Chapter 4
IoT in Practice: Examples: IoT in Logistics and Health

Martin Fiedler and Stefan Meissner

The previous chapters gave a first impression of the ARM as common ground for the Internet of Things. In the following sections we will introduce use cases and sample scenarios (scenes) that have been used as a practical evaluation of the ARM in specific applications. Using the ARM in a top-down process, starting from an application description, most of the scenes introduced were realized as demonstrators within a specific work-package of IoT-A. The second, bottom-up approach of reverse mapping an existing application to the ARM is shown with a scene brought in by the stakeholder group of IoT-A.

The use cases described focus on the domains of retail/logistics and healthcare. This is due to the importance and relevance of these domains, but as IoT-A aims to provide an ARM for the Internet of Things, the ARM should also be applicable to other major domains such as manufacturing or entertainment. The denominator that the two domains considered have in common is that they affect many people – both now and in the future. There is a connection between nutrition and health, with many people opting for healthy food to prevent diseases; others act in accordance with a health plan prepared by their doctor after a diagnosis. Technology can be used to support both cases and makes it easier to eat and stay healthy.

The first part of this chapter covers the retail and logistics use case. It focuses more on enterprise-related processes. Here we also introduce a "red thread" example, which is used within the technical part of the book (see Chaps. 5, 6, 7, 8, 9, and 12). The second part introduces the health use case and an existing application which will be used to reverse map to the ARM.

M. Fiedler (✉)
Fraunhofer Institute for Material Flow and Logistics IML, Joseph-von-Fraunhofer Str. 2-4, 44227 Dortmund, Germany
e-mail: Martin.Fiedler@iml.fraunhofer.de; www.iml.fraunhofer.de

S. Meissner
University of Surrey, Stag Hill, Guildford GU2 7XH, UK
e-mail: s.meissner@surrey.ac.uk; www.surrey.ac.uk

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In general, we defined day-in-a-life scenes with specific characters living through them in the storyline.

4.1 Storyline of the IoT-A Use Case "IoT in Retail and Logistics"

Nearly every single one of us has to do some shopping and in doing so, we gather experience with the retail industry; therefore it is part of our daily life. As technological innovations permeate other parts of our lives, retail is also being increasingly penetrated by different technologies that support and help us in many different situations: for example, smart mobile phones equipped with shopping applications that manage our shopping lists or our dietary information. This presents retailers with the new challenge of integrating their business into the consumer's world and vice versa.

On one hand, information which is generated by customers (e.g. product ratings) might be of high interest to retailers, especially product and category managers. On the other hand, information which is owned by a retailer is not always just of interest for retailers themselves: for example, looking at the traceability of individual goods, real-time queries on a mobile device for the customer or the availability of products in a certain store.

To realize traceability of individual goods during the whole product life cycle and to create transparency all along the supply chain, the first step is to serialise each individual item. This takes place at some point during the manufacturing process. Adding additional sensors to the items to collect various environmental information as well as counting the carbon emitted by the products itself helps to increase transparency (Fig. 4.1).

Privacy concerns that arise from tracking the items of customers outside the store using tags can be addressed by solutions that help both the supply chain and the customers.

Other examples of serialized objects include an NFC tag on a laptop to track the ownership and add built-in accelerometers to it to record physical transport damage. Many kinds of different data are recorded on the way from the point of origin to the point of destination and are transmitted during the transport or at handover and could be made visible by the system at any time.

Using smart mobile phones in combination with RFID- or NFC-tagged products provides advantages not only for manufacturers, retailers and customers, but also for delivery and anyone involved in logistical processes for these products.

With this scenario in mind, the future Internet of Things applied to the retail domain could unfold as follows from a user's perspective:

> Ted, the delivery man for a gardener, uses his IoT phone to manage transport orders, scan tagged items or load carriers and receive status messages from sensors added to the items he is currently transporting (in our case, sensitive orchids). This way, he knows the

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Fig. 4.1 The retail and logistics domain

circumstances of the products without having to do a visual inspection (i.e. stop his truck, which would mean a delay).

When he arrives at the local supermarket, Ted lets the load carriers he delivered pass through an RFID gate which recognizes them automatically. After briefly talking to John, the store manager, Ted sends the sensor record history saved on his IoT phone to John's IoT phone via NFC. The manager can now see that on the way to the store, there was a critical rise in temperature at one point, which causes him to visually inspect the orchids and decide whether he still wants to accept the delivery. Since John identifies the orchids as fine, he sends a message of approval to Ted's IoT phone.

