DeimSy – A Scenario for an Integrated Demonstrator in a Smart City

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Introduction

IT systems pervade our daily life – at work as well as at home. Public administration or enterprise organization can hardly be managed without IT systems. We come across devices executing software in nearly every household. Increasing size (in terms of lines of code) and features of IT systems have brought us to a point, where IT systems are the most complex systems engineered by mankind. Current research areas, like ubiquitous computing, pervasive computing, or ultra-large scale systems [1], want to enable the engineering of future software systems by sharing a common trend: Complex software systems are no longer considered to have well-defined boundaries. Instead future software systems – so called IT ecosystems [2] – are composed of a large number of distributed, decentralized, autonomous, interacting, cooperating, organically grown, heterogeneous, and continually evolving subsystems. Adaptation, self-x-properties, and autonomous computing are envisaged in order to respond to short-term changes of the system itself, the context, or a user's expectation. Furthermore, to cover the long-term evolution of systems becoming larger, more heterogeneous, and long-lived, IT ecosystems must have the ability to continually evolve and grow, even in situations unknown during development time. This work was funded by the NTH School for IT Ecosystems. NTH (Niedersächsische Technische Hochschule) is a joint university consisting of Technische Universität Braunschweig, Technische Universität Clausthal, and Leibniz Universität Hannover. The NTH School for IT Ecosystems has been established in order to deal with IT ecosystems. It deals with the research questions associated with IT ecosystems in three research projects: AIM, ruleIT, and LocCom. Research project AIM deals with methods and tools to guarantee the functionality of a complex IT ecosystem especially when a top-down design is not possible anymore. Within AIM adaptive information- and collaboration architectures considering independent evolution of subsystems as well as suitable control mechanisms are examined. Therefore all levels starting at the hardware level, continuing with virtualization and modeling up to interface-based formal verification are considered. Research project LocCom elaborates methods, concepts, and tools for decentralized IT ecosystems enabling new emergent services and guaranteeing quality of service. Thus adaptive processes on all levels from reconfigurable hardware over protocols up to modeling and inference methods are examined. Using context information in a generalized form will be crucial for this project. Research project ruleIT examines the question, whether an IT ecosystem consisting of autonomous components meets its users' requirements. Within a top-down design, ruleIT derives rules during the design steps from requirements elicitation until validation. These rules will be used for verification during development as well as for validation during runtime. To achieve this, ruleIT will combine methods from software engineering and systems engineering, extend them and adapt them towards the development of fragments of IT ecosystems. This enables, that IT ecosystems remain dependable and controllable despite the inherent autonomy of their parts. In order to show their research results more vividly, each research project provides parts of a joint demonstrator which is a prototype of an IT ecosystem. This report describes an exemplary sequence of events, which is covered by the demonstrator, by accompanying typical inhabitants of a smart city like New Songdo [3] during their travel. We will show, which benefits they gain from an IT ecosystem.

Vision of a Smart Airport

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Scenario: Vision of a Smart Airport

The scenario describes an exemplary sequence of events on a usual day at an airport like Frankfurt Airport [4]. We assume that an **IT ecosystem** is established at this airport, consisting of several **IT components** and subsystems. We will accompany Bob, Anna, and Chris during a travel to show the benefits, they would gain from an **IT ecosystem**. Within the NTH Focused Research School for **IT ecosystems** we will develop a demonstrator which will enable the scenario presented here to show the impact of our research results. In the scenario the protagonists Bob, Anna and Chris use small devices called **SmartFolks**. **SmartFolks** can be imagined as computing devices like PDAs. **SmartFolks** themselves represent their owners within the **IT ecosystem** and act as an interface to the **IT ecosystem**.

Step 1 (Journey to the Airport). While Anna is leaving her home, her **SmartFolk** reminds her as she closes the door that she forgot some things. Due to sensors in the drawer of her desk the **SmartFolk** detects that she forgot her identity card and reasons that she forgot her passport and her travel documents too. On the way to her car she suddenly remembers that she wanted to buy some sunglasses. After a quick look at her wristwatch she decides to catch up on it at the airport and therefore adds the sunglasses to the **SmartFolk**’s shopping list.

