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Development of a mobile application with the technology of RFID for managing drugs in hospitals and pharmacies

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Mannheim, 31.08.2018

Jacqueline Franßen

Abstract

Development of a mobile application with the technology of RFID for managing drugs in hospitals and pharmacies

The following thesis is focussed on the development of an mobile hybride application which can be run on Android as well as on iOS devices. The application is specialized in the use in hospitals and pharmacies. The scope of the application contains the registration, tracking as well as the management of pharmaceuticals and drugs, realized by the technology of RFID.

Entwicklung einer mobilen RFID-Anwendung zum Arznei-Management in Krankenhäusern und Apotheken

In der folgenden Arbeit wird die Entwicklung einer mobilen, hybriden Anwendung für Android- und iOS-Smartphones beschrieben. Die Anwendung wurde für den Einsatz in Krankenhäusern und Apotheken entwickelt. Das User-Szenario beinhaltet die Erfassung, Verfolgung und Verwaltung von medizinischen Arzneimitteln und Medikamenten, welche mittels der RFID-Technologie realisiert wurde.

Contents

Chapter 1

RFID Technology

The following chapter will discuss the reasons why choosing the technology and the scope of the RFID technology. It will start by explaining fundamental information and functionalities of RFID readers, tags and further equipment to build a RFID application. After that, some 'State of the Art' applications and use cases will be shown. In the end, there will be mentioned some large companies which provide medical RFID solutions.

1.1. Motivation

Concerning the organization and management of medical devices or patients in a hospital, there exist many problems. In the following, some examples of these problems as described by Ajami and Rajabzadeh [1] will be given. First of all, when it comes to decision making, e.g. about the correct treatment of a severe illness, many physicians are stumped for an answer or their opinions are divided. Secondly, poor communication between nurses and physicians deteriorates medical supply. For instance, if a nurse notices that a patient needs a more tranquilizer because he became very nervous, she has to tell the doctor to dose the patient with the correct amount of tranquilizer. But often, a physician is occupying another patient. So, the communication is one problem but the other problem is the staff shortage. Thus, inadequate patient monitoring is emerges. And sometimes, there is the risk of misidentification of patients. To explain the last point, there is an easy example: At the urology department are two elder patients, Paul Schmitt and Jochen Schmitt. They are not brothers or related to each other and suffer from different types of illness. Paul suffers from kidney insufficiency whereas Jochen suffers from prostatic lithiasis. The first one needs a dialysis every day whereas the second one needs a radiosurgery. Because both patients are unable to walk themselves, nurses and clinical staff have to bring them to the particular treatment room. The problem should be easy to understand, both patients have the same surname but need completely different treatments. If the treatments would be commuted, their health status would deteriorate and they might die because of the misidentification. Another important point for hospitals is the budget and their possibilities to investigate in new technologies which makes the enrollment of a new RFID system more challenging. Furthermore, clinical staff and phycisians have to be introduced into the new technologies. Not only the human factor plays a significant role but also the existing systems, such as the Hospital Information System (HIS), Radiology Information System (RIS) or Laboratory Information System (LIS). If a new identifying system or software should be integrated into a hospital or healthcare institution, it has to be deployed suitably to the existing system architecture. To achieve the last point, Ajami and Rajabzadeh [1] recommend starting with small RFID projects and mentions countermeasures to increase the acceptance of such applications by healthcare institutions. To give an example, the regulations to protect patient's privacy should be mature to achieve more institutional support. Besides, there should exist more customized RFID systems which accomplish the individual tasks of their users. To explain the positive impact of using RFID systems, in the following, a few applications will be described briefly (see also [1]). Firstly, Ajami and Rajabzadeh describe a Medication Administration System which automatically verifies medication and generates the corresponding medication medicine. There exists multiple intents of developing a Administration System, such as preventing human errors (like for example mislabeling of tissue specimens in gastrointestinal and colorectal surgery endoscopy units). The second most common error which occured were that patients have been labelled incorrectly. To avoid these errors, an initiative of developing an application of RFID technology to specimen bottles was started. The aim of this initiative was to create a paperless pathology requisition system and the correct confirmation by both the endoscopy nursing staff as well as the endoscopist for each specimen bottle. As a result of deploying the application, specimen-labeling errors were significantly reduced. Another RFID system, called Wisely Aware RFID Dosage (WARD) system should prevent the risk of medication errors triggered by medical staff. It is based on integrated barcode and RFID tags which should demonstrate effective and safe patient care environment. To give another example of RFID applications, the following paragraph will describe the Mobile Intelligent Medical System (MIMS) which includes a mobile nursing care system using RFID technology. There are many implemented functionalities in the MIMS, such as the tracking of patient's vital signs across various locations and in different medical facilities. The vital sign monitoring enables medical staff to watch critical ill patients carefully and permanently and reduces the risk of serious harm resulting from slow provision [1]. The mobile application MIMS offers alarming services in case of emergencies and can always be taken everywhere. Behind the frontend, a rule-based clinical decision supports medical staff and the mobile nursing environment. Last but not least, MIMS has been extended to most medical domains and has been integrated with other HIS.

