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Future of Interoperability

InterFuture

Mag. Kaltenbrunner Rainer - IDC

Mag. Neuschmid Julia - IDC

Dr. Bieber Ronald - OCG

DI Baumann Wilfried - OCG

Mag. Meir-Huber Mario

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Executive Summary

Digitization of society is moving ahead as new technologies continue to expand into our professional and private lives. In order to make best use of information and communication technology (ICT), interoperability and interfaces between different elements of technology are essential. Interoperability is a cross-sectional function, and means that different technology elements can interoperate, while users can select between and combine different providers, products, and services. Interoperability helps to boost innovation and keep ICT markets open and competitive.

In the "InterFuture" technology roadmap, special attention is drawn to the technology and interoperability outlook for Austria. Interoperability is increasingly important in relation to emerging technologies, such as cloud computing, the Internet of things, mobile applications, and Big Data, as these are the technologies with the strongest potential in the Austrian market. The dynamic nature of the rapid changes and developments in technology, however, means that the impact of common standardization efforts is limited, leaving individual vendors to create their own standards. In order for the market to achieve its potential, sponsorship of research in fields such as sensor networks, automatization, and car-to-car communications is required. Moreover, standardization efforts in these areas, and go-to-market strategies for smart home solutions and cloud solutions in particular, will need strong support. Big Data, semantics, and linked data will be key research and development topics and areas of investment interest in the near future. The roadmap highlights open source activities as key drivers of interoperability, and research projects need to explicitly emphasize the openness and interoperability of their planned solutions. A specialist body could be established in Austria to promote interoperability within the country, and to actively impact and influence transnational developments in this field.

Zusammenfassung

Die Digitalisierung der Gesellschaft schreitet voran und neue Technologien nehmen Einzug in unser Berufs- und Privatleben. Um Informations- und Kommunikationstechnologien (IKT) bestmöglich nutzen zu können, bedarf es einheitlicher Schnittstellen und Standards. Interoperabilität als Querschnittsmaterie stellt sicher, dass verschiedene Technologieelemente und Daten zusammenspielen können, dass AnwenderInnen aus einer Reihe unterschiedlicher AnbieterInnen, Produkte und Services wählen können, diese vergleichen, kombinieren und austauschen können. In diesem Sinne fördert Interoperabilität Innovation sowie offene und wettbewerbsfähige Märkte.

In der vorliegenden Technologieroadmap "InterFuture" wird ein spezielles Augenmerk auf Technologietrends in Österreich gelegt und damit verbundene Fragestellungen der Interoperabilität behandelt. Interoperabilität gewinnt rund um innovative Technologien wie Cloud Computing, Internet der Dinge, mobile Applikationen und Big Data zunehmend an Bedeutung. Es sind jene Technologien mit dem höchsten Potential am österreichischen Markt. Den rasanten Technologieentwicklungen hinken allerdings Standardisierungsprozesse hinterher. Um Marktchancen bestmöglich zu nutzen, sind Förderungen in den Forschungsbereichen Sensoren und Netzwerke, Fahrzeugautomatisierung und Car2Car-Kommunikation gefragt. Hinzu kommen die Unterstützung von Standardisierungsprozessen in den genannten Bereichen und die Ausarbeitung von Go-to-Market-Strategien speziell für Smart-Home-Lösungen und Cloud-Systeme. Auch besteht Bedarf an Investitionen in Forschungsfelder rund um Big Data, Semantic Web und Linked Data. Generell sind Open-Source-Aktivitäten wesentliche und zu unterstützende Antriebsfaktoren zur Erreichung kompatibler Lösungen. Forschungsprojekte sollten Offenheit und Interoperabilität der geplanten Lösungen berücksichtigen. Eine zu errichtende Stelle für Interoperabilität könnte zum einen das Thema innerhalb Österreichs vorantreiben und zum anderen von Österreich ausgehend auf länderübergreifende Maßnahmen aktiv Einfluss nehmen.

1 Introduction

1.1 Overview

Digitization of the society is moving ahead and new technologies expand into professional and private life. In order to make best use of technology, interoperability and interfaces between different technology elements are essential. The main goal of this study is the development of a technology roadmap that provides an information basis for the Austrian research funding program "Information and Communication Technology (ICT) of the Future". Interoperability of products and services is seen as a cross-cutting issue in ICT. It occurs on different levels referring to technology, concept and business. To outline this, the study first starts with describing technologies relevant to interoperability in chapter 2.1, where different interoperability levels such as the network stack or protocols are presented. Moving up one step in the abstraction layer, relevant domains of interoperability and challenges between persons, organizations, objects, and systems are described (chapter 2.2). These first chapters emphasize on the status quo and state-of-the-art technologies. As we also require a future-oriented discussion, we point out emerging technologies and high-impact concepts like cloud computing and big data in chapter 3. This is where interoperability needs to be addressed and actively supported. Last but not least, insights to the importance of interoperability are given by a market study conducted at leading Austrian institutions and businesses (chapter 4). The study concludes with a set of recommendations on a general, technological, and standard level in chapter 5.