To look at the customer's perspective of our scenario, we switch to Salomée, a young woman representing a customer:

This Saturday, Salomée decides to try out the new supermarket (where John is the store manager) that opened recently. She is a young lawyer and a single mother. Salomée recently took up her first position at a big law firm, and therefore has to put in long hours, leaving her son in day care. Balancing work and family time is difficult. Therefore, she usually does all of her shopping on Saturday morning, even though she hates the long queues that usually form then. As a single parent she is very price-conscious, but she still wants her child to get healthy nutrition and she also cares about the environment, preferring local products with a small carbon footprint.

As she enters the supermarket, she is positively surprised by its spaciousness and its calm atmosphere. Salomée has a shopping application installed on her IoT phone – it allows her to receive information about products when she scans them or when the store's backend system recognizes certain behaviour or circumstances. The software also keeps track of Salomée's shopping behaviour in order to provide more personalized and thus more efficient suggestions.

Today, Salomée is looking for cheese, so she enters the refrigerated section. Once she finds a packet of cheese that catches her interest, she reads its NFC tag to get more information about it from her virtual Shopping Assistant and to compare it to other kinds of cheese she has bought before. Thanks to the application, she quickly finds the cheese she wants to buy.

Now that Salomée has found a cheese she likes, she wants to buy her favourite wine. The Shopping Assistant on her IoT phone can now tell her about the prices of wines she has bought before and if one of these wines is out of stock, shows a recommendation for a similar wine.

Today, Salomée has to acknowledge that there are no affordable wines available that she likes so she starts to leave. This and the fact that she has got cheese in her shopping cart causes a big TFT display to show an announcement for a 30 % discount on wine for anyone buying cheese. Salomée is happy to return and buy a bottle of wine she had considered too expensive earlier.

In parallel, John and his crew have to struggle with the always busy Saturdays. They have to replenish the empty shelves and need to know what the customers need next. Cameras on the ceiling and other ways of understanding the customers support them, helping them to be more efficient and provide the best services to the customers.

Some automatic processes simplify the staff's tasks. The orchids (delivered by Ted) have sensors attached to them that monitor environmental features critical to the quality of the flowers. The sensors send this information to the price tags to enable automatic price adjustment according to product quality. Since the air conditioning in the store is currently not set up correctly, the orchids' price is lowered by 10 % due to a rise in ambient temperature. Continuing her shopping, Salomée passes the orchids, sees how beautiful they are, and to her surprise, realises there is a discount on them as displayed on the electronic shelf labels. She immediately takes one as a present for her neighbour who loves flowers. As the supermarket is crowded today, she uses her IoT phone to participate in a virtual queuing system at the checkout, meaning that she can browse the shelves while already being in the queue for checkout.

After Salomée has finished grocery shopping and is about to return home, she receives a notification on her IoT phone telling her that Robert, her father, has used his last ampoule of insulin. The notification recommends that she stops at a pharmacy to buy new medication. Salomée is glad to see that her IoT phone can show her the location of the closest pharmacy in the area.

She enters the pharmacy and picks up a package of insulin ampoules. The clerk scans the medication and is asked by the local pharmacy software to ask for Salomée's health ID to verify that she is allowed to buy this kind of drug. Salomée hands over her health ID and when the clerk scans it, the software confirms that Salomée is permitted to buy the medication.

In summary, this storyline gives us an impression of how IoT-A components can help consumers and retailers to handle or manage daily challenges. It shows that IoT affects the whole supply chain: starting with the production site, through transport and retail, up to the customer, IoT can facilitate the whole process and improve the service.

4.2 Introducing the ARM with a Recurring Example (Logistics)

The ARM itself – and therefore this description as well – has a certain complexity. In order to ease the process of understanding the overall concepts and the different components that make up the ARM, we will exemplify concepts of the ARM with a "recurring use case" scene (also known as a "red thread") throughout the book. This allows us to complement the sometimes abstract and top-down discussions of ARM concepts with a real, tangible use case.

We have selected a modification of the specific IoT-A use case scene of "Transport monitoring with smart load carriers" that can be found in (Fiedler et al. 2012), because the issue of transport monitoring in logistics is familiar to many readers and offers aspects that are relevant for basically all components in the ARM, while at the same time not being too complex itself.

The "Transport monitoring with smart load carriers" use case scene shows how live sensor monitoring of smart load carriers can prevent the goods transported from being damaged due to environmental influences. The load carrier is equipped with sensors and can communicate with other devices via wireless radio technology. With this hardware, every load carrier continuously measures its environmental parameters and sends all measurements via the embedded event service to the mobile phone of the truck driver who has subscribed to this service.

