C++ or Java, created a demand for a graphical representation of their classes and system functions. To satisfy the need for formal specification of software-intensive systems, e.g. the Unified Modeling Language (UML) was developed in the 1990s. It was set as a standard for system modeling by the International Organization for Standardization (ISO) in 2000 and is continuously enhanced by the Object Management Group (OMG). Similarly and approximately at the same time *Simulink* was developed by The Mathworks. This tool is better suitable for modeling dynamic systems which are to be found in control theory and physical processes. However, *Simulink* is proprietary and has its own graphical programming language.

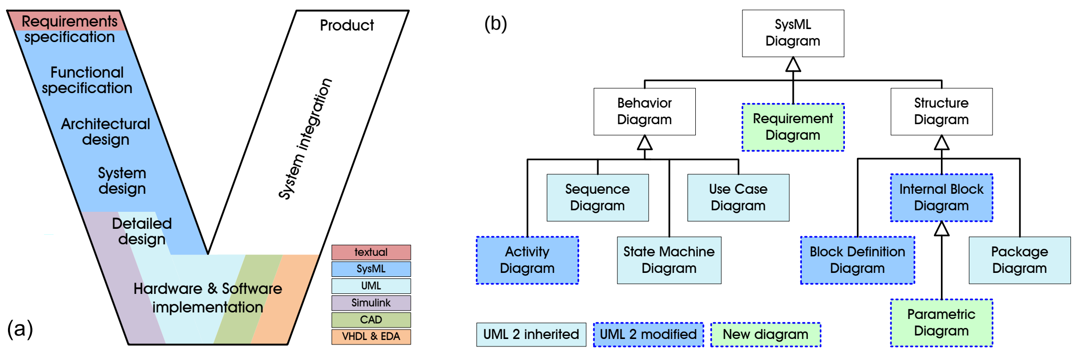

Figure 4: (a) Adaptive usage of modeling languages during the system development process according to the V-model and (b) diagrams of the SysML according to the OMG

For modeling systems in detail, i.e. for detailed design at lower development level, modeling languages as for instance the UML and *Simulink* are very useful, but they get to the limits if the system development process shall be covered at top level. At this initial stage a structured capturing and elicitation of requirements associated with a requirements management, a functional specification and an architectural design are essential (cf. Figure 4a). To deal with these challenges the System Modeling Language (SysML) was published in September 2007 by the OMG. SysML is based on the UML and most language elements were directly inherited or only slightly modified. Some diagram types were omitted and in reverse some novel elements like the requirements diagram were established. The recent version 1.3 of SysML was published in June 2012 and covers nine different types of diagrams (cf. Figure 4b).

An advantage of model-based engineering using the SysML (or the UML, respectively) is the strict model separation into a so called model repository containing the entire model elements and the so called views. The views describe via specific diagrams various relations and activities within a system. This enables developers to focus on their individual details and not being distracted by the whole and complex thing.

Another strength of the SysML is in the elicitation and analysis of requirements as well as in the functional and an architectural design, which are top level tasks in the left branch in the V-model. Although other software tools like IBM Rational Doors or a simple word processor like Microsoft Word can be used for textual capturing of requirements the further elicitation and analysis should preferably be done in a SysML model [12]. SysML modeling will maintain traceability and a seamless transition of the requirements into a functional specification, an architectural and system design (cf. Figure 4a). The close relationship of SysML and UML facilitates a transition from system design to detailed design. At this development level a changeover to modeling tools using the UML or *Simulink* can be desirable, because they even provide auto coding functionalities. During implementation mechanical design is supported by CAD and electrical design by VHDL or EDA, respectively. This advanced chain of modeling languages has been proven amongst others when introducing MBSE at Saab Aerosystems [13]. This chain offers the advantage of using each modeling language in an optimal way. Still a weak point is a non-automated information changeover between the models, which may result in additional modeling work. However, due to their similarities, SysML and UML exhibit a high potential for a seamless modeling of software-intensive systems in the design and the implementation phase.

