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AUTOMOTIVE · RAILWAY · AVIONICS
MULTICORE SYSTEMS

ARAMiS Scenarios and Requirements

The ARAMiS Cyber-Physical Systems Scenario.

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Table of Contents

Table of Figures

Table of Tables

Abstract

In this document an envisioned scenario is described that illustrates the future of mobility using revolutionary technologies currently in development. The comprehensive CPS scenario spans over the relevant mobility domains (automotive, railway, avionics) such that, on the one hand, for each of these domains tie points can be found to their own specific scenarios and, on the other, cross-domain topics of interest permit the analysis of interaction and mutual interference possibly arising between domain-specific scenarios as well as the analysis of the interplay the domain-specific scenarios with the global, cross-domain scenario.

1 Introduction

Advanced features in the mobility domains of automotive, avionics and railway require high-performance computing technologies for complex processing or increased networking, as current technologies used in control devices run up against their performance limit. Future control units must perform a greater number of more elaborate functions simultaneously. The objective of the project ARAMiS is, through the use of multi-core technology in the mobility domains, to create the technological basis for further enhancing traffic safety, efficiency and comfort as well as energy savings.

1.1 Target group for the Document

In this document, a contrived future mobility scenario is presented that combines the automotive, the railway and the avionics domains. The scenario describes the journey of a family from Munich to Oslo and chiefly highlights the enhanced comfort and support from the viewpoint of the end users. With the help of this scenario, the reader becomes aware of the reach and sophistication of the envisioned systems. No special knowledge is necessary for understanding the scenario itself, but a little computer technical awareness can be of help for understanding the technical assumptions catalogued in Section 2.2.

1.2 Objective of the Document

The above mentioned future scenario allows the reification of goals and requirements of Cyber-Physical Systems (CPS) for the mobility domain. Moreover, it makes apparent the need for connecting CPS of different (sub-)domains. Indeed not only mobility subdomains, automotive, railway and avionics, must cooperate with each other, further domains can be integrated as well. So for instance the health domain is involved when a convoy of autonomous vehicles needs give way to an ambulance, the energy domain is touched when an electric (or plug-in hybrid) vehicle needs be guided to the next charging station, the traffic authority can be informed of undesired situations or behaviour, the meteorological agency can improve a navigation service using the weather forecast.

1.3 Typography

The following typographic conventions are used in this document:

Glossary term	Terms, which are defined in the ARAMiS glossary are represented in the font ***Italic Bold***
Term	Terms, which have a defined meaning only in the context of the document, are represented in the font *Italic*
`Term`	Code is represented in `Courier New`
`C:\Project\MyCode.c`	File names are represented in *`Courier New italic`*
[1]	Numbers in brackets indicate references to sources which are listed in an annex

1.4 Document Structure

Section 2 provides an introduction to Cyber-Physical Systems (CPS) in general and in particular to the future scenario to be developed later on, and furthermore details the assumptions made on the technology available for the realization of the scenario. In Section 3, the scenario itself is developed. In Section 4 some conclusions are drawn.

2 Cyber-Physical Systems

As defined in [2], Cyber-Physical Systems (CPS) are systems with embedded software (as part of devices, buildings, means of transport, transport routes, production systems, medical processes, logistic processes, coordination processes and management processes), which:

- directly record physical data using sensors and affect physical processes using actuators;
- evaluate and save recorded data, and actively or reactively interact both with the physical and digital world;
- are connected with one another and in global networks via digital communication facilities (wireless and/or wired, local and/or global);
- use globally available data and services;
- have a series of dedicated, multimodal human-machine interfaces.

The result of the connection of embedded systems with global networks is a wealth of far-reaching solutions and applications for all areas of our everyday life. Subsequently, innovative business options and models are developed on the basis of platforms and company networks. Here, the integration of the special features of embedded systems – for example, real-time requirements – with the characteristics of the internet, such as the openness of the systems, represents a particular technical challenge.

The automotive industry is, in terms of sales, by far the most important industry in Germany. In 2008, $345.9 \cdot 10^9$ € were generated. The next most profitable industry, mechanical engineering, obtained $225.5 \cdot 10^9$ €. Around 747,000 people in 2009 were employed in the automotive industry in this country [3]. The sector contributes around 40% by far the largest share of total research and development expenses of the German economy. These were approximately € 22.1 billion in 2009 [4]. Their trade surplus makes far more than half of the total export income in Germany.[1]

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[1] In 2009, the proportion of the total German export surplus was of 55%, see [5].

The mobility domain proves to be ideal in order to show the potential and significance of CPS. Therein the majority of innovations boost safety, comfort and/or efficiency. CPS can be increasingly used to network vehicles extensively, both with one another and also with devices, data and services outside of the vehicle.

2.1 Mobility Scenario

In the development of the scenario below we limit ourselves to point a reference to specific passages of the documents addressing the automotive, the railway, and the avionics domain, respectively. Connections to further domains are simply mentioned and not further elaborated.

The scenario’s starting situation is as follows:

> Ms Rosemarie Weber plans to spend the next Christmas break with her two children at her mother's, Ms Pauline Mayer. The Weber family lives in Munich, Ms Mayer lives in Sandvik near Oslo. Ms Weber's intention is to pick up her children from school and from there to travel directly to her mother.