1.2. Aim and Scope

Ajami and Rajabzadeh [1] mention three important purposes of RFID technology. The first purpose of using RFID is to improve the tracking of objects. It is mainly used to follow products through a specific supply chain or to follow medical devices an drugs in the clinical workflow. There is also the possibility to track a product to a particular patient or to identify clinicians who administered medication to patients. The second purpose for which RFID technology is appropriate is the inventory management (see section 9). Inventory Management is significant for managing an organization, like a hospital. There are many complex processes where information about the location, time and the amount of material is necessary (e.g. towels, duvet covers). The third and last purpose of RFID technology, mentioned by Ajami and Rajabzadeh [1], is validation. Using RFID to identify and validate data is an effective method for ensuring the quality of a hospital or healthcare setting. It ensures that the patient being treated is the right patient.

uhf, reaching signal

1.3. General Information

According to Ajami and Rajabzadeh [1] RFID technology is capable of an automatic unambiguous identifiation without being placed in the line of sight of their objects. The data between RFID tags and readers is transmitted through radio waves.

In the 1940ies, the technology was firstly used to identify airplanes during war. Today, it is used in several different areas, like for example in manufacturing, supply chains, agriculture, transportation systems, healthcare services etc.

1.3.1. Components of an RFID application

Ajami and Rajabzadeh [1] mention five main components existing in a RFID system. Firstly, there is the RFID tag attached to an object ensuring its unique identification. Secondly, the has to be an antenna which detects each tag and creates a magnetic field. The antenna is connected to its reader which receives the tag's information and is able to manipulate tags. Thirdly, in every RFID system has to exist a communication infrastructure which enables the interaction of readers and tags through an Information Technology (IT) infrastructure. Lastly, to enable users to connect to the RFID infrastructure and to control its modules, there has to be established a application software, such as a database or user interface.

RFID tags

Henrici [2] states that there are two types of RFID tags: Tags with 'Smartcard'-like functionality and 'Auto-id' systems. The first type of RFID tag provides extended functionalities and has computational capabilities. Furthermore, sensors can be attached to the 'Smartcard'-like tags which measure and control temperature and can be used for telemetry applications. In contrast, the 'Auto-id' systems imply the automatic identification of its objects. Generally spoken, RFID systems can be seen as a subset of 'Auto-id' systems.

When it comes to the variety of RFID tags, three fundamental types are distinguished: Active, semi-active and passive RFID tags [2] which all constist of an antenna, a microchip and packaging. Active RFID tags consist of a microchip and have their own power source. As a characteristic, they are more expensive than the other two types. After that, semi-active tags or also called 'hybride' tags have their own power supply which is only used to support the microchip. The transmission or communication between semi-active tag and reader is implemented by using the power of the reader's field. Lastly, the passive RFID tags do not consist of a power source and only work in the reading range of the reader. They harvest their needed energy from the electromagnetic field of the reader and are cheaper than active tags. Moreover, passive tags are lighter than active tags and provide a long-lasting service. In constrast to active tags, passive tags are limited in their read range and functionality.

According to Henrici [2], the memory capacity of passive RFID tags can vary from single bits to kilobytes which is not much. As a recommendation, an external database to store tag-specific data should be used. For instance, a memory of 12 byte is very common to store Electronic Product Code (EPC). Concerning the memory technology, Henrici distinguishes two general types of storage: non-volatile and volatile storage. Non-volatile storage can be divided into read-only (fixed after manufacturing), Write Once Read Many (WORM) and read-write which set the access privileges to the memory. The opposite of non-volatile storage is called volatile storage and is used for example to perform calculations after power-up. Besides, Henrici mentions tags which check passwords or implement ciphering algorithms to ensure data privacy. To visualize the tag's data and to provide real-time measurement, passive tags can be equipped with displays, buttons and temperature sensors.