1.2 Defining Interoperability

Interoperability is defined by the following statement:

Interoperability is a property of a product or system, whose interfaces are completely understood, to work with other products or systems, present or future, without any restricted access or implementation.[1]

[1] Interoperability Working Group Website, 2015.

We identified several degrees of interoperability that constitute a co-existence of solutions, compatibility, de-facto standards, interoperability, and interchangeability. In detail the degrees of interoperability are:

Co-existence

This term means that two solutions can be used in parallel without blocking each other. If, for example, two or more versions of the same program can be installed and run on the same server, the term co-existence is used[2].

Compatibility

Compatibility means that products or systems can work together or communicate with each other. Compatibility is a rather weak term. It does not specify the amount or nature of interoperability and it is frequently used in a way that is only marginally superior to co-existence. The term itself carries no information on how this interoperability was achieved. If a product or system is labelled with this term one has to question "in what way" and "with what"? Maybe one product is only compatible with products from the same vendor? Obviously the two products share at least parts of their interface but it remains unclear whether these interface definitions are publicly known or proprietary/non-public.

De-facto standard

A de-facto standard means that one product or system is dominating the market and other products adopt the dominating product's interfaces. This term implies that there are publicly known interfaces and that the adoption is widespread. De-facto standards usually develop from very successful products.

Interoperability[3]

Interoperability is the ability of a system or a product to work with other products or systems without any special effort on the part of the customer. In most cases information exchange is a central aspect of interoperability which can be divided into syntactic interoperability and semantic interoperability. The term cross-domain interoperability emphasizes the ability of some solutions to span different social,

[2] IBM WebSphere MQ information center, 2016.
[3] Wikipedia entry on interoperability.

organizational, political, or legal entities working together. There are two main approaches to achieve interoperability, namely post facto and ab initio approaches. In detail they are:

a) post facto

A vendor might be forced to make his existing product interoperable with another product. This could, for example, be done with a "broker" component that can convert one product's interface into another product's interface on demand[4].

b) ab initio

The design of the product follows open standards from the beginning.

Distinguishing between the two cases is important because investing in post facto approaches might only have a short-term effect while investment in ab initio approaches will probably have longer lasting beneficial effects for interoperability. This latter case will be the most relevant for our study. Obviously, the existence of open standards is a prerequisite for this case.

Interchangeability

The definition of interchangeability differs slightly from the definition of interoperability by the requirements posed on the result: "If interoperability is the measure of how well devices can interact, interchangeability is the measure of the degree to which multiple items are directly substitutive. More simply, if device A and device B are functionally equivalent, they are interchangeable."[5] The requirements seem somewhat stricter than for interoperability but other than that, what was said for interoperability also applies to interchangeability.

Interoperability is a topic that cannot be applied to a specific technology or concept. Interoperability is a cross-sectional issue in all technologies and concepts with different characteristics. It is therefore very similar to security which is also relevant to all technologies[6].

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[4] Wikipedia entry on interoperability.
[5] Plexxi, 2013.
[6] Hötzendorfer et al., 2015.

1.3 Open Source as Important Driver for Interoperability

Interoperability is often achieved through the use of open systems, services, software, and platforms, so that the use of open source technologies is seen as a highly beneficial factor for interoperability. The importance of open source is outlined in different sections of the study and finds its way to the set of recommendations in chapter 5. As open source is a key theme in the study, the study authors decided to outline this aspect already in the introductory section. Open source technologies basically follow open standards (or contribute to standards) and therefore, have the power to greatly improve interoperability for specific domains. In this paper, several technologies and technology concepts (which are defined as “emerging technologies”) are described with diverse relationships to open source technologies. Two currently significant technologies such as cloud computing and big data have a contrasting position towards open source technologies. Cloud technologies are heavily dominated by proprietary standards, whereas big data is based on an open source technology. This is also outlined in the corresponding sections (cloud: 3.1.2, big data: 3.1.4). The study authors recommend to support open source technologies, as this will have a high impact on interoperability.

1.4 Economic Impacts of a Lack of Interoperability

The study outlines economic challenges and user opinions on interoperability. One great threat that arises due to absence of interoperability is vendor lock-in. If vendors can build their own de-facto standards, vendor lock-in can make a customer dependent on a specific vendor for products and services, and the customer might be unable to use another vendor without substantial switching costs. The study authors could see no vendor lock-in with open source technologies which brings us back to chapter 1.3. A key element to improve interoperability is to reduce the vendor lock-in effect.