In the scenario Ms Weber plan is worked out. Ms Weber enters departure time as well as from and to locations, a maximum cost amount for the entire route as well as passengers’ names in her smart device. The mobile device is connected to various providers and to Ms Weber’s private cloud, and makes her suggestions for the trip from her home to pick up her children at their school in the city centre and onward to her mother. Ms Weber decides to use public transportation to the school, from there to continue with her children to the airport with a hybrid car-sharing vehicle (CSV) with autonomous driving capabilities, and finally to reach Oslo by plane, as this is the most energy-efficient and least expensive alternative. The necessary travel documents such as public transport ticket, CSV authorization and flight ticket are transmitted to the mobile device of Ms Weber. Further profile details are automatically taken into account; e.g., preferences concerning meals on board are directly transmitted from Ms Weber’s private cloud to the airline.

2.2 Technological Assumptions

Three main components are required to realize a scenario as described in this document (see Figure 1):

- **Connected Vehicles** — cars must have a reliable permanent access to assistant and alerting services;
- **Smart Sensor Networks** — new smart sensors or existing sensors made smart (e.g. surveillance cameras with

analytical features) must be interconnected into a robust network to serve all kind of mobile devices;

- **Location Based Services** — using the cloud, these services can increase the accuracy of alerting services. In our model case described below: If the car "knows" that it is driving in front of an emergency vehicle and has to give way, some pre-conditioning can speed-up the right reaction in case of an alert.

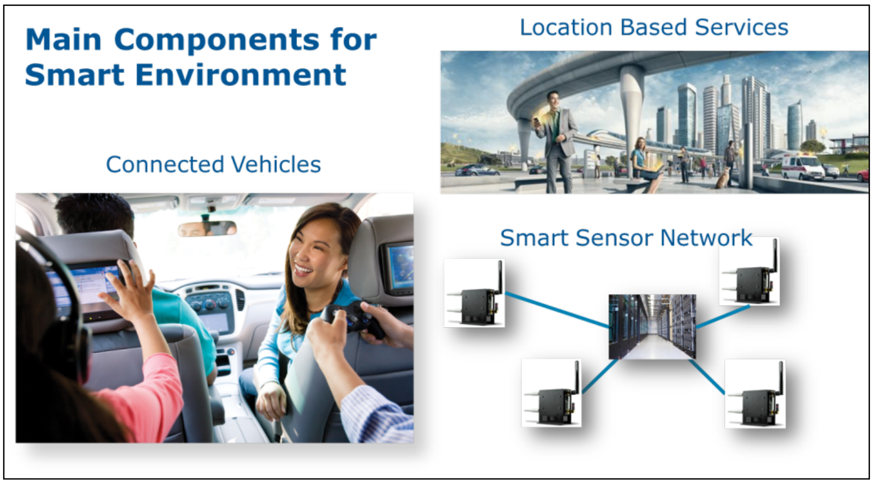

Figure 1: Three main components required

The main common feature of these components is dependability, and each component has a specific set of dependability requirements, as briefly shown in Table 1 and explained below.

Smart Environment Component	Specific Requirements
Connected Vehicles	• Real Time Functionality • Functional Safety • Connectivity QoS
Smart Sensor Network	• Data Security • Availability • Functional Safety • Manageability • Connectivity QoS
Location Based Services	• Accuracy • Client to Cloud Architecture • Connectivity QoS

Table 1: Dependability requirements of components

Connected Vehicles

The system in the vehicles must be able to react within milliseconds once an alert was received. Low latency is crucial.

As drivers rely on the assistance system they may tend to reduce their attention. Therefore it must be guaranteed that the system does what it is supposed to do in any instance.

Regarding connectivity, the Quality of Service (QoS) is the most important single requirement.

Smart Sensor Network

Data generated by the sensors as well as their fusion must be protected against manipulation.

High-level availability must be ensured through a fault-tolerant and self-healing implementation of the sensor network.

Sensors may provide fuzzy, uncertain data. Drawing the right conclusions nonetheless is indispensable to ensure an alerting mechanism as specified.

Many sensors will be connected via wireless systems. This means at least the same QoS requirements apply as for connected vehicles as detailed above.

Location Based Services

Accuracy of the position is important. But for users of today's navigation systems, messages like "You entered a dead end road, if possible please make a U-turn" are customary while driving. This means, GPS (i.e., positioning) alone may not be sufficient especially in urban environments. Other data from the sensor network could improve accuracy so that users know they are, e.g., in front of a school and children may unexpectedly enter the street at precisely that time but not ten minutes later.

In order to ensure a seamless and secure connectivity protecting applications from intrusion of malware, a Client to Cloud Architecture can be used that is based on common standards for each layer.

QoS requirements are identical to those for the two components above.

As most of the communication in the scenarios in this document relies on mobile interconnection, a closer look on which features today describe QoS for broadband applications using Long Term Evolution (LTE) is mandatory (see Table 2 and [8]).

Application	Latency	Jitter	Packet Loss	Guaranteed Bandwidth
WWW Surfing	Uncritical	Uncritical	Uncritical	Uncritical
VoD	Important	Important	Critical	Critical
IPTV	Critical	Critical	Critical	Critical
VoIP	Very Critical	Very Critical	Very Critical	Critical
Video-conferencing	Very Critical	Very Critical	Very Critical	Very Critical
Gaming	Very Critical	Very Critical	Very Critical	Very Critical

Table 2: Criticality of features according to application

Applications like Video Conferencing and Gaming already require the highest QoS level. For safety-related applications, whose QoS must be at least at the same level, there must be mechanisms that guarantee their proper operation even in case of competition for bandwidth. For Intelligent Transportation Systems (ITS), the bandwidth requirements are as follows:

WAVE (Wireless Access in the Vehicular Environment, also known as IEEE 802.11p) allows the use of WLAN technologies in ITS-Systems with specific requirements like very short authentication associations and somewhat increased transmission power and range. Through WAVE a couple of messages like Decentralized Environmental Notification Messages (DENM) or Cooperative Awareness Messages (CAM) that are sent and received between once and 10 times per second from and to vehicles.

