Chapter 5
Case Studies

Abstract Within this chapter, two projects are demonstrated as case studies in which the Use Case Methodology as well as the concept for architecture models are used with our tool-support. Additionally, further domains – Electro Mobility, Smart City, Maritime and Industrie 4.0 – are introduced that adopted the Smart Grid Architecture Model (SGAM).

Keywords Architecture modelling · Requirements engineering · Use cases · Domain specific modelling · Stakeholder management

5.1 Use Cases for Active Assisted Living (UC4AAL)

The German project *Use Cases als Basis zur interdisziplinären Konvergenz in Smart Grid und AAL – UC4AAL (Funding code: 01 FS 13028)* aims at the transfer and extension of the IEC 62559-2 Use Case Methodology (cf. Chap. 2) from the Smart Grid to the Active Assisted Living (AAL) domain. Therefore, these domains are considered in the context of complex and cross-domain systems as well as from the standardisation perspective (cf. Chap. 1). As mentioned in previous sections, the standardisation faces new challenges to gather and describe requirements for future complex systems e.g. to detect standardisation gaps (cf. Chap. 1). Supporting these challenges by the project UC4AAL is one of the main goals. The known vertical approach to describe a system's functionalities within one domain cannot be applied for Smart Grid and AAL (the top-down approach, cf. Sect. 2.2). On the one hand, the number of involved actors is too high, and on the other hand, ambiguous ideas of these systems make it difficult to specify general requirements. Thus, the vertical approach should be replaced through a horizontal approach, in which scenarios are described through the interaction between actors (the bottom-up approach, cf. Sect. 2.2). Scenarios allow a complete consideration and analysis of new systems in the area of standardisation. Prior experiences in E-Energy projects and discussions of the international IEC standardisation mandate M/490 show that the known Use Case Methodology from the IT sector can be used for the use case description in standardisation.

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Additionally, the transferability for the Use Case Methodology is checked as main goal of this project by including the domain AAL into previous work of the mandate M/490. Additionally, the concept of IHE profiles (cf. Sect. 2.4), which is a well-known methodology in the AAL sector, is included into the Use Case Methodology. For supporting use case description and administration for the large number of use cases as well as to allow use case analyses, an IT-Tool – the Use Case Management Repository (UCMR, cf. Sect. 4.1) – has been developed.

During the project, various use cases from the AAL Joint Program [4] have been described and included into the UCMR for demonstrating its functionality. These examples are used to perform test cases with various reviewers with different backgrounds to check and to improve the extension of the Use Case Methodology through the IHE profiles. Findings from this process are part of the development of the UCMR. The project results are described in the previous Sects. 4.1 and 4.2 as well as on the German conference *Mensch und Computer* [6]. Additionally, these results are applied on further complex and cross-domain systems, like Smart Cities [5, 7, 8]. This indicates that the Use Case Methodology and the IHE-process can be successful transferred to other domains.

5.2 DISCERN

The European project *DISCERN – Distributed Intelligence for Cost-effective and Reliable Solutions (Funding code: 308913)* aims to support Distribution System Operators (DSO) with services and tools that enable them to assess the optimal level of intelligence in their distribution network [3, 19, 20]. The basis of the overall concept of DISCERN is to utilise the experience of major European DSO with innovative technological solutions for a more efficient monitoring and control of distribution networks. The complementary nature of the demonstration sites with regard to specific challenges as well as technological and operational solutions serve as the main resource of DISCERN.

The knowledge sharing between the DSO is organised by use cases based on the IEC 62559-2 template, which are gathered and stored in the UCMR. These use cases describe solutions for monitoring and controlling the distribution network for future applications in the Smart Grid. During the knowledge sharing process, the DSO can take various roles: leaders, learners, and listeners; these roles describe the 3L concept of DISCERN [19]. A *leader* has good knowledge on a particular topic that has been implemented through the DSO, i.e. a DSO with this role shares its knowledge. A *learner* is a DSO which learns from the information provided by the leader. A *listener* studies the information provided by leaders and learners to check whether the implementation of a new function through the learner is successful. Based on this information, the listener decides whether this function and its implementation process can be realised for its own operation. Due to the classification in roles, use cases from different perspectives as well as technical specifications and alternatives can be created.