Step 2 (Parking at the Airport). The flight itinerary is available on Anna’s **SmartFolk**. Hence, the **SmartFolk** knows her departure terminal. As Anna is on her way to the airport the **SmartFolk** guides her to a parking lot that is conveniently located regarding her flight details. An airport system takes care that not all **SmartFolk** users are transferred to the same free parking lot and that they will have free access routes. Anna chooses a different parking lot than the suggested one; consequently, the system recognizes the discrepancy and asks Anna to give reasons for that. Anna gives the feedback that she chose a parking lot in the shadow as it is a very sunny day.

Step 3 (Traffic Accident). Chris is also driving to the airport while a traffic accident occurs on the streets near his current location. The accident blocks the entrance to one of the parking garages. Observation systems, e.g., **SmartCameras**, integrated in the car and in the airport infrastructure notice the accident and send a distress signal to the Traffic Management Center (TMC). The information about the accident is spread amongst other system components. After the TMC has received and processed the message, it reacts accordingly by adjusting and redirecting traffic. Chris, located in the immediate vicinity of the accident, follows the new directions and arrives at a different parking garage.

Step 4 (Orientation). As Anna arrives at the airport, her **SmartFolk** guides her to a **SmartBase** in her vicinity. **SmartBases** are displayless and interfaceless sources of information spread across the airport. Compared to classical InfoKiosks or PointOfSale systems (e.g., ticket machines) **SmartBases** need less and more simple components leading to lowered costs, less energy usage and they are more resilient to vandalism. Thus it is feasible to deploy larger numbers of **SmartBases** inside and outside of an airport. The user interface for accessing the information is provided by **SmartFolks** which communicate wirelessly with **SmartBases**. Not all **SmartBases** are connected to a backbone network, some might even lack an electrical feed using some form of energy harvesting instead. **SmartBases** hold several information queryable by Anna: While Anna is accessing information relevant to her, the **SmartFolk** also downloads information which is not requested by her. This "parasitic" information will be automatically uploaded to other **SmartBases** as Anna passes them. After some time the **SmartFolk** will silently delete the "parasitic" information due to expiry criteria. Step 5 (Transportation Request). At an entrance of the airport, Anna requests transportation using her **SmartFolk** and waits for an autonomous transportation vehicle (**SmartTransport**), to bring her to the designated check-in desk. At the same time, large groups of travelers arrive at the train and bus station near Anna’s entrance and are moving towards her position. She does not know that most **SmartTransports** are at a location far away from this entrance at this moment, and, by coincidence, the majority also reports a low battery power level. Anna is surprised that after a short while, a sufficient number of **SmartTransports** is arriving to cope with the large crowd of waiting passengers around her.

Step 6 (Shopping during Waiting Time). Using her **SmartFolk** Anna noted on her shopping list that she needs sun glasses. While she is at the airport the **SmartFolk** compares the entries on her shopping list to proposals made by shops that are near to her. Sensors recognize that Anna is either on the escalator or on the moving walkway. The **SmartFolk** offers two possibilities for the next steps: First, go shopping and then eat something. Second, eat something and then go shopping. Both possibilities are suggested via video and Anna can choose the option according to her preferences. The feedback from interviews with several **SmartFolk** users is evaluated statistically. Bob, another **SmartFolk** user in the airport, does never react to the advertising of duty-free shops. At an interactive request he responds that being on business trips he has no time to go shopping. Because this is also mentioned by other people, the **SmartFolk** developers integrate a new rule into the system: For traveling businessmen do not consider the way to duty-free shops.

Step 7 (Waiting Time, Goods Transport). While Anna is waiting for the check-in, she observes the autonomous transport and delivery of goods to a nearby airport shop. Several transport vehicles have to pass a narrow opening along their way concurrently causing a small congestion. The vehicles organize and coordinate themselves, so the waiting time is spread evenly among them.