RFID readers

In this section, RFID readers will be explained in detail. To start with, one has to imagine existing objects which are tagged with a RFID tag. To implement functionality to these tags and to connect them to a middleware or a backend system, a detector is needed. This detector is the RFID reader and consists of an antenna, a power supply for passive tags, a microprocessor (to control devices) and an interface for forwarding data to the processing backend system [2]. Generally, two different types of readers can be distinguished: Stationary and mobile readers. To give an example of the use of stationary readers, they can be used for goods receiving or stock management. Furthermore, stationary readers are fixed to a specific location and need permanent network connection. On the opposite, mobile readers do not need permanent network connection and are used for querying prices in a supermarket. As mentioned in the section before 4, RFID tags and readers communicate via electromagnetism. The reader's detection range depends on the frequency as well as the electromagnetic field [2]. In general, four frequency ranges can be differenced: Low Frequency (LF) (125-134 kHz),High Frequency (HF)(13,56 MHz), Ultra High Frequency (UHF) (868 MHz-915 MHz) and Microwave (2,54 GHz-5,8

GHz). Each frequency range has its own physical characteristics, such as the needed size of antennas or the read range. Furthermore, each reader has its own electromagnetic field. Such fields are distinguished into near field and far fields: Near fields, also called magnetic or electric fields work with induction and capacitive coupling whereas far fields consist of electromagnetic waves. The measuring unit of electromagnetic fields is called field strength and the maximal field strength depends on national regulations. These national regulations limit the electromagnetic compatibility to avoid disturbing other systems. The functionality of passive tags within near field is different from passive tags in far field. In near field, the tags send data to the reader using load modulation. This mechanism does not work in far fields: Here, the sended frequency is backscattered [2]. All in all, readers are able to query tags and to read and write tag data. But the storage of information and the information processing does not take place in readers or tags, but in the middleware or backend systems. These will be explained in the following paragraph.

RFID backend systems

As Henrici [2] mentions, the backend can be divided into two parts: Middleware and applications. Both of them run on the same computer within the same network which is important for the permanent connection to RFID readers and all existing tags. The advantages of a middleware in this use are that no adaption of appications is needed, an open and neutral interface for other applications is provided. Besides, as the middleware is used to aggregate and filter data the processing is moved from tags into middleware so that tags only have to identify objects. As a result, modularity of the system is maintained.

Concerning the data management of RFID systems, data is barely stored on RFID tags because of the limited resources in low-cost tags. It is recommended [2] to store tag information on an encapsulated database. As an advantage, databases provide high flexibility to change data or to execute queries without the tags being present. Furthermore, the backend infrastructure should use a Secure Sockets Layer (SSL) or Transport Layer Security (TLS) protocol to ensure a secure transmission of data. Finally, the data would be transmitted and stored in a backend infrastructure on a central storage [2].

1.3.2. Functionality of RFID system

First of all, when developing an RFID system, it is important to think about the unique identification of each object. To enable a reliable identification of objects, only one RFID tag should be attached to each object. The tag itself has a 'read-only' or in some cases 'rewrite' internal memory which enables users to get or change the object's information [1]. Secondly, the RFID reader generates magnetic fields to enable the RFID system to locate objects (via tags) within its range. Additionally, the high-frequency electromagnetic energy and the query signal which is generated by the reader triggers tags to reply to the query. Each query can have a frequency of 50 times per second [1]. Thus, it is possible to generate large quantities of data which have to be filtered by supply chain industries. Each filter is routed to a backend information system, using a software similar to 'Savant' which is used to control the data. 'Savant' acts like a buffer between the HIS and the RFID reader [1].

1.3.3. Security and Privacy of RFID systems

Security and privacy in the healthcare sector is a very important and highly discussed issue. As Henrici [2] mentions, there exist two fundamental fears about the RFID technology. The first fear concerning marketing purposes, such as creating very detailed customer profiles which lead to a vast amount of information. Secondly, the technology offers the possibility to keep people under surveillance which implies advantages and disadvantages. As an advantage, the patients' life gets more confortable and companies will be more productive. As a negative result, people's privacy is violated and the application's security is not addressed properly. Aside from the two fears, Henrici describes several risks of RFID systems, such as the ease of disrupting the service which indicates data security and privacy problems.

1.3.4. State of the Art

There exist many companies which develop Radio Frequency Identification (RFID) solutions and applications. In this paragraph, three important medical companies which provide RFID solutions, will be presented.