The business value of the scene is clear: as around 20 % of perishable goods never reach the consumer, but are disposed of beforehand, either in the store or in the supply chain, the utilization of IoT sensors is an interesting concept for implementing quality control for perishable goods and thus reducing waste and increasing margin gains at the same time. In transportation, there is a huge potential for innovative logistics models, such as rescheduling at distribution centres based on the estimated quality of the goods in order to reduce waste and finally get the products to the consumers in good shape (see Fig. 4.2).

To make the use case description more concrete and easy to grasp, we present the use case from a user's perspective. This description supplements the specific IoT-A scene with security features:

> Ted is a truck driver transporting highly sensitive orchids (can be substituted with any perishable goods) to a retail store. After loading the orchids on his truck, he attaches an array of sensors to the load carriers in order to measure the temperature. While he is driving, Ted gets hungry and decides to stop and have lunch. He parks the truck at a resting spot, turns off the engine and goes into a nearby restaurant. Unfortunately, Ted forgot that by turning off the engine, the air conditioning for the transported goods (the highly sensitive orchids) shuts off too, and since it is a very hot day, the temperature inside the truck starts to rise. When the temperature reaches a predefined critical level inside one of the load carriers, one of its sensors notices this and sends an emergency signal to Ted's IoT phone. Due to its delicate nature, this signal cannot be received by the phones of other drivers.
>
> On the IoT phone's display, Ted can now see that the orchids in load carrier number 6 are in danger due to a high temperature. He therefore rushes back to the vehicle and turns the air conditioning back on. The IoT phone also keeps track of any alert messages it receives from the load carriers and saves this message history for future inspection in a way that cannot be altered. When the truck reaches the retail store for delivery, the sensor history is transferred to the store's enterprise system and the sensors authenticate themselves as not having been tampered with.

4.3 Use of the ARM in the Scene "Sensor-Based Quality Control" (Retail)

Another short example shows how sensors monitor perishable goods in a store. The sensor infrastructure measurements are used to estimate the quality of a rare and expensive form of Chinese orchid. Depending on the luminance, humidity, and temperature of the environment, the estimated future quality of the orchids is

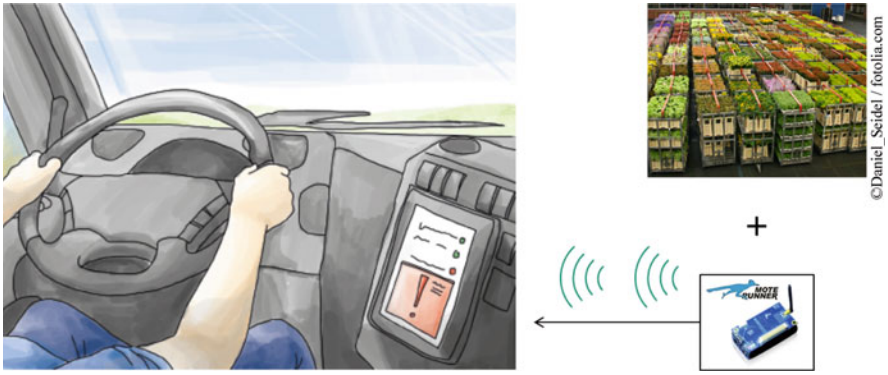

Fig. 4.2 The recurring example (“*red thread*”)

determined and prices are reduced, even before a perceivable degradation of quality occurs. By applying this sensor-based quality control and combining it with dynamic pricing, the store can ensure that the goods are sold before quality degradation is likely to occur.

From a user’s perspective this scene is as follows:

> This Saturday, Salomée decides to try out the new supermarket that opened recently. As she enters, she is positively surprised by its spaciousness and its calm atmosphere. Her mobile shopping application points her to a special offer of non-food items, namely rare and fragile orchids from China.
>
> She immediately thinks of her neighbour, Heinrich, who loves flowers and would appreciate them as a gift from her. Just as she approaches the shelf with the orchids, she sees their price going down by 10%. Happy about the price reduction, she immediately picks an orchid and continues shopping.

From a business and industry perspective, the scene demonstrates two important retail-related concepts: dynamic pricing and quality control of perishable goods. Dynamic pricing as a real-time tool for price optimization strategies has always been crucial for profit maximization. In contrast to the state of the art, dynamic pricing in the use case featured is not performed based on static information such as best before end dates in the transaction data of the backend Enterprise-Resource-Planning (ERP) system, but is based on real-time IoT data gathered from a sensor infrastructure.