The transmission rate goes up in case of an incident; for instance if a number of cars suddenly brake at the same time and in the same place. In that situation each vehicle sends a 120 byte position data DENM once per second (ETSI TR 102 638 V1.1.1) to all other vehicles in the cell. Within an LTE network with 6000m inter-site distance and 3 sector sites in a rural area, this provides capacity for Uplink (UL) and Downlink (DL) listed in Table 3 (see also [7]).

Scenario	Vehicles per cell
UL+DL 1 incident	2250
UL+DL 10 incidents	400
UL+DL 20 incidents	200
UL+DL 40 incidents	100

Table 3: LTE capacity

This seems to be sufficient in rural areas if no other applications compete for bandwidth at the same time.

In an urban environment this situation looks different. Vehicles send 120 byte position data CAM 10 times per second (ETSI TR 102 638 V1.1.1), which are forwarded to 10 closest cars. In an LTE network with 500m inter-site-distance and 3 sector sites, the capacity looks as follows (see [6],[7]):

- average data throughput
    - 250 moving cars/km² on average gives 18 cars/cell
    - 18*120*8*10*10 = 1.728Mb/s/cell DL
- Peak data throughput
    - intersecting roads (267 m and 3 lanes per direction) per cell
    - 1 car every 30m means 107 cars/cell gives 10.2 Mb/s/cell DL

If further ITS data traffic comes on top, DL capacity quickly reaches the capacity limit in case of 5MHz bandwidth.

Solving the issues around QoS and bandwidth resulting in a dependable infrastructure capable of providing all services described in this paper is not part of ARAMiS. Given that there are multiple projects underway dealing with these problems, it is assumed that for most of these issues solutions are available at the time the described scenarios become reality.

3 Scenario Description

The present section describes the envisioned scenario. The presentation is partitioned according to the stages of the journey which constitutes the mobility scenario.

3.1 Leaving Home

Remember that the plan of Ms Rosemarie Weber, domiciled in Munich, is to spend the Christmas break together with her two children at her mother's, Ms Pauline Mayer, in Sandvik near Oslo. Ms Weber's idea is to collect the children from school and from there to travel directly to Sandvik. In order to optimally organize the trip, she enters her address, the school address and her mother's address as well as her criteria concerning duration, cost, environmental friendliness, and energy efficiency of the journey, in her smart device.

The Travel Management and Traffic Control System (TMS) suggests that Ms Weber goes to the school using public transportation, with her children in a car-sharing vehicle (CSV) to Munich airport, and finally by plane to Oslo where they will be picked up by Ms Mayer. Figure 2 gives an overview of the subsequent stages of Ms Weber's journey.

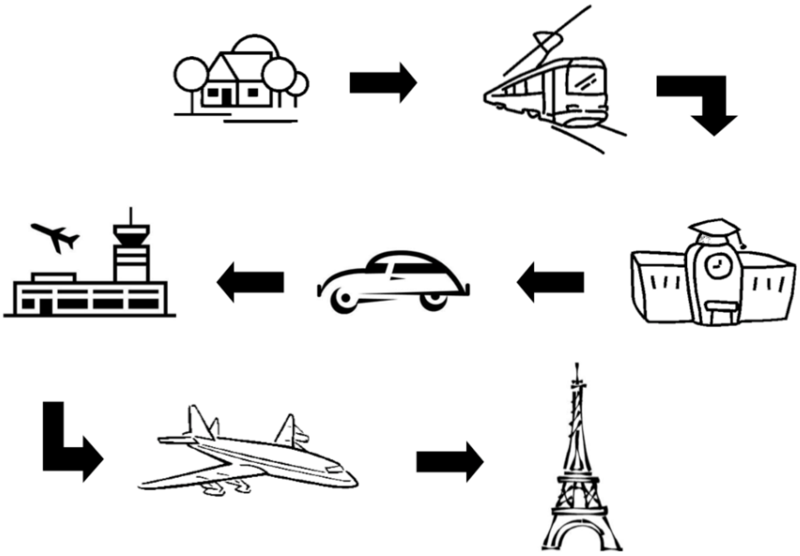

Figure 2: Overview of the stages of the journey

Ms Weber accepts the suggestion with the proviso that the car be hybrid and capable of autonomous driving. The TMS issues a ticket for Ms Weber's ride in the urban railway, a car reservation according to her preferences, and three flight tickets from Munich to Oslo; name and age of the passengers as well as Ms Weber's possibly further preferences are stored in the cloud.

3.2 Local transportation (from home to school)

Local transportation **Hint:** *Additional Future Input of Railway would fit here.*

Shortly before departure Ms Weber gets a notice on her handheld device about the current status of the local transportation train. As the train is delayed, she takes the opportunity to call and have a little chat with her mother. Afterwards she leaves her home; as she and her children will be away longer, the home is automatically locked, energy saving mechanisms of all devices are enabled, lights switched off and the home security activated. Figure 3Figure 3 depicts those functions. Finally she reaches her train on time.