Dipole Company

To start with the first company, in the following, the spanish company ’Dipole’ [3] will be depicted. ’Dipole RFID’ was found in Barcelona 20 years ago with the aim of developing systems for intelligent identification, data capture and systems integration. In their product scope, Dipole provides three main products. The first product contains RFID as well as Near Field Communication (NFC) solutions which should improve optimizing processes, realizing industry 4.0 and the Internet of Things (IoT). The second product consists in manufacturing RFID tags to measure the according user needs of Dipole’s users. The third product is composed of consulting services, RFID software and systems integration. In their section ’RFID Hospital and Health’, Dipole mentions some use cases for their RFID solutions. To give an example, the correct administration of banked blood can be controlled by using RFID tags. Or, when product stock or termination date of medication and drugs in a hospital have to be observed, RFID tags provide a simple and large-scale use instead of controlling the stock manually (which also brings the risk of human errors). For broader use in hospitals, such as managing whole buildings and improving their workflows, RFID solutions should be considered as well. There exist many hospitals which administrate their workflows with paper-based solutions. As a consequence, the processes are getting very slow and data is duplicated. Furthermore, the communication between several departments is flawed and causes further problems. Another health service, provided by Dipole, is the ’Traceability of Analysis’. In a hospital or a healthcare institution, there are many processes which embody information about clinical analysis, blood tests and blood preservation. These information are very important for patient’s diagnosis and treatment. In a laboratory, all tissue samples are stored and several cultivation processes have to be controlled. To increase efficiency of these processes, establishing a RFID system to track and identify all samples correctly would be a useful solution. When it comes to the management of buildings and workflows, the asset tracking forms an important part. Dipole distinguishes two different classifications of assets: Reusable Transport Items (RTI) and products of high value, e.g. elements from the IT and mobile machines. The second type of elements needs specific control in real-time. For an appropriate tracking of IT elements it should be possible to locate each item in a global and detail view to be sure that it is settled in the correct place and under the right conditions, such as the correct temperature or low air humidity. Another use case is guaranteeing the correct dosage of medication to patients which is very important for patient's health and and the work of nursing staff. To simplify the dosage of medication to each patient, RFID tags can be sticked to the pill cases to ensure the correct distribution in real-time. Concerning the management of patients, it is possible to track patients indiviually by wearing bracelets which contain a RFID tag. Currently, the tracking of persons is very controversial because the patient's privacy is offended by enabling his persecution. On the other side, RFID bracelets enable to register patient's actions in real-time and ensure their safety. For example, if a patient suffers from epilepsy, it is dificult to predict an epileptic shock. But if he wore a bracelet which constantly synchronizes his health status with the system, doctors would be able to act preventively against such shocks and could minimize his risk to die of his illness. Not only managing whole buildings is important but also the tracking and control of material in the operating rooms plays a significant role. For instance, in operating room A exists a mobile Computer Tomograph (CT) whereas operating room B only has set of instruments for surgery. When there is a emergency and the patient needs a CT because the doctor cannot say if he needs the suggested operation but in the operating room B does not exist a CT, it is necessary to detect the next mobile CT rapidly and not to deteriorate the patient's health status.

Cardinal Health Inc.

Cardinal Health Inc., with its headquarters in Dublin and Ohio, founded 100 years ago, [4] is a global company which provides integrated healthcare services and products. There exist four product fields in the scope of Cardinal Health Inc.: logistics, caring of patients, business solutions, and guidance of patients. Cardinal Health Inc. provides Inventory Management Solutions [5] which are specialized on hospital's inventory. In a promotional video, they quote different types of inventory systems, such as the '2-Bin-Kanban' system which is adapted for low cost items needing right sizing and bulk level. A second inventory system which provides management for low cost items needing oversight at the each level is the 'Barcode' system. For high value implantables and physician preference items, the company advertises RFID as best used technology. In the video [5], they claim that reading RFID tags is fast, e.g. 100 tags can be read in seconds. Moreover, RFID tags implicate ease of use for users and support user's needs very quickly. The physician does not have to care about the data capture of his observation because all RFID tagged items are automatically tracked and the measured data is captured by backend interfaces which synchronize to other IT systems (like Materials Management System or Billing Systems). In addition to that, automatic data capture avoids redundant data entries, provides errors and saves time. Another important fact about RFID technology is its accuracy and uniqueness. Cardinal Healthcare Inc. advertises that RFID applications enable automated real-time tracking at a unique item level. Beyond, these applications provide a pro-active management of expired and recalled products. As a result, RFID applications lead to a streamlined workflow in which charges are automatically captured for accurate billing and compliants as well as clinical documentation are supported. All in all, Cardinal Health Inc. claims that by using its Inventory Management Solution for hospitals will enable physicians and nurses to focus more on patient care and spend less time on managing supplies [5].

Terso Solutions Inc.