Step 8 (Checkin). Now, Anna is joining the queue for the check-in desk but a tourist party blocks her way. Fortunately, she arrived early and therefore is not in hurry. However, a married couple next to her has only five minutes left to check in. The **SmartFolk** tells Anna to step aside. The tourist party steps aside as well and lets the couple go to the desk.

Step 9 (Baggage Drop). Going away from the check-in desk Anna asks herself how her baggage is transported over the airport. The transportation of baggage is done by an autonomous transportation service. A variety of **SmartTransports** performs this task by self-organization. The baggage items must be carried between different locations in the airport like check-in desks, baggage security check stations, start and landing zones of airplanes, etc. Additionally, there are observation systems (e.g., **SmartCameras**, sensors, RFID readers) placed around the area, which gather and provide information (e.g. current traffic volume) and possibly changing requirements or arising disturbances. This information...
is used by the SmartTransports (in terms of self-organization and interaction) in order to achieve a good performance of transportation.

Step 10 (Waiting Time). After checking in, Anna is bored waiting for her flight. She walks around the airport hall and passes some info points which are placed everywhere on the airport. One of these info points shows on his display ideas for improving the check-in devices and provides the possibility to add own ideas. Watching some clips of other passengers Anna gets a better idea: With the help of her handbag Anna reenacts like she puts luggage on a conveyor at the check-in counter below instead of lifting it. In the past she was often annoyed with this issue. With her SmartFolk Anna films her action and, after this, sends the clip to the info point. Now, her clip is shown as alternative part within the check-in film. After a specific period of time the developers of the check-in devices download the passengers’ Ideas from the info points and have a lot of new and inspiring proposals they can realize.

Step 11 (Passport Check). Now, Anna decides to go to her gate. To reach this area she has to pass the passport check where she holds her passport beneath a small device. Briefly afterwards a green lamp flashes up, the turnstile before her is unlocked, and Anna passes the check point. In a queue beside her she recognizes that another traveler is escorted by a security man after his third illegal try.

Step 12 (Waiting Time). After passing the security check Anna has to wait an hour until boarding. In order to use the waiting time meaningfully, she decides to search for more information concerning her travel destination. The SmartFolk recommends sights and presents photos taken along her travel route. These pictures are partly from public sources (e.g., http://www.flickr.com) and partly from tourists currently returning from her destination. Of course, tourists do not want to share their private photos, thus intimate pictures are not sent to Anna. Nevertheless with this information Anna gets a nice overview of the sights she definitively wants to see.

Step 13 (Boarding). After some time of waiting, Anna boards the airplane. Due to the dimensions of the airport, she has to take another SmartTransport from the gate to her plane. As previously stated in step 3, the airport contains a TMC for traffic management and control inside the airport (The norms and additional traffic rules must be defined by the TMC, which can be considered an “Organization”). After Anna’s airplane is taking off, a broken autonomous vehicle or obstacle which blocks the first established route has been detected by SmartCameras installed on a bus and around the airport.

Step 14 (Departure, Travel Time, Returning). During Anna’s journey the airport system is enhanced whereas the system architecture and the application itself are maintained. Amongst others, an expert system module is integrated because of the more and more fine-grained rules: No advertisements for duty-free shops are displayed to traveling businessmen except this person is inside the shop or has enough time (see step 6). Now, being a traveling businessman Bob does not get any advertising of the duty-free shops. While Anna and Bob are on their travel Chris returns from his journey. Because of a very profitable offer he bought a newly developed SmartFolk. Now he is curious whether the developers did a good job and whether the new device integrates itself without any problems into the IT ecosystem of the airport.