Next to the Use Case Methodology, the SGAM approach is applied in the project [18, 19]. For the described use cases, the conforming Smart Grid Architecture Models (SGAM) have been developed. Thus, the project has shown that use cases described by the IEC 62559-2 template can be transferred to the SGAM. Therefore, an XML schema has been developed which links elements from the use cases description with the components of the SGAM to enable a smooth transformation from the use case to the SGAM [18]. For collecting and visualising use cases and the SGAM, the tool-support described in the previous Chap. 4 is used. Due to the application of the tool-support, further ideas and comments are collected for developing the UCMR and the three-dimensional visualisation. Additionally, a broad acceptance from the users has been registered during the work with the tool-support [2].

5.3 Transfer to Other Domains and Future Application

In the last chapters, the architecture model for the Smart Grid domain has been explained (cf. Chap. 3), and additionally, concepts from the AAL domain about the use case model and the AAL architecture model are introduced (cf. Sect. 2.4). In this section, further (reference) architecture models from several domains are described [21] to give an overview on current application areas Electric Mobility [16, 22], Smart City [8], Maritime [9], as well as Industrie 4.0 and its legal aspects.

5.3.1 Electric Mobility Architecture Model (EMAM)

The domain *Electric Mobility* considers the application of electric vehicles in the Smart Grid as well as the connection between car, cable, pole, and point-of-common coupling (PCC). The architecture model is called *Electric Mobility Architecture Model (EMAM)* and an example is shown in Fig. 5.1. The layer concept is the same as for the SGAM (cf. Sect. 3.1.2). Thus, the layers are not explained in this chapter again. However, domains and zones are described briefly to demonstrate their links.

The EMAM has been developed as high-level model to demonstrate relations and connections between components from the electric mobility sector. The domains depict the energy conversion chain similar to the SGAM domains, however, in a more detailed manner from a consumer perspective. The zones demonstrate the connection between the electrical vehicle and its internal functionality with the power grid, the future Smart Grid. The domains are extracted from the German Standardisation Roadmap for Electromobility [23]; they are mentioned by [22] as follows:

- The *Distribution* represents the infrastructure and organisation which distributes the electricity to the customer, like households and SMEs.
- *Distributed Energy Resources (DER)* are small power plants which are directly connected to the public distribution grid with small-scale power generation technologies (in the range of 3–10.000 kW).