Terso Solutions Inc., formed in 2005 in Madison (Wisconsin, U.S.), is specialized on RFID product development and provides several RAdio Frequency IdentificatioN (RAIN) RFID solutions. RAIN RFID [6] is a wireless technology which enables the wireless connection of items to the internet. As a global alliance, RAIN RFID promotes the universal adoption of UHF RFID technology which can be compared to the WiFi Alliance. RAIN uses a standardized GS1 UHF Gen2 protocol to connect all members (network, software, readers, tags, items) of its solution. However, Terso Solutions Inc. has developed a solution for Medical Field Inventory Tracking which prevents a wide range of services to hospitals. In a promo [7], the company shows its solution which connects the RFID technology to medical field by integrating RFID into the medical kit. By using this Medical Field Inventory Tracking, sales can be instantly recorded, field inventories and reverse overstock situations can be run. Besides, automated inventory reporting is possible which brings the side benefit of eliminating shipping costs. Each wrap can be located by the system and the closest needed device is shown. The advantages that accrued are better handled recalls, eliminated overnight shipping demands and reduced expired products. All in all, Terso Solutions Inc. provides two large RFID applications: The 'RFID for Compliance and Product Integrity' and the 'RFID for Compliance and Implant Tracking' which have also been approved for case studies in two hospitals in the U.S.. The first hospital where Terso Solutions Inc. performed its 'TrackCore' case study was the North Kansas City Hospital. RAIN RFID-enabled intelligent cabinets, integrated with TrackCore Inc.'s tissue and implant tracking software as well as the 'TrackCore Operating Room' were tested. Furthermore, 'Jetstream', a cloud-based platform from Terso was proved at 'North Kansas City Hospital'. The second case study was implemented at St. Dominic Hospital. The tested application included Terso's autoated tissue and implant tracking solution using RFID.

1.3.5. Examples

Chapter 2

Development of Medication Tracking Application

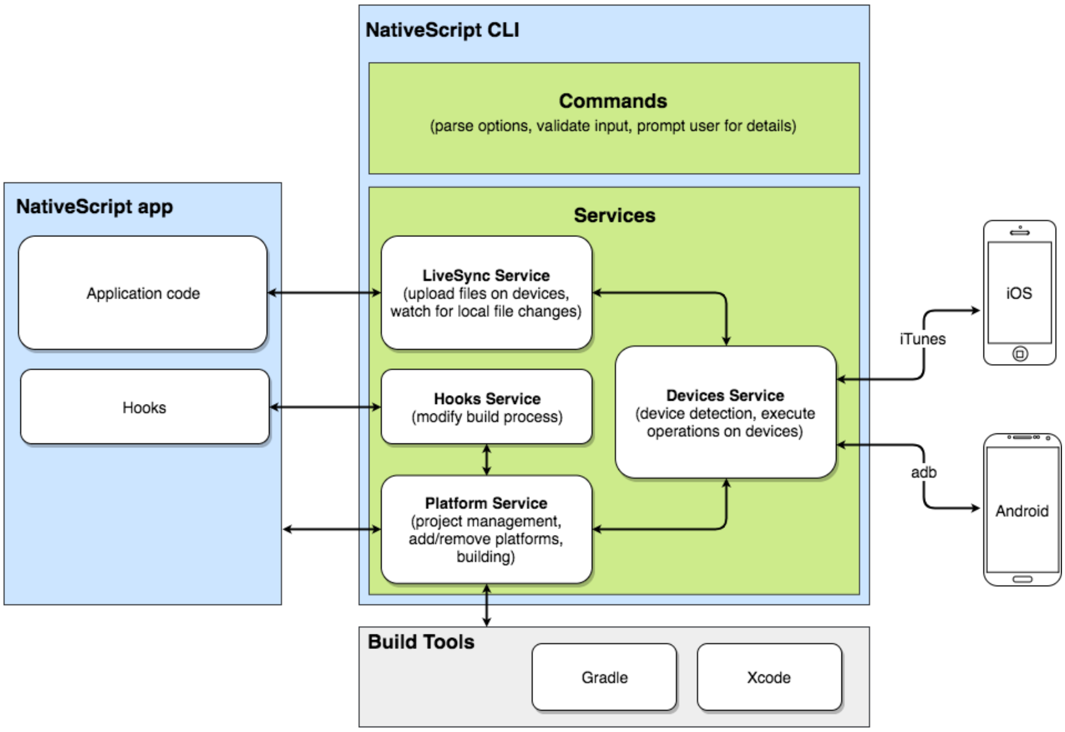
2.1. Used platforms and technologies

2.1.1. Native Development with NativeScript

There exist several ways to create a mobile application. But the challenge is to develop a consistent solution for the existing systems, like e.g. Android or iOS. To face the challenge of developing both an Android and iOS application, one has to think of the usage of web development technologies, like for example HTML5, CSS and Javascript. These technologies provide the advantage of using the access to browser/internet connection.