4.4 Storyline of the IoT-A Use Case “IoT in Health and Home”

Leaving behind the retail and logistics domain, we now introduce the second use case domain, health and home. This domain focuses more on human-related processes in the IoT. The patient’s related perspective of the complete day-in-a-life scenario is as follows:

> After having enjoyed a nice dinner with his daughter Salomée the night before, 55 year old Robert wakes up in the morning. Robert is proud of his daughter, with whom he has good contact. It’s always nice meeting up with her, as Salomée has a lot to talk about, which reminds him a little of himself when he was younger and more healthy. Robert suffers from high blood pressure and has type II diabetes, and since he has already suffered from one heart attack, he is considered a high-risk patient. He is participating in a program organized by his health insurance company – the program monitors his health continuously and remotely. As his wife died a while ago, Salomée is registered at the health insurance company as a family member who supports Robert with his housekeeping and simple medical care. This relationship is stored in Robert’s electronic health record (EHR).
>
> This morning, Robert is still thinking about the things Salomée was talking about the night before, and he leaves his IoT phone behind in his bedroom. The IoT phone is Robert’s new IoT-capable smart phone which Salomée has told him a lot about. Normally, Robert carries his IoT phone everywhere he goes. A backend system reminds him to take medical measurements in a daily routine, usually three times a day. Now, Robert cannot hear the reminder alarm. Since the alarm is not acknowledged, the system looks for nearby IoT devices such as lights or buzzers in the vicinity of Robert and uses those devices to attract his attention. Robert sees the lights flashing in his living room and instantly remembers what this means, as it has happened before. He goes to his bedroom and picks up the IoT phone to acknowledge the alarm.
>
> He is guided through the measurements he has to take by the application on his smart tablet. He has to measure his blood pressure, heart beat, blood glucose level, current weight and give an indication of the activity he was performing immediately before taking the measurements. All measurements are stored in the system and are analysed automatically, with a notification sent to his doctor if any values are outside the normal range. The system calculates the amount of insulin he must inject. As Robert has to take more insulin than usual he takes his last NFC-tagged ampoule of insulin out of his medicine cupboard and this action is recognised immediately. The insulin stock level in Robert’s medicine cupboard is tracked, and as soon as it reaches a predefined refill level, an alarm is raised. Salomée’s IoT phone is notified to advise Salomée to buy insulin on behalf of Robert at a nearby pharmacy as she is registered as a supporting family member. After Robert takes his insulin dose, his electronic health record is updated accordingly.
>
> Later on, Robert suddenly feels lightheaded and he presses a panic button he is wearing as part of a bracelet. The system detects that his mother, Jane, who he lives with in the same flat, is nearby and notifies her of the situation. Jane finds Robert and sees that there is no need for further action since he has already eaten a candy bar he always carries with him.
>
> In the afternoon, Robert leaves his flat. He is driving to visit his daughter when he is involved in a car accident. The other driver must have overlooked him in the bad weather conditions. Luckily, the acceleration sensor of Robert’s IoT phone instantly recognizes that something dangerous may have happened and queries his condition from his body sensors. The devices agree that Robert is in danger and, after a short time during which Robert can confirm he is safe, an emergency message is released, sending the location data of where the dangerous condition arose as well as his personal ID to the emergency centre. Using location-based lookup, the nearest emergency centre is alerted and asked to send an

ambulance to Robert immediately. The ambulance arrives at the car crash within seven minutes and picks up Robert and the other driver to take them to a hospital.

Arriving at the hospital, the check-in is quick, even though Robert is unconscious. Fortunately, the check-in procedures can be performed directly through interactions between Robert's identity card or health ID card and the hospital admission desk. The clerk first looks for Robert's health ID card but cannot find it. He finds only the identity card, which he can also use to check Robert in. Using an IoT-enabled mouse, Robert can be identified by the local hospital software via his national identity number. The software can be used to grant the hospital access to data from the national identity database that is required for check-in and also allows the receptionist to look up all necessary medical insurance data as well as his entire medical file – making it easy to prepare all helpful information for the doctor beforehand with no time-consuming effort. And again, it pays off to have signed up for the program as Robert gets precedence over a young man who seems to have broken his arm but still has to spend time filling in all the paperwork. After the quick check-in, Robert is looked after by the medical personnel who treat his wounds.

The hospital Robert is staying at is equipped with the Hospital Information System (HIS). This system continuously monitors the environmental conditions (temperature, humidity) in the rooms and prevents incorrect medicine being administered to the patients. Robert had to stay at the hospital overnight as the doctors had to monitor his reaction to the medical treatment. The next day during the morning routine, the temperature readings for Robert and a fellow patient in the same room are too high, indicating a small fever. However, an analysis shows that since the patients shall only be exposed to constant environment conditions the related room temperature in turn was too low due to a failure of the heating system. A facility manager is automatically called by the HIS to repair the defect.