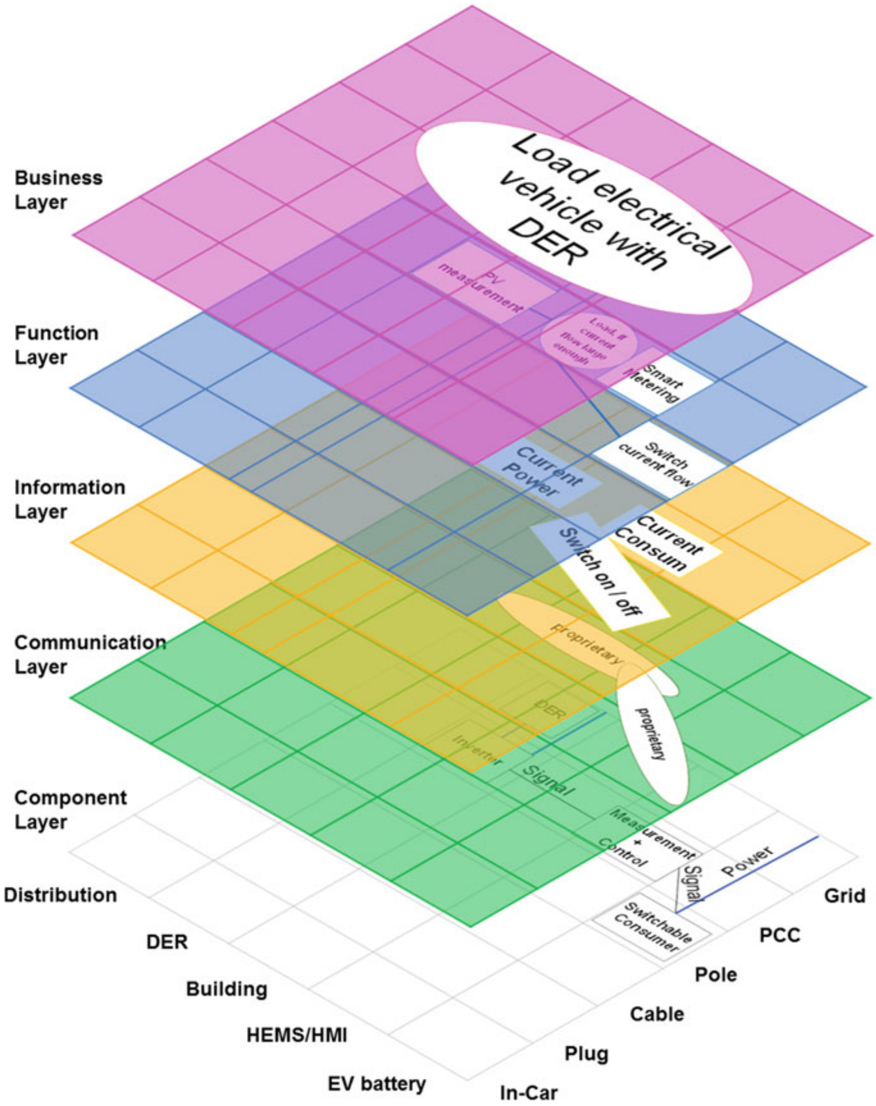

Fig. 5.1 Electric Mobility Architecture Model (EMAM)

- The energy distribution within a household or SME is demonstrated in the domain *Building*.
- The *Home Energy Management System (HEMS)/Human Machine Interface (HMI)* represents the control system for the energy distribution in households and SMEs.
- The *Electric Vehicle (EV) battery* stores the energy and can be located in an EV or a charging station.

The zones are also derived from the German Standardisation Roadmap [23] and are mentioned by [22] as follows:

- All components and systems within the EV are part of the zone *In-Car*, like control units, multimedia equipment, and navigation tools.
- The *Plug* describes the interface of the EV, which for example provides data about the battery level.
- The *Cable* represents the connection to transfer power and information between the EV and the charging station.
- The battery charger and the charging station are depicted as zone *Pole*, which is connected to the energy distribution system within households and SMEs.
- The interface between the pole and the power grid (distribution network) is described by the *PCC*. Thus, this zone supports the communication for services with external providers.
- The *Grid* represents the power grid where associations like virtual power plants or vehicle fleets act.

5.3.2 Smart City Infrastructure Architecture Model (SCIAM)

The Smart City Infrastructure Architecture Model (SCIAM) is shown in Fig. 5.2. It describes one particular new derivative from the original SGAM. First introduced and discussed in the German DIN/DKE Smart Grid Standardization roadmap for Smart Cities [24], it is a proposal based on the success of the original model of the SGAM. Instead of the business layer, a so-called *action layer* is proposed but not yet agreed upon [8]. Additionally, the zones are adopted from the SGAM, i.e. they cover a mostly hierarchical way of structuring physical locations. *Market*, *Enterprise*, *Operation*, *Station and Field* as well as *Process* form the zones axis. This list can be considered as a natural ordered list not being based on a bag principle. At this place, the layers and zones are not explained in more detail and we refer to Sect. 3.1.2 in which they are described for the SGAM.