3.2 Creating a Framework: The Need for Tailoring

SysML was opted to start a model-based development process at top level. Before beginning to model a major project in SysML, detailed planning is required, because the SysML itself neither governs a development process nor sets a detailed definition for the correct application of language elements [12]. There is the need for tailoring to adapt to an intended modeling process. Tailoring activities which result in a customized framework are depicted in Figure 5 and subsequently described.

A framework can be considered as a kind of model template that defines language elements, sets structural guidelines and also establishes modeling rules. Basic elements for a framework are an individual modeling profile and a specific model library. A profile enables the extension of the vocabulary of the SysML to support an adaption to system specifics by introducing suitable stereotypes. The benefit of this extended modeling language vocabulary is a clarification of properties and relations within a system. The model library is a set of physical units and dimensions to define interfaces within the system. It is even possible to store entire transmission protocols for information exchange or entire model blocks which are repeatedly in use in a model library [12], [14].

Before defining new stereotypes or model library elements, it is important to define modeling rules. Rule-making comprises a setting of naming conventions as well as a specification of the model structure and interfaces of model elements. Rules enable an unambiguous understanding of the model by all involved parties and a parallel working on the model by multiple engineers. Furthermore the potential reuse of parts of the model is enhanced. Rule-making is a prerequisite for automated model checking, which supports the designer to detect rule violations. A model checker is able to

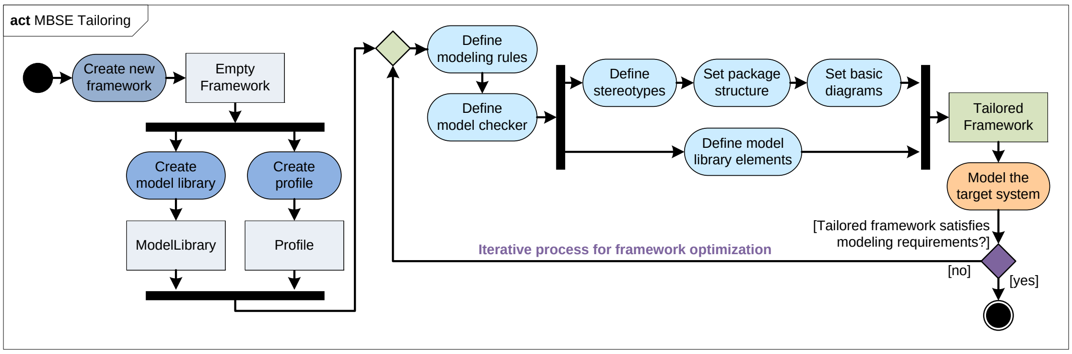

Figure 5: Tailoring activities for creating an adequate modeling framework

find syntactical (e.g. the misuse of a language element) but also contextual modeling errors (e.g. a non-satisfied requirement) [12].

The next step to an adequate modeling framework is the extension of the vocabulary of the SysML by defining the stereotypes to elaborate the generated profile. Packages organize the structure of a model. Thus, splitting the model repository into different modeling aspects (e.g. requirements, system structure, views etc.) to create corresponding packages is the next activity. Setting a package structure recurs on every system level (i.e. system, sub-system and component). A subsequent activity is setting basic diagrams for each package. A defined selection of diagrams for instance provides an overview of the package content and thus helps to navigate within a package and the different system levels [14].

The definition of the model library elements must follow the beforehand defined modeling rules, however it is independent from the package structure and thus can be accomplished as a parallel activity. All these activities lead to a tailored framework which enables and supports the modeling of the target system. To improve the pre-defined framework during the modeling process there exists an iteration loop for further framework optimization.

4 RESULTS AND DISCUSSION

Using the SysML in MBSE is still an emerging trend. For the design of complex systems the SysML has a high potential to cover an existing gap of modeling languages at early development phases. Integrating NFC in the aircraft cabin is a challenging task, because this specific part of system has to interface with various processes in air transport and must satisfy requirements of many different stakeholders. An overall benefit can only be achieved if the system design starts at top level, i.e. with capturing requirements comprehensively for the entire air transport system. SysML provides the opportunity to cope with the complexity of this system and can be used in the MBSE-approach at an initial development phase.