1.5 Methodology Used in this Study

This paper uses a multi-step methodology, which was carried out by the project partners simultaneously. The key focus of this study is to integrate both, the economic and scientific aspects of interoperability. The project partners covered this in their key domain – International Data Corporation (IDC) with the business background and the Austrian Computer Society (OCG) with the scientific background. The following figure demonstrates the iteration in the project.

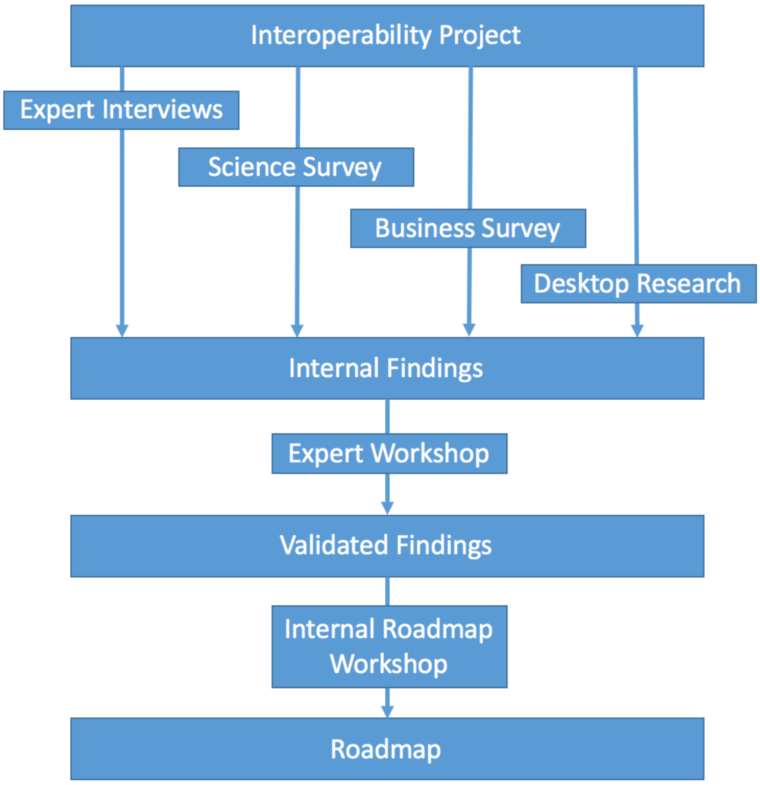


Figure 1: Methodology used in this study

After the project kick-off, several key tasks were carried out:

- **Expert Interviews.** Interviews with selected experts in the field of interoperability were done. In order to achieve this, a comprehensive research with different databases (ACM, Springer, IEEE, Scopus) was conducted to find out who is actively publishing in the field of interoperability in Austria. An internal workshop at the end concluded the research, where all researchers were evaluated against the aims of this study. After that, the researchers were contacted and interviewed in person. The 15 interviews provided detailed information about the research focus, their work, their recommendations, and other research groups in the same field. The personal interviews also provided background information that cannot be obtained by a structured interview. The interview results provided input and recommendations on current technologies (chapter 2), concepts (emerging technologies, chapter 3), research hot spots and business aspects (bother chapter 4), and the roadmap (chapter 5).

- **Business Survey.** An online survey was carried out among Austrian end users, to analyze the impact on the business. It provides insights on the importance of interoperable solutions in businesses. The survey identifies challenges that users are facing in case solutions are not interoperable with existing systems, and gives suggestions what needs to happen to further push interoperability. More than 150 IT-managers and decision-makers were asked for the status quo in their businesses. The survey results are shown in chapter 4.3, and the questions are attached in the annex. The "user's voice" was input for the recommendations and roadmap in chapter 5.
- **Literature Review.** Scientific articles were identified that are relevant for interoperability and were published within a given time frame by Austrian research teams or by researchers working in Austria. The literature review was a key input for the description of the status quo of interoperability in Austria (chapter 2), and the identification and description of emerging technologies (chapter 3).
- **Technology Investigation.** With the result of the literature review above and some further research a hierarchical list of relevant technologies and concepts for interoperability was created. This resulted in a description of the status quo of interoperability (chapter 2), and a description of emerging technologies (chapter 3).
- **Science Survey.** With the findings of the literature review and the technology investigation above, an online survey was created and conducted. The aim was to evaluate the status quo of interoperability in Austria. The goal was to consult as many experts as possible. Our target group consisted of all authors from our list of relevant publications. The author affiliations give a good impression which institutions were involved in the research effort that led to the publications: The largest group was formed by universities, followed by universities of