For the SCIAM domains, a new axis has been developed. The SCIAM describes a model to visualise functions in a Smart City which affect more than one domain; thus, the domains for Smart Cities depict the different areas in cities which influence the quality of life, efficiency of urban operations and services, and competitiveness [13]. The domains are mentioned by [24] and depict the major areas of a Smart City are *Supply/Waste Management*, *Water/Waste Water*, *Mobility Transport*, *Healthcare/AAL*, *Civil Security*, *Energy*, *Building*, and *Industry*. These domains can be explained in a more detailed manner through further architecture models, like the SGAM (cf. Sect. 3.1.2) for *Energy*, the EMAM (cf. Sect. 5.3.1) for *Mobility Transport*, or the AALAM (cf. Sect. 3.3) for Healthcare/AAL. Thus, the SCIAM does not only demonstrate a single information flow but a number of various scenarios, like the implementation of smart traffic lights or the waste management for industry, which describe an information flow across multiple domains and can be demonstrated with this model.

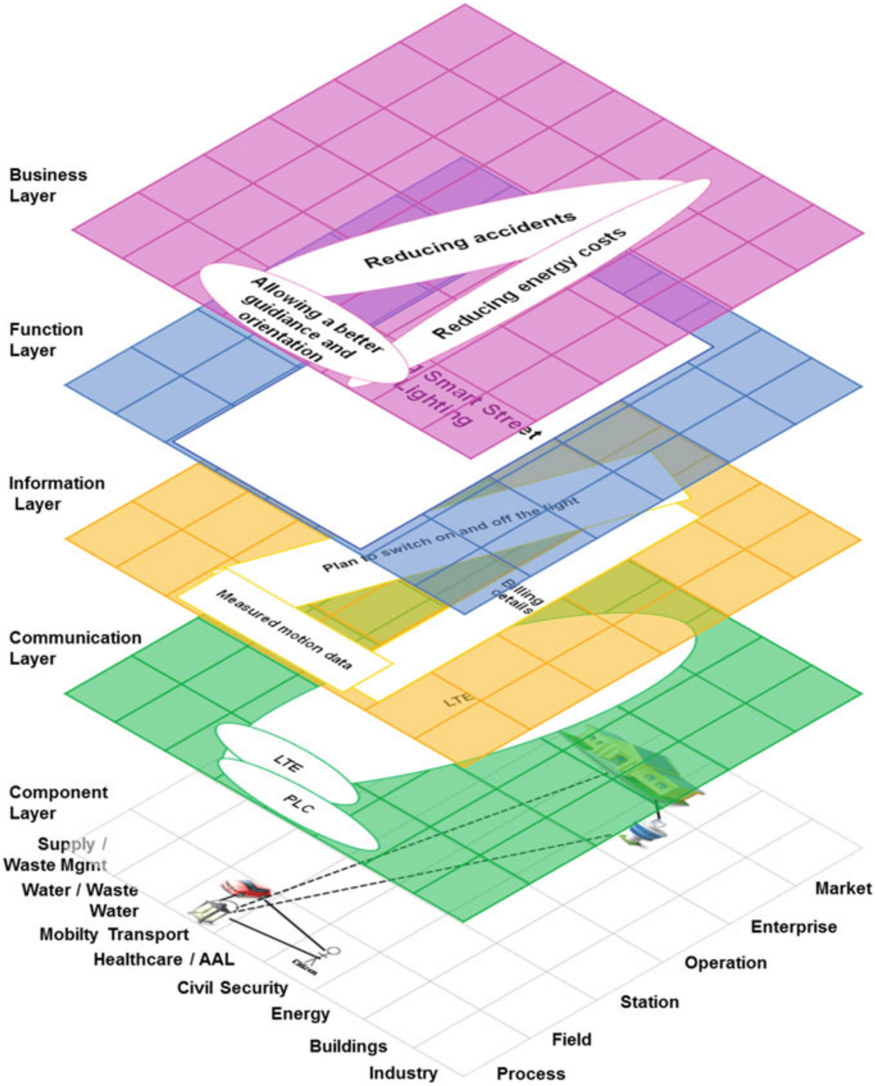

Fig. 5.2 Smart City Infrastructure Architecture Model (SCIAM)