Step 15 (Catastrophe). A catastrophe exercise was conducted and filmed by the security cameras. The participants were interviewed afterwards to identify, if the existing system acts as they expected. One criticized aspect was that participants who want to rescue victims were evacuated first and afterwards they had to return against the flow of refugees. After the analysis the application was enhanced by an evacuation application according to the participants needs. In case of a catastrophe only the evacuation application is available. Within this application a SmartFolk user now has the possibility to choose between two rescue relevant configurations: either the Evacuation or the Helper configuration. A user chooses the Evacuation configuration in case he wants to ensure his own life, while he chooses the Helper configuration in case he decides to rescue other people. There is a catastrophe at the airport. A plane crashes in the waiting hall of Terminal B. A fire breaks out. All software agents located at the airport are informed; consequently the SmartFolk provides the evacuation application. Chris is close to the waiting hall of Terminal B. His new SmartFolk offers Chris the two configurations provided by the evacuation application. Chris decides to help injured people and is directed to the first casualty.

Step 16 (At the train station). Bob isn’t affected by this catastrophe. He just wants to get his connecting train as fast as possible. Certainly, this aim is shared by all travelers. The IT ecosystem detects who has to come first and ensures the minimal property by means of verification that nobody misses his train. While the mass around Bob starts moving the SmartFolk calms Bob down and informs him that he still has a bunch of time until his train arrives.

Step 17 (Return Journey). As Bob’s train enters the station his SmartFolk recognizes the new context and shifts its environment profile from “silent” to “mobile”, i.e., the vibration alarm is activated and the volume of the ring tone is increased.

Conclusion

In the previous section we introduced a demonstration scenario to illustrate the research questions behind IT ecosystems. These research questions will be addressed in the three research projects (AIM, LocCom, and ruleIT) of the NTH Focused Research School for IT ecosystems. The scenario presented here is not “paperware”. It will be further refined towards a complete scenario specification: Software and hardware components will be derived from the scenario. These need to be provided by the research projects. Since these components will interact with each other in the demonstrator, all research projects need to agree on the interfaces between these components. This interface specification will describe syntactical aspects describing the structure of the interface as well as semantical aspects. Thus, it defines the behavior of components appearing in the demonstrator. It is essential to enable the research projects to develop these components loosely coupled while keeping the integration risk low. The integration of the IT ecosystems from these different components enables us to show the impact of our overall research within a visionary demonstrator, which is an IT ecosystem. Anyhow, it is still a long road to go until we achieve this demonstrator. The refined scenario specification and an infrastructure enabling the integration of the scenario parts will be elaborated in the following.
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Glossary
**IT ecosystem:** An IT ecosystem is a system composed of a large number of distributed, decentralized, autonomous, interacting, cooperating, organically grown, heterogeneous, and continually evolving subsystems. **SmartBase:** SmartBases are autonomous information storage systems, equipped with wireless transmission capabilities. **SmartCamera:** A SmartCamera or an intelligent camera is an embedded vision system that is capable of extracting application-specific information from the captured images, along with generating event descriptions or making decisions that are used in an intelligent and automated system. (Definition taken from [3, p. 21]). **SmartFolk:** SmartFolks can be imagined as small devices with some computing power like PDAs. In the scenario (see section 2) SmartFolks embody their owners Anna, Bob and Chris within the IT ecosystem and act as an interface to the IT ecosystem. **SmartTransport:** The term SmartTransport stands for a driverless, intelligent, autonomous transportation vehicle within the airport. People, baggage, as well as goods are transferred between different locations using SmartTransport. Due to the variety of transportation tasks, they are not necessarily assumed to be uniform regarding their technical abilities and equipment. The SmartTransport is using and sharing infrastructures of the airport like communication and transportation networks, acting by its own initiative. Hence, it can be seen as an intelligent agent within the IT ecosystem. **TMC:** The Traffic Management Center (TMC) is an intelligent entity (an organization in the context of IT ecosystems) responsible for the management and control of traffic within the airport. Its aim is to keep the system in balance and therefore to ensure an efficient and uninhibited flow of traffic in the transportation network. The TMC defines the organization structure by specifying the roles that can be enacted by agents, the relations between the roles, the norms which refer to its members, and the location-based norms which imply a specific behavior of the agents that are located in the defined area.

References