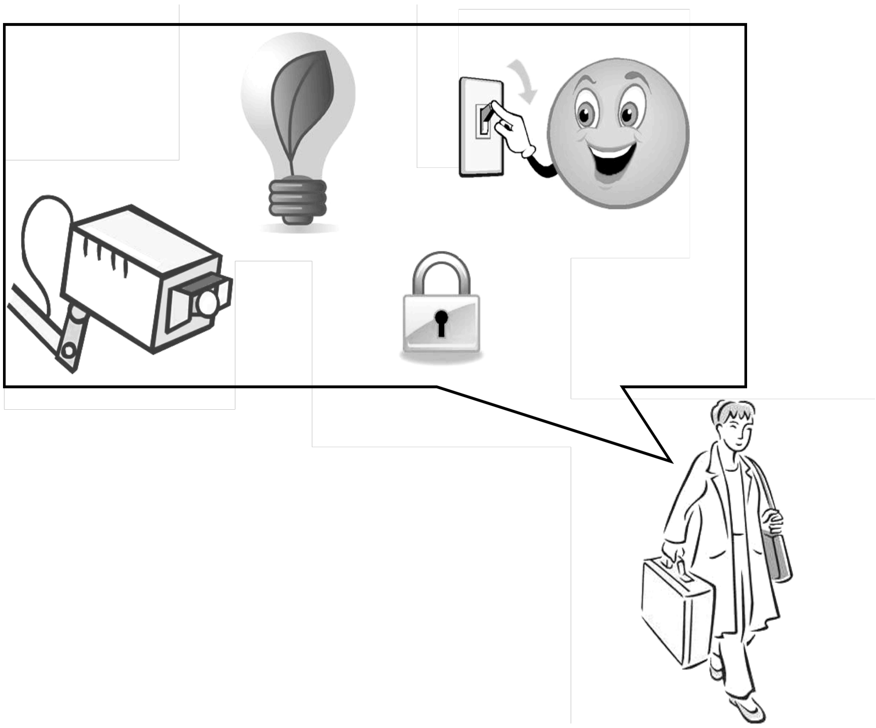

Figure 3: Home is automatically taken care of while away

3.3 At School

Due to the cancellation of the day’s last lesson, Ms Weber's children are allowed to go earlier to their day-care centre nearby. This occurred once Ms Weber already set off to school, and she is informed via her smart device of the new location where to pick up her children. At the day-care centre, the children join their respective project teams, organized to collaboratively do their homework. Pupils' worksheets and further class material are stored in their smart devices (see Figure 4).

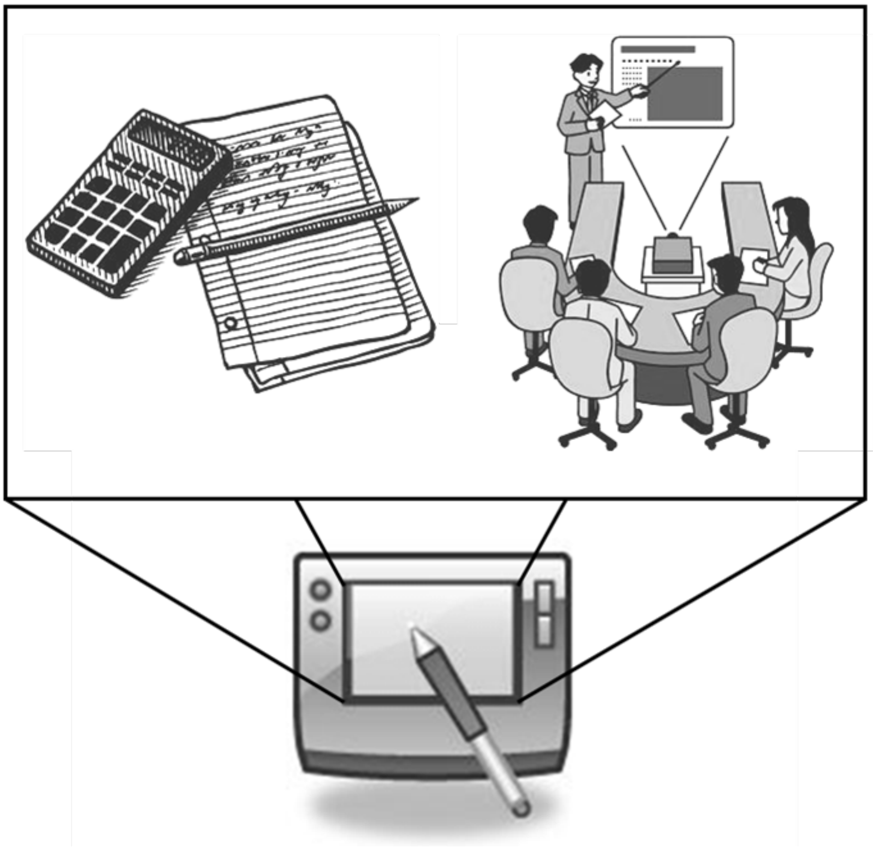

Figure 4: Class material on smart device

The younger child's group is not yet done with the homework by the time Ms Weber arrives at the day-care centre. Spontaneously, the group members decide to stay a little longer and complete their task. Given that Ms Weber and her children have a plane to catch, the homework group resolves to keep in touch with the leaving child by means of the videoconferencing support put at disposal by the infrastructure.

The TMS provides for the security of the data exchanged. The information stored in the cloud, the access to the video streaming and further information exchanged by the pupils, etc., are protected. Ms Weber needs not have any concern regarding security issues.

3.4 Car-Sharing (from school to airport)

Parts of the script in the following driving scenario have been derived from the automotive “highly automated driving use case 4.2”.