Based on this initial proposal, a model has been developed and brought to attention of IEC SEG 1 as well as the SSCC-CG (Smart and Sustainable Cities and Communities) at European level. Looking at this model, it is apparent that a different granularity than in the SGAM is needed as the SGAM cube is at most one lane in the overall SCIAM scope. Therefore, the group has to develop a more high-level view on the use of the designation schema and limit itself to focus on the convergence aspects of individual domains in order to achieve synergies between them.

5.3.3 Maritime Architecture Framework (MAF)

The Maritime Architecture Framework (MAF) is shown in Fig. 5.3. It describes another derivation from the SGAM, this time in the maritime sector. The MAF has been discussed and developed during the project *EfficienSea2* as an architecture framework to depict information exchange between maritime actors and services

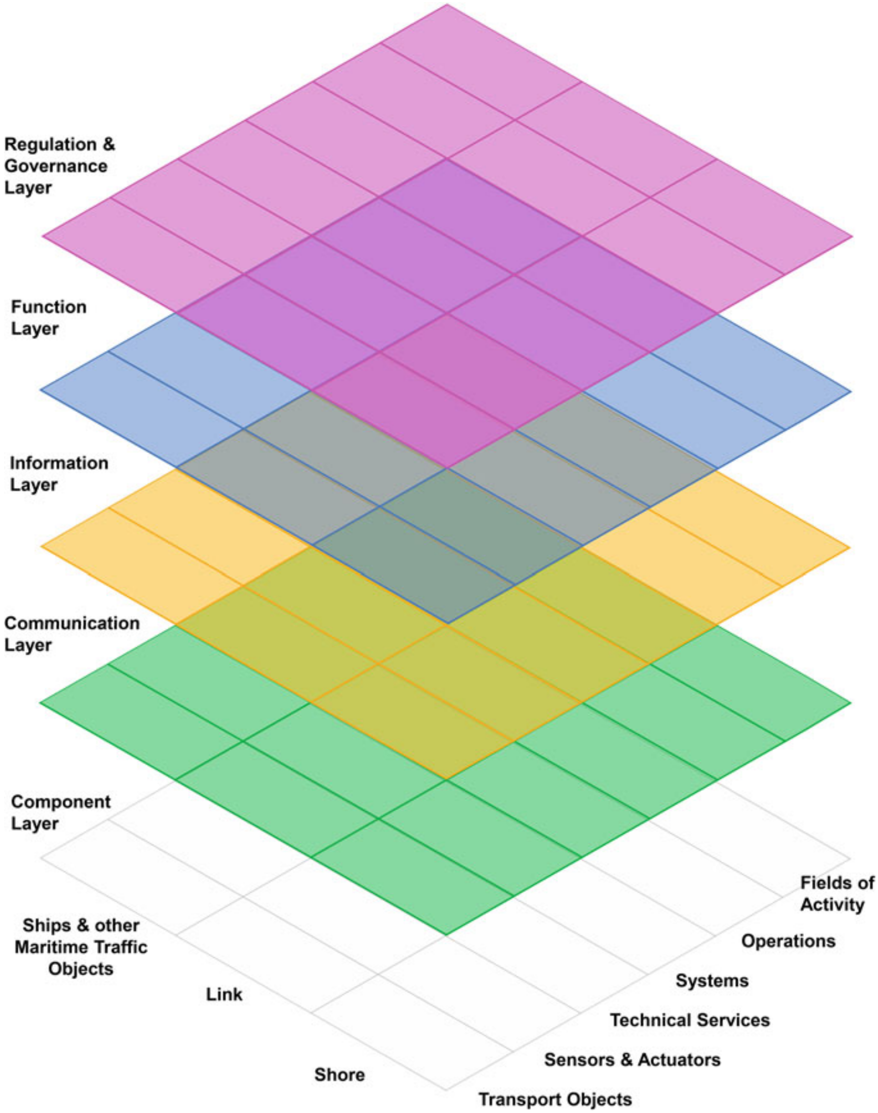

Fig. 5.3 Maritime Architecture Framework (MAF)