Activities for tailoring the modeling process were carried out to create an appropriate modeling framework. Creation of a profile (i.e. a vocabulary for modeling) and a model library (i.e. a set of physical units and dimensions) can be achieved by following these proposed activities. A feedback loop within these activities allows an iterative framework optimization.

When following the proposed tailoring process (cf. Figure 5) the definition of stereotypes to generate a project specific profile is now possible. Based on an example given by [15] a more detailed classification of requirements was accomplished. Figure 6 depicts the generic metaclass *requirement* which was extended by three different stereotypes, to indicate in detail the type of a requirement and its origin, priority and ownership. Further modeling work will show whether this chosen classification is reasonable or if a further refinement could improve an illustration of the relations.

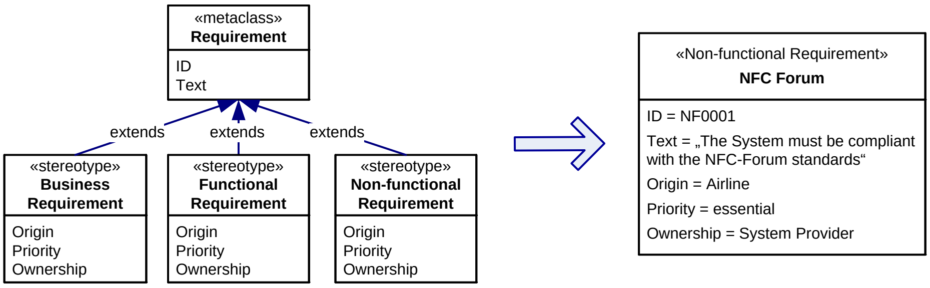

Figure 6: Creating stereotypes for different types of requirements

Another important prerequisite when modeling a system is the definition of the system context. For a complete capturing of system requirements all involved stakeholders within the system context, i.e. the system boundary, have to be considered [15]. Figure 7 shows the stakeholder context for using NFC in air transport and in the aircraft cabin. The SysML metaclass *actor* was extended by using self-defined stereotypes to differentiate between the groups of stakeholders. This diagram shows in a distinct manner that a substantial number of stakeholders are participating in the projected NFC system. The MBSE-approach allows a specific determination of use cases for each stakeholder without the need of having an in-depth knowledge of the overall system and other stakeholders businesses and applications.

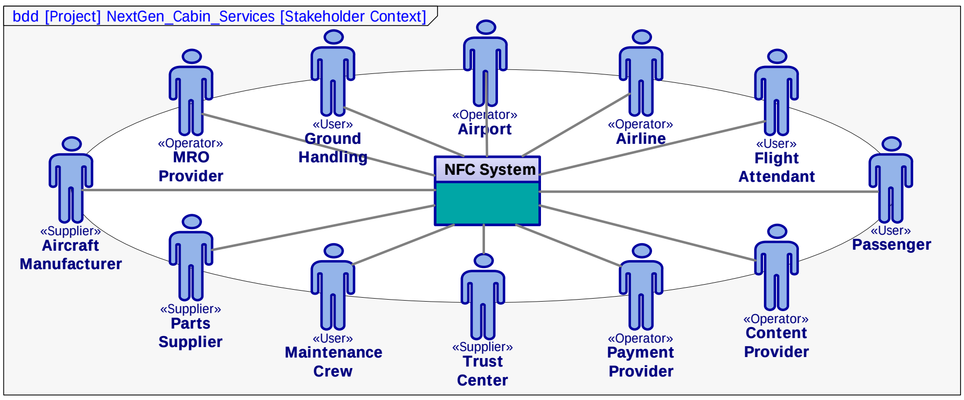

Figure 7: Creating stereotypes for stakeholders in an NFC system context

Although the presented tailoring process for an appropriate MBSE framework seams to create more effort prior to the project, this effort will pay off by the benefit of a manageable formal description of the complex system starting at top level of the development process. It is obvious that the SysML will suit the need of a consistent and model-based development process for an integration of NFC into the aircraft cabin. Further work will show the comprehensive modeling and analysis of system requirements and a model-based derivation of a functional specification and system architecture.

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