For the route connecting the school with the airport the TMS booked an e-mobility car of a car-sharing provider. Ms Weber picks up her dedicated car in front of the school. The car has her driver profile already preloaded, so that the seat and entertainment system is automatically adjusted to her preferences. In addition, the discussion of her child’s homework group is streamed to the in-vehicle infotainment (IVI) system and distributed to the corresponding rear-seat screen. The screen allows interaction via the integrated microphones and pointers – this way, the younger child exchanges with the classmates as being physically with them. The car-sharing provider has been informed upfront about the distance the car needs to go; the battery is pre-charged accordingly, including extra battery load to account for unforeseen circumstances.

As Ms Weber and the two children enter the car, the navigation system starts and suggests the most efficient route to the airport. The system checks the actual traffic situation in real-time. There is an increased traffic volume due to the start of the summer vacation. The IVI offers Ms Weber to book the “premium lane” on the autobahn, which includes a guaranteed arrival time at the airport as an option. The car leaves the parking slot automatically and integrates itself in the traffic flow. To avoid red traffic lights and areas with high traffic density the speed of the car is adapted to the traffic. Figure 5 depicts the situation.

The traffic lights are taken into account in two ways. On one hand, there is a coarse-grained traffic dynamics reduction that is triggered by the (smart city) backend in communication with all connected cars. On the other hand, there is direct communication between traffic lights and cars that provides fine-tuning with more precise local information, including an analysis of movements in front of the car. This communication influences the recuperation system by putting the car into a ‘sailing’ drive mode where it decelerates slowly as well as the start/stop system for actual stops and restarts.

Figure 5: Most efficient route via the “premium lane”

During the drive on the autobahn, the car is being automatically alerted by car-to-car communication about an approaching rescue vehicle on the “premium lane”. The car informs Ms Weber, immediately changes lanes, and reduces its speed. Figure 6 illustrates this constellation. (**Hint:** *eHealth connection*)

In this car-to-car communication, the rescue coordination center informs the rescue vehicle about the accident location to ensure quick appearance with global optimization of the route in the backend that uses the most up-to-date traffic information. (**Hint**: smart mobility connection)

At the same time, the backend informs all vehicles on the closest sections of the route about the upcoming approach of a rescue vehicle. When the rescue vehicle is actually approaching, that information is updated in direct car-to-car communication broadcasted by the rescue vehicle.

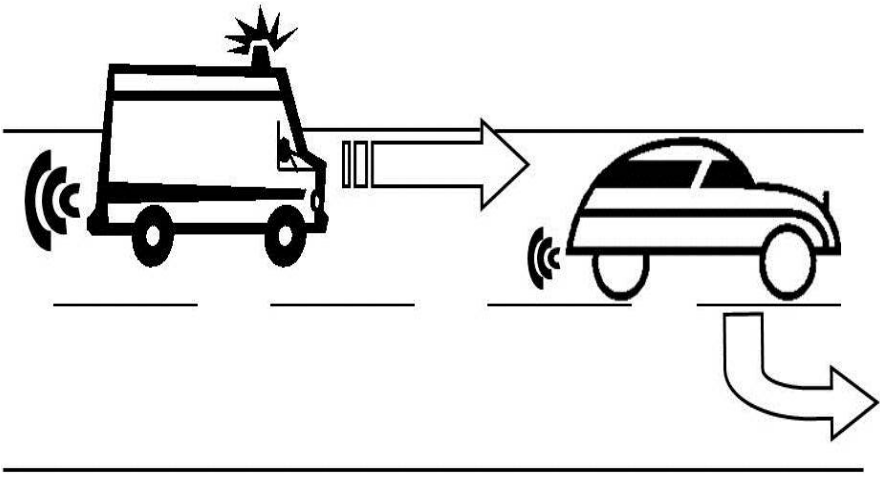

Figure 6: Making way for the rescue vehicle

Back on the “premium lane” the car’s speed is controlled by the supervisory TMS which avoids traffic jams, taking into account the pre-booked arrival time at the airport. The TMS detects unconnected cars and monitors them using cameras. The performance of unconnected cars is taken into particular consideration during traffic control and planning.

Suddenly the car in front brakes, but the collision can be avoided as the optimum evasive manoeuvre is initiated by the TMS and applied to all connected cars. Unconnected cars are considered accordingly in the scenario; see Figure 7.

Thereby, the emergency brake application is calculated within the vehicle and the information is forwarded to the backend. By Car-to-X communication, the braking manoeuvre is also broadcasted to other vehicles in the direct neighbourhood. This kind of information about braking manoeuvres is also collected in the backend, to issue a general warning to the traffic section in case the traffic is prone to producing a traffic jam or an accident.

This last step assumes that within 10-20 years all cars will be equipped with a CPS connection that allows for such communication. This assumption is feasible as there were similar assistant functions in the past that have become standard by now, for example, anti-lock brake systems. One important aspect to discuss here is how to ensure a ‘failsafe’ in case the connection to the backend is missing, e.g., when the vehicle that needs to brake is inside a tunnel. It has to be assumed that complicated functions will fail sometimes, so the quality of service in safety functions has to be carefully determined.