NativeScript Sidekick

editor for writing simultaneously apps at one moment (both for Android and iOS devices)



The architecture of NativeScript Applications

Figure 2.1.: The adopted from [8]

2.1.2. NoSQL Technology: MongoDB

Characteristics of NoSQL Databases

Reasons and Advantages of MongoDB

strong consistency and atomicity secondary indexes ad hoc queries querying/indexing/updating similar to relative databases (like SQL/Microsoft Access)

2.1.3. Impinj RFID Lector and Antenna

General Information

Examples

2.2. Application development

2.2.1. Challenges during development

Mongodb integration within nativescript application –> with Node JS package installer but synchronization with data from Mongodb was difficult

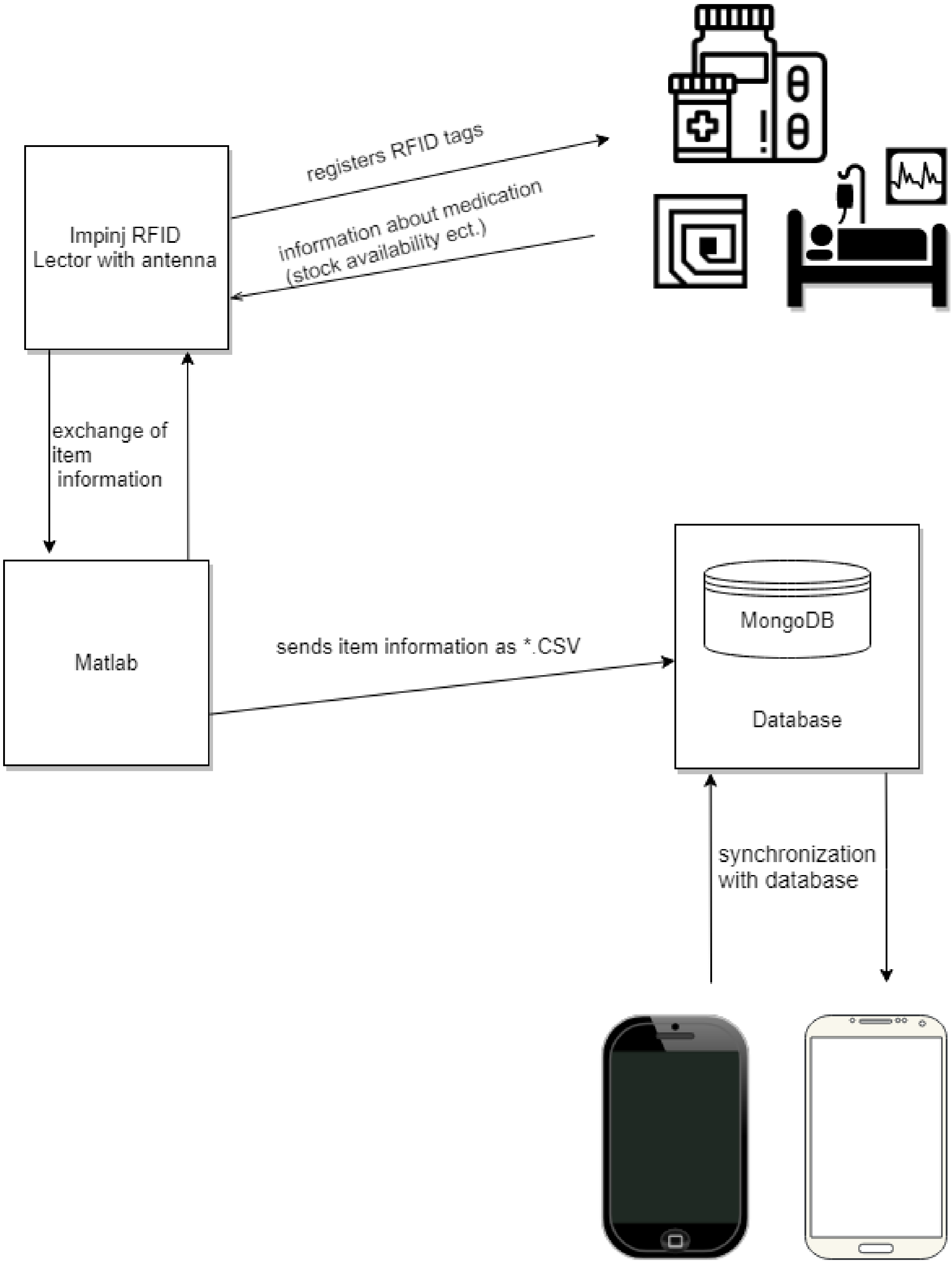
2.2.2. Progress of development

User Scenario

Software Architecture

picture of general software architecture: 2 antennas, 1 lector (RFID Impinj), Database (MongoDB), GUI: Android and iOS Application

2.2.3. Possibilities of extension



The developed system architecture of the mobile RFID application

Figure 2.2.