For further medical treatment and to monitor his condition, a nurse visits Robert twice a day. The nurse administers medication to Robert as he needs this for the pain caused by his wounds. In the evening, the nurse scans Robert's identification tag followed by the tag for the box of medicine (ampoules) and suddenly an alarm is triggered. The medicine the nurse is about to administer is the correct one, but the dose in the ampoule is too high due to an error in the hospital pharmacy. The problem occurred could be resolved by the nurse administering the correct dose manually and documenting the mismatch in her tablet PC.

4.5 Use of the ARM in the Scene "Remote Patient Notification" (Homecare)

In the first scene of the health use case, the Remote Patient Care application notifies the patient of actions they have to perform. These actions can be related to administering medicine or to taking measurements at a regular interval.

Patients carry personal devices such as smart phones or tablets which can become IoT-enabled. Applications running on these devices can hence make use of all functions of the IoT-A compliant platform.

In this scene, the patient is notified by an alarm ringing on his IoT phone. This alarm is not acknowledged and therefore the application looks for nearby resources such as light switches or buzzers in the vicinity of the last known location of the patient and uses these devices to attract the patient's attention. The scene ends when the patient finally acknowledges the alarm.

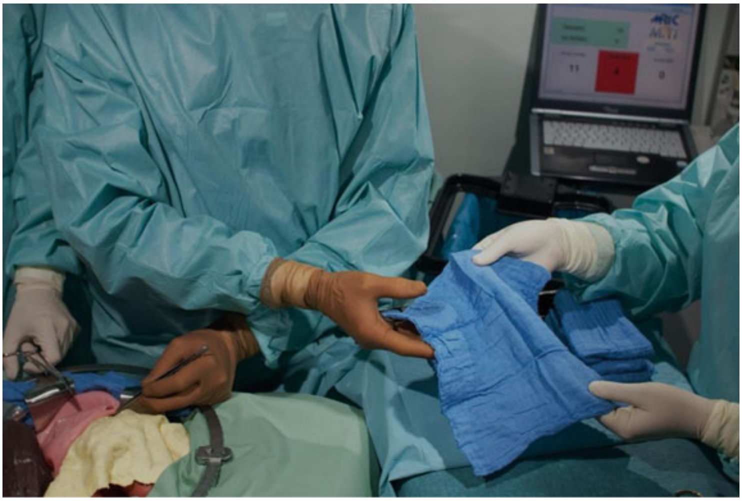

Fig. 4.3 The MUNICH scene of tracking stomach towels during surgery © Technical University of Munich

4.6 Reverse Mapping of the ARM in the Scene "In-Surgery Tracking of RFID-Tagged Stomach Towels" (Hospital)

This scenario will be used to reverse map an existing real-world implementation to the ARM. Further details on reverse mapping of the reverse mapping of the MUNICH platform can be found in Chap. 12. This scenario was included by Prof. Christoph Thümmler, who is actively contributing in the e-health area. The specific application was implemented with help of the MUNICH platform by Celestor, Napier University Edinburgh, Technical University of Munich and Siemens.

This use case scene is about counting stomach towels used inside the abdomen during surgery on a patient. After the operation, no towels may be left in the abdominal cavity (the human body) and assurance is required that this is the case. Therefore, each towel is fitted with an RFID tag enabling it to be tracked during surgery. Figure 4.3 shows ongoing surgery with the blue stomach towels.

The RFID-tagged towels can be tracked by three antennas from different positions in the operating theatre:

- Mayo stand (instrument table): towel is unused.
- Operating table: towel is in use.
- Used towel container: towel is used.

Each towel is used in a specific order. Initially, a batch of "unused" stomach towels is located on the instrument table. Towels which are put into the patient's body are "in use". Finally, towels which are not needed any more after the surgery are put into the towel container and are attributed status "used".

Assurance is required that no towels are left inside the patient's abdomen when the operation has finished. In more technical terms, this means that after the operation has finished, all the towels that were "in use" must be in status "used", meaning in the waste bin.

From a business perspective, up to 100 stomach towels can be used within one single surgical procedure. Towels left in the patient's abdomen can cause severe and even fatal infections. As there are no official numbers, e.g. no central databases on towels left in a patient's body, the numbers differ: studies indicate 6,000–9,000 incidents per year. A business case evaluation example based on its use case can also be found in Chap. 12.

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