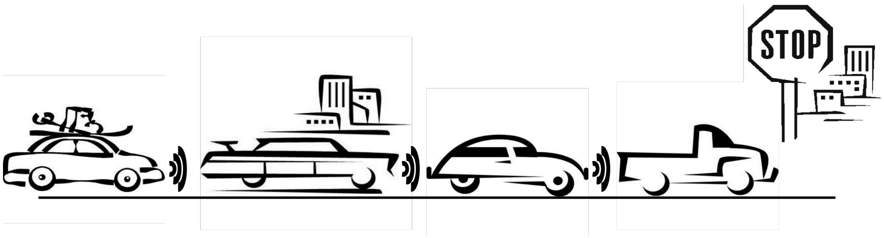

Figure 7: Avoidance of collision

Close to the airport an Unmanned Aerial Vehicle (UAV) registers heavy rain at position "A (48.456303,12.148819)" with wind direction SE. This information is sent to the TMS, which communicates the upcoming weather situation to every intelligent Road-Side Unit (RSU) within a suitable radius. These RSUs collate the information received with the data they locally sense (wind, rain). The TMS analyses if there is a risk of aquaplaning, in which case a number of actions are taken (see also Figure 8):

- unconnected cars are warned using traffic signs,
- cars equipped with advanced navigation systems are informed in real-time through the system,
- Ms Weber’s car and others with car-to-x (C2X) close-range communication capabilities receive the warning through nearby RSUs (802.11p). The cars technology (ABS, ESP etc.) adapts to the slippery road,
- autonomous driving convoys lower their speed automatically.

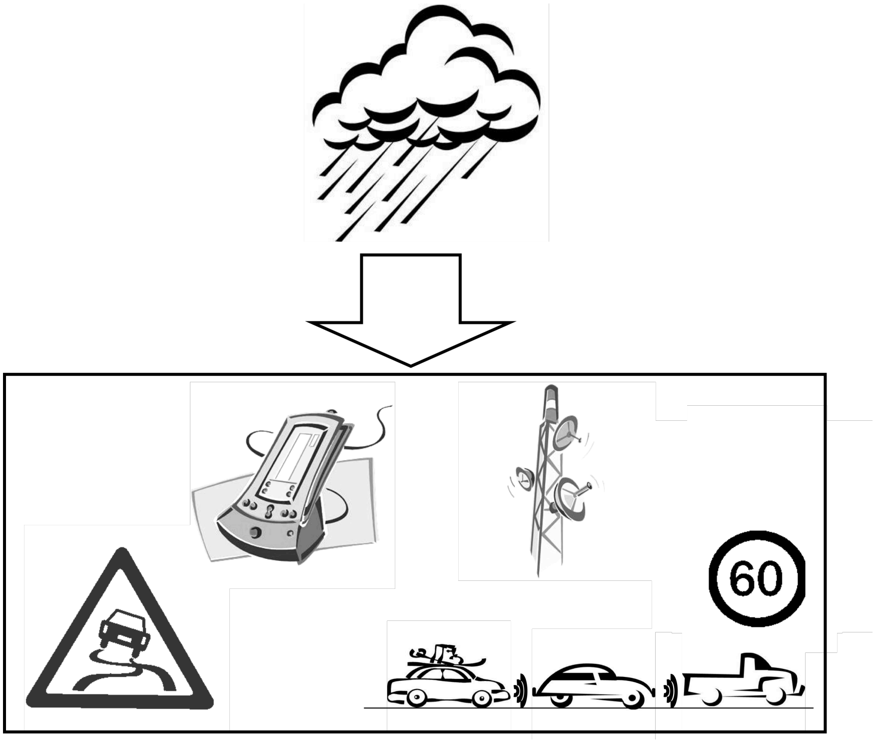

Figure 8: Actions taken to avoid aquaplaning

Ms Weber arrives at the airport; the car stops and parks in front of the departure entrance according to the flight details, which are sent to the car through the TMS and frequently updated. Ms Weber and her children get out of the car, and label and dispatch their luggage using the automatic check-in counter at the entrance; see Figure 9. The car drives autonomously to the parking deck for e-mobility cars of the respective car-sharing provider. Based on a calculated re-booking possibility of the arriving car of less than 10% and since there is enough time to recharge, the TMS directs the car directly to the solar power station for recharging.

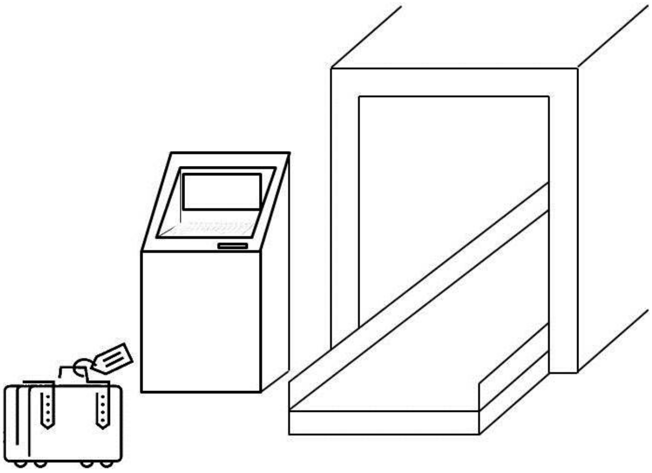

Figure 9: Automatic check-in

3.5 Flight (Munich towards Oslo)

At the gate, the flight is announced and Ms Weber and her children embark the plane and take their reserved seats. After the boarding is completed, the aircraft takes off in the direction of Oslo.

When the plane has reached a certain height and changes to cruise flight mode, the passengers are allowed to use their personal electronic devices to connect to the wireless passenger network on-board. After reading the digital version of the on-board magazine and ordering drinks and duty free perfumes, Ms Weber starts to watch a TV series. The younger child connects to the school working group via a video conference tool using his tablet device and re-joins the video session that was already joined in the car to the airport. The elder prefers to download the last issue of her favourite children’s comic. All these options are depicted in Figure 10; the security of the data exchanged is guaranteed.