Chapter 3

Einbinden von Grafiken und Sourcecode

3.1. Bilder

Natürlich können auch Grafiken und Bilder eingebunden werden, siehe z. B. Abbildung 3.1.

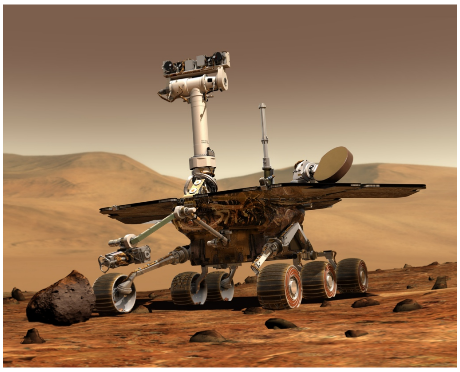


Figure 3.1.: Ein Nasa Rover

Man kann sich auch selber ein Makro für das Einfügen von Bildern schreiben:

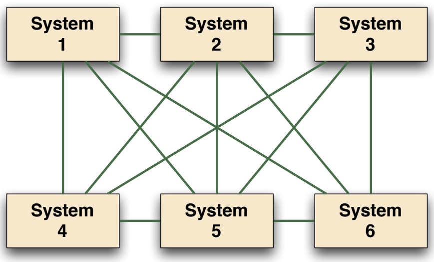


Figure 3.2.: Point to Point

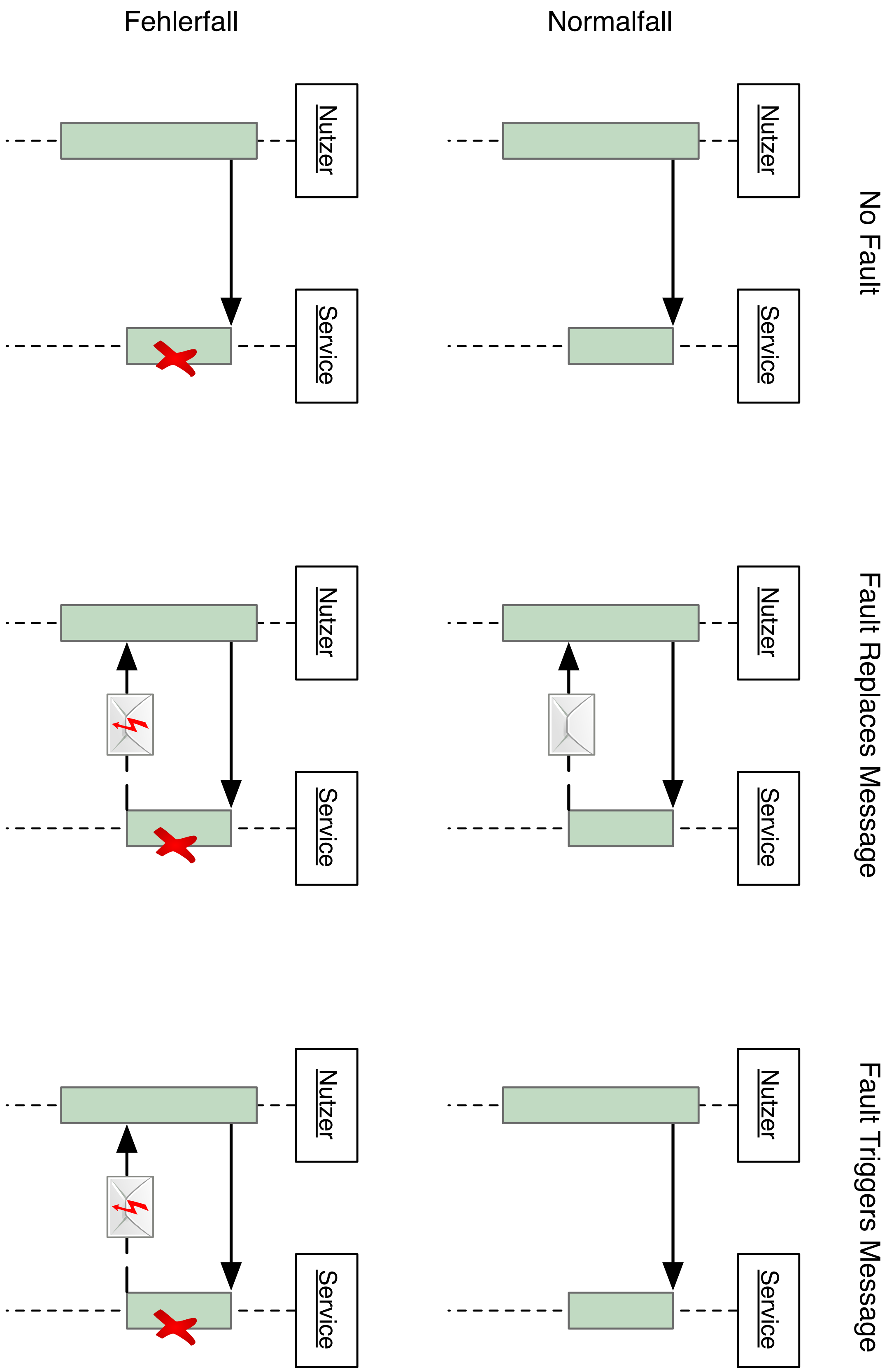


Figure 3.3.: Sehr große Grafiken kann man drehen, damit sie auf die Seite passen

3.2. Formelsatz

Eine Formel gefällig? Mitten im Text $a_2 = \sqrt{x^3}$ oder als eigener Absatz (siehe Formel 3.1):

$$\begin{bmatrix} 1 & 4 & 2 \\ 4 & 0 & -3 \end{bmatrix} \cdot \begin{bmatrix} 1 & 1 & 0 \\ -2 & 3 & 5 \\ 0 & 1 & 4 \end{bmatrix} = \begin{bmatrix} -7 & 15 & 28 \\ 4 & 1 & -12 \end{bmatrix} \tag{3.1}$$

3.3. Sourcecode

Man kann mit Latex auch ganz toll Sourcecode in den Text aufnehmen.

3.3.1. Aus einer Datei

```
/**
 * Grundlegendes Interface, um Verschlüsselung durchzuführen. Mit
 * Hilfe dieses Interfaces kann man Nachrichten verschlüsseln
 * (über die {@link #verschluesseln(Key, String)} Methode) und
 * wieder entschlüsseln (über die {@link #entschluesseln(Key,
 * String)} Methode).
 * @author Thomas Smits
 */
public interface Crypter {

    /**
     * Verschlüsselt den gegebenen Text mit dem angegebenen Schlüssel.
     *
     * @param key Schlüssel, der verwendet werden soll.
     * @param message Nachricht, die Verschlüsselt werden soll.
     *
     * @return verschlüsselter Text.
     * @throws CrypterException Probleme mit der
     *           Verschlüsselung aufgetreten.