from a Maritime Cloud [17]. The *Maritime Cloud* is a framework which provides standardised protocols and functions for identity and role management, authentication, encryption, service discovery, and bandwidth efficient messaging in a geographic context for the maritime sector. Thus, the information exchange between the Maritime Cloud and further actors from the maritime sector has to be created interoperable. Actors are various software systems on-board, off shore as well as on shore, and personal devices, like smart phones and tablets.

The construction of the interoperability layer is analogous to the SGAM – apart from the *Regulation and Governance Layer* which replaces the *Business Layer* – hence, the layers are adopted and not explained at this place (cf. Sect. 3.1.2). For the domains and zones, new axes are developed that match the maritime sector. The domains are based on the International Maritime Organization (IMO) e-navigation strategy and divide the architecture into a ship-side and shore-side view [17, 25]:

- *Ships and other Maritime Traffic Objects* are actors which are at sea; these can be vessels, cargo or passenger ships.
- The *Link* describes the connection between actors from the ship-side to the shore-side with telecommunication methods and protocols. This includes actors like radio tower and transmission masts.
- Actors on the *Shore* are sea ports, docks, halls, and third-parties where ships land or which organise the shiploads.

Similar to the other architecture models, the zones describe the hierarchy and aggregation of management and control systems [17, 25]. The zones are:

- All components and systems which can execute a physical action are depicted in the zone *Transport Objects*, e.g. ship, crane, port, transmission masts.
- The zone *Sensors and Actuators* includes all components which are needed for receiving or sending data, like antenna, transceiver, ISO 11898, etc.
- Single services are shown in the zone *Technical Services*, e.g. IEC 61162 and NMEA (National Marine Electronics Association) 2000.
- Actors, information objects and protocols for operating and control services are displayed in the zone *Systems*, e.g. the vessel traffic service (VTS).
- In the zone *Operations*, the operating and control units from global, regional, national or local perspective are depicted, like the VTS centre.
- In the zone *Fields of Activity*, systems are described which support markets and eco systems along the maritime domain, e.g. a traffic message broadcast.

5.3.4 Reference Architecture for Industrie 4.0 (RAMI 4.0)

The Reference Architecture Model for Industrie 4.0 (RAMI 4.0) is the most sophisticated derivative of the SGAM as of today, developed by the German Electrical and Electronic Manufacturers' Association (ZVEI) [14]. Based on the German Industrie 4.0 concept, the main aspect is the re-use of the GWAC interoperability stack. In addition to *Business*, *Function*, *Information*, *Communication*, and *Asset* representing the *Component* layer, a new layer called *Integration* is introduced [21]. On the integration layer, components or systems are placed which display production plants without an own ICT interface as a virtual representation in the digital value chain [1, 15]. The further layers are explained in Sect. 3.1.2 for the SGAM. The RAMI 4.0 visualisation is displayed in Fig. 5.4.