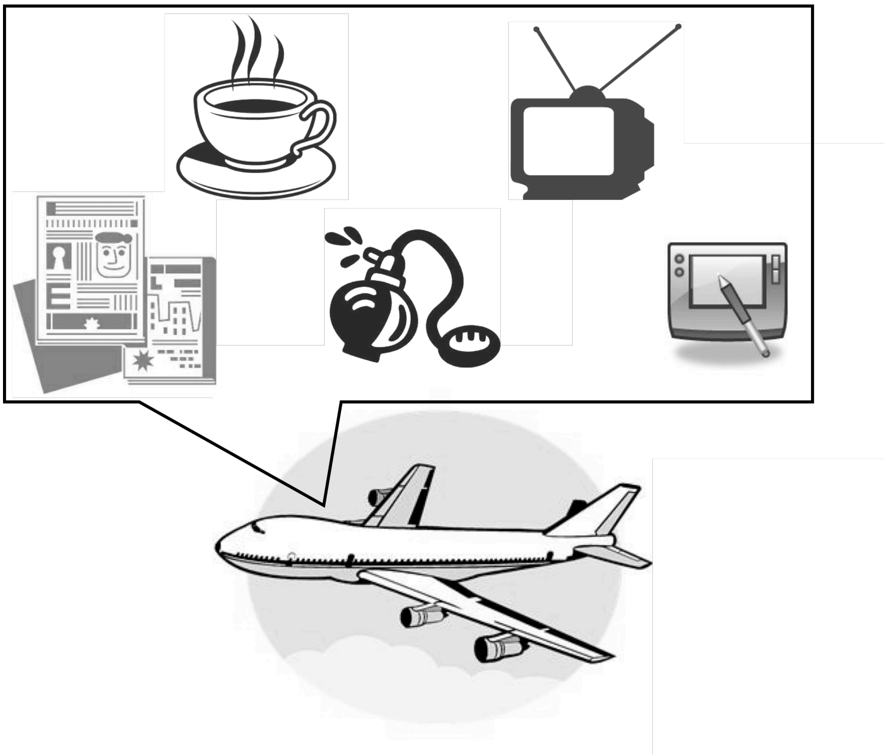

Figure 10: On-board infotainment

After twenty minutes into the flight, Ms Weber is informed on her personal smart device that someone rang the bell at her home. She tabs on the notification on the screen and the video and audio signal from her home's door camera is transmitted to her smart device. She recognizes her neighbour and talks to him for a while. She informs him that they will be in Norway for the next few days and wishes him a nice holiday season. This situation is illustrated in Figure 11.

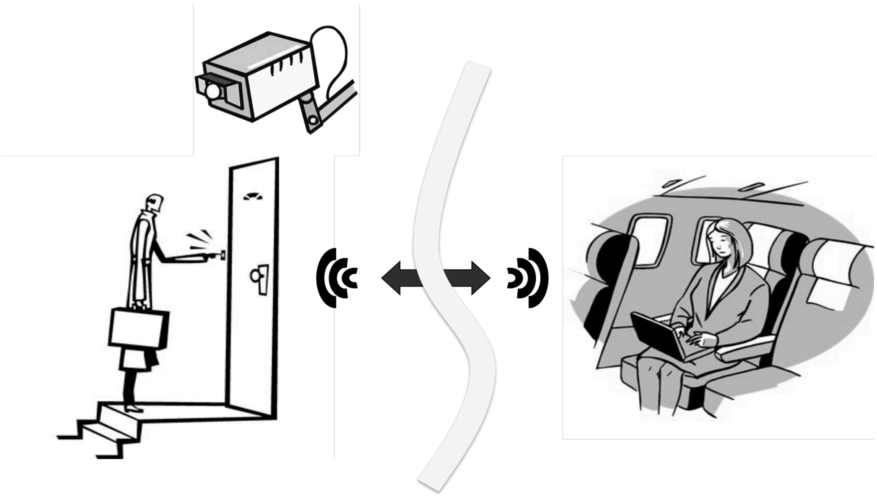

Figure 11: Talking with neighbour at front-door while flying

Meanwhile the pilot notices a warning on the weather RADAR and is informed by air traffic control that there was a major incident on an oil platform with a huge fire and catastrophic leaking into the North Sea. To ensure the safety of the passengers, the flight is dynamically re-routed by SESAR[2], but can still reach Oslo with the available fuel. The system organizes the new flight routes of all the planes in the airspace and schedules them to safely reach their airports (see Figure 12).