     */
    public String verschluesseln(Key key, String message) throws CrypterException;
}
```

Listing 3.1: Crypter-Interface

3.3.2. Inline

```
    /**
     * Testet den Schlüssel auf Korrektheit: Er muss mindestens die Länge 1
     * haben und darf nur Zeichen von A-Z enthalten.
```

```
 *
 * @param key zu testender Schlüssel
 * @throws CrypterException wenn der Schlüssel nicht OK ist.
 */
protected void checkKey(Key key) throws CrypterException {

    // Passt die Länge?
    if (key.getKey().length == 0) {
        throw new CrypterException("Der Schlüssel muss mindestens " +
                "ein Zeichen lang sein");
    }

    checkCharacters(key.getKey(), ALPHABET);
}
```

Listing 3.2: Methode checkKey()

List of Abbreviations

RFID	Radio Frequency Identification
NFC	Near Field Communication
IoT	Internet of Things
CT	Computer Tomograph
RTI	Reusable Transport Items
IT	Information Technology
UHF	Ultra High Frequency
RAIN	RAdio Frequency IdentificatioN
HIS	Hospital Information System
RIS	Radiology Information System
LIS	Laboratory Information System
EPC	Electronic Product Code
WORM	Write Once Read Many
WARD	Wisely Aware RFID Dosage
MIMS	Mobile Intelligent Medical System
LF	Low Frequency
HF	High Frequency
UHF	Ultra High Frequency
SSL	Secure Sockets Layer
TLS	Transport Layer Security

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Appendix A

Erster Anhang

Hier ein Beispiel für einen Anhang. Der Anhang kann genauso in Kapitel und Unterkapitel unterteilt werden, wie die anderen Teile der Arbeit auch.

Appendix B

Zweiter Anhang

Hier noch ein Beispiel für einen Anhang.