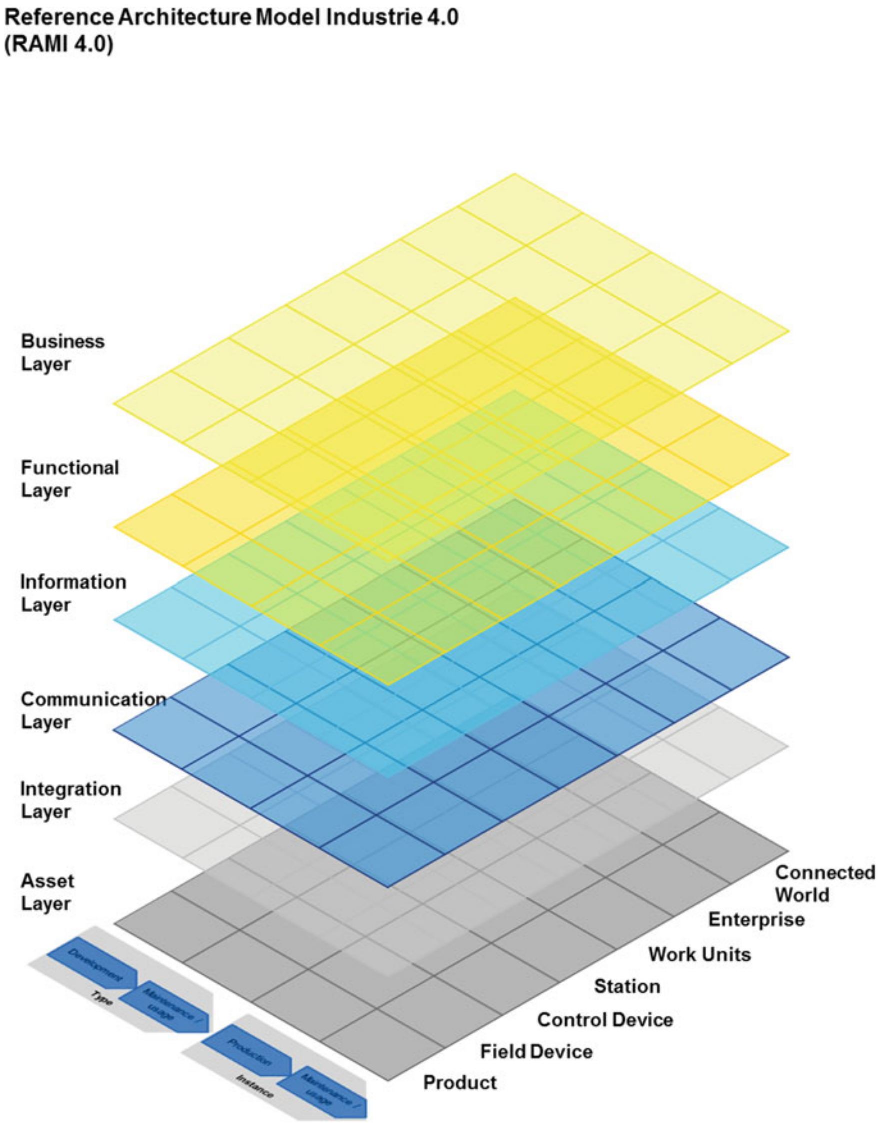

Fig. 5.4 Reference Architecture for Industrie 4.0 (RAMI 4.0)

The domain and zone axes are not custom taxonomies, but are based on the IEC 62890 value stream chain and the IEC 62264/61512 hierarchical levels, respectively. The *Domains*, as value stream chain [1], describe the life cycle of systems or products, and establish the distinction of:

- A *Type* is always created with the initial idea, i.e. a product comes into the *Development* as well as the *Maintenance/Usage* phase for testing the first samples.
- Products, that are manufactured industrially, are in the domain *Instance* which consists of the steps *Production* and *Maintenance/Usage*.

The distinction between *Type* and *Instance* is done to show whether the product is in the development (or rather prototyping) or production phase. The connections between plants and the data exchange can vary between these two phases so that the distinction makes sense. Additionally, if a product is improved by new functions, it is reported back to the development phase to produce prototypes before the actual production begins.