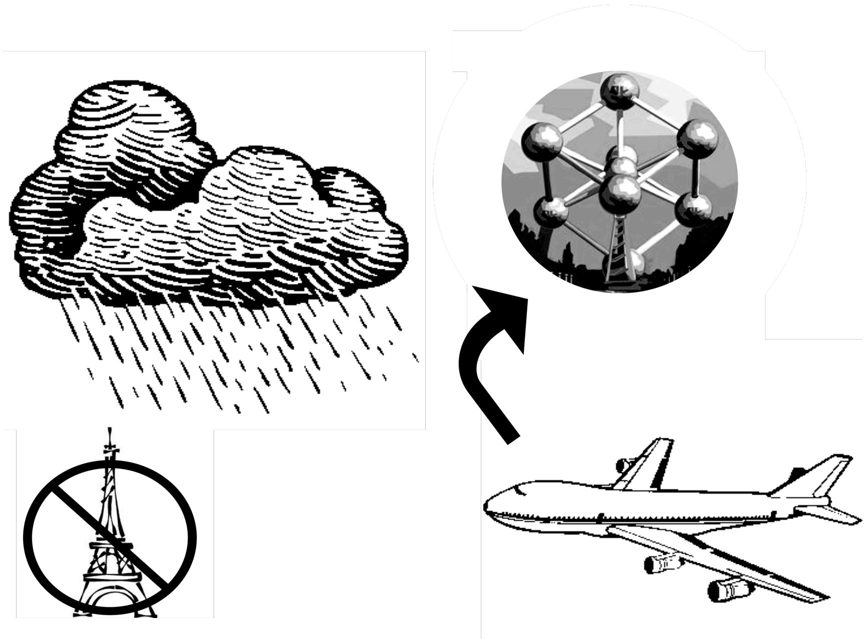

Figure 12: Redirection of the flight to Brussels

To warn the passengers of the expected turbulences, the pilot switches on the seatbelt signs in the passenger service unit and makes afterwards an announcement to all cabin loudspeakers in order to inform the passengers of the redirection. Ms Weber's announcement provokes a pause of the film shown on the overhead displays.

Ms Weber's TMS is informed of the redirection and the plane's estimated arrival time in Oslo. Right after the customer service

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[2] The SESAR (Single European Sky ATM Research) programme, an ambitious research and development projects launched by the European Community, is the technological and operational dimension of the Single European Sky (SES) initiative to meet future capacity and air safety needs.

system prompts her if she would like to notify anybody of the incident, Ms Weber receives a call from her mother, Ms Mayer. The old lady has a headache and would prefer not to drive to the airport to pick them up. So instead of using the customer service system, Ms Weber uses the TMS to change her final destination to Sandvik and the system automatically chooses the next available train to Sandvik and reserves seats in the family waggon in order to ensure that Ms Weber and her children are able to reach their final destination. Ms Weber is informed about the train reservation, how to reach the station from Oslo airport, and also the reserved seat numbers. The TMS also organizes the luggage transfer, as depicted in Figure 13. Smart Logistics ensure that the bags are not directed to the baggage carousel at the airport but to the train to Sandvik instead.

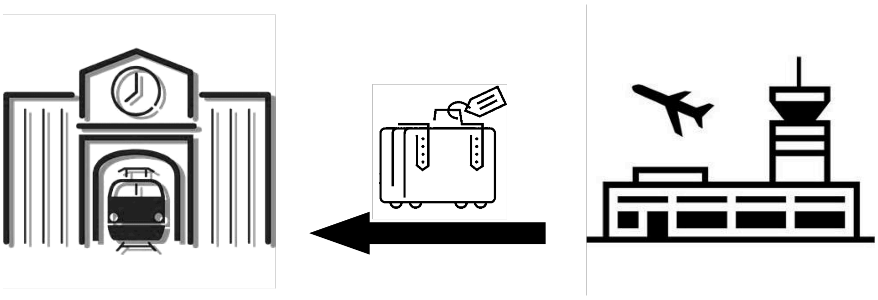

Figure 13: Luggage transfer to the train

Ms Mayer, Ms Weber’s mother, is informed of the change of route and her public transportation ticket altered accordingly. This communication, as already pointed out above, is secured.

3.6 Railway (Oslo to Sandvik)

Once Ms Weber and her children occupy their train seats, she discretely discusses via chat with her mother about Christmas presents for the children. By now the younger child has finished his homework and asks his mother for a soft drink. The elder joins her brother in the request. Ms Weber agrees to the request and using the app on her smart device orders the refreshments for the children and a cappuccino for herself.

Having done this and before the order arrives, they notice an attendant talking to a senior passenger. Ms Weber explains the situation to her children. The man’s pacemaker detected an irregularity in his heart rhythm; therefore, the Telemedicine System (TS) automatically intervenes: It notifies the train personnel as well as the man’s cardiologist. The attendant is guided through the immediate actions to be taken by his smart device. An ambulance with the adequate equipment and remedies is sent to the next train stop, which is to be reached within 20 minutes. The man’s health is thus properly nursed. The TMS and the TS collaborate with each other; safety-critical concerns of situations like this are appropriately taken care of.

The comfort of the rest of the passengers is therefore likewise allowed for. Thanks to the combined infrastructure, no delay is provoked by the incident while the health of the fellow passenger is optimally looked after. This way and among other things, no congestion of phone lines is caused by a significant number of passengers notifying their relatives and friends about a delay.

Ms Weber and her children finally arrive at their destination, where the grandmother cheerfully welcomes them.

4 Conclusions

The presented comprehensive, cross-domain CPS scenario links the domain-specific ones and enables the analysis of their interplay. It encompasses the interconnection of the automotive, the railway, and the avionics domains as well as cross-domain topics like, e.g., sustainability.

Intelligent, integrated, and intermodal transportation services are a good example of having both physical and cyber components. A first aspect is physical interoperability among the varied transportation modes and the passengers and goods to be transported. A second aspect consists of intelligent integration of heterogeneous information on components ranging from simple sensors on cars and planes to complex Traffic Management System (TMS) systems running in large data centres. The progress made in sensing and actuation, in networks and communications, as well as in algorithmic and computing offer enormous opportunities for measuring travel time and reliability on a more frequent basis and more accurately than possible today. Wireless technologies, ubiquitous communication networks, communications devices, and geographic location technologies all contribute to a future where (a) locally, travellers have better knowledge of the TMS around them, and can make informed decisions to optimize their personal mobility, and (b) globally, the TMS has better knowledge of the locations of travellers, and can make control and pricing decisions more effective and efficient for the entire system.

Acknowledgments

The authors are indebted to Lisa Hüfner for the beautiful pictures.

Appendix 1: Content Model Items

See D1.1 Appendix A1 for the ARAMiS Content Model.

References

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