The *Zones*, as hierarchical levels, describe different functionalities inside a factory or a plant. These functions are complemented through the zones *Product* and *Connected World* to map the complete Industrie 4.0 environment [1, 14]. The zones are explained by [1, 11, 12] as follows:

- The *Product* describes the unit which is produced by a system or machine.
- For considerations within single machines and systems in factories, the zone *Field Device* is added which represents the functional level of an intelligent device, e.g. smart sensor.
- A *Control Device* describes a physical unit, that combines a mode selector, an adjuster for manual control of the actuating drive and a reference-variable adjuster for the controller.
- Complete machines and systems are illustrated in the zone *Station*.
- Dissimilar machines grouped together to produce a family of parts having similar manufacturing requirements are mentioned as *Work Units*.
- An *Enterprise* consists of one or more organisations sharing a definite mission, goals and objectives to offer an output such as a product or service.
- The zone *Connected World* depicts the interface to external firms, component suppliers and customers, etc.

The main purpose of the model is defined by ZVEI as follows: The model shall harmonise different user perspectives on the overall topic and provide a common understanding of relations between individual components for Industrie 4.0 solutions. Different industrial branches like automation, engineering and process engineering have a common view on the overall systems landscape. The SGAM principle of having the main scope of locating standards is re-used in the RAMI paradigms, also using it as a reference designation system.

The next steps for proceeding with the modelling paradigm is to come up with "101 examples" for Industrie 4.0 solutions in the RAMI, provide proper means for devices to be identified and provided discovery service modelling for those devices, harmonise both syntax and semantics and focus on the main aspect of the integration layer which is introduced in order to properly model the communication requirements in factory automation [15, 21].

5.3.5 Legal Reference Architecture for Industrie 4.0 (ju-RAMI 4.0)

As a co-evolutionary model to the aforementioned RAMI 4.0 model from the previous section, the so-called legal reference architecture model 4.0 (ju-RAMI 4.0 as by the German abbreviation) has been developed in the very context of the AUTONOMIK Industrie 4.0 funding scheme [10]. One of the aspects of having more and more complex systems interacting with each other is the separation of the individual organisations participating and operators of system-of-system parts. Legal aspects come into play in terms of liability for components, products and copyright for processes or solutions.

The ju-RAMI 4.0 aims at providing simple access to terms and wording used in the legal domain to lower the entry barrier for technical aspects to take into account legal risks and challenges at development time for the solution. One particular aspect is the visual representation of various dimensions of legal requirements in order to structure those aspects during the lifetime and -cycle of the product. Different legal domains (privacy, intellectual property, liability, etc.) are addressed and put in context with the original RAMI 4.0 reference designation system. While the model itself cannot address all legal issues from the jurisdictional point of view, it provides a useful visualisation of certain keywords for starting the discussion of various legal aspects of the product development phase as well as the inherent attributes of the intelligent product. As law is not a natural science but more or less interpreted, provided solutions can only hint to needed aspects to be discussed with legal departments. The authors claim to provide compliance barriers by defining risks and liability involved. This can lead to a better understanding of legal aspects of industrial internet solutions.

The axes of the ju-RAMI 4.0 are defined as follows. The vertical axis covers the defined and needed legal domains (like intellectual property rights, data protection law, workers protection law, civil rights, ...); the horizontal axis entails the actors participating in the development based on the original RAMI 4.0 model and clusters them in four areas of actors groupings. Finally, the third axis covers the risks involved when a certain legal requirement is not met. The authors suggest the following main advantages of the ju-RAMI [10]:

- Initial structures of the mapping of legal aspects and technical scope is provided.
- Initial overview on risks involved with the development as well as the operational scope is provided.
- Initial mitigation strategies to cope with risks identified in the model are included.

- Identification of legal processes to be followed to properly address the issues as product development and life cycle is given.
- One-stop-shop for glossary terms for partners with a more technical background exists.
- There are gap analyses for certain aspects which are arising from disruptive technological innovation like e.g. 3-D printing and corresponding rights to e.g. the shape models used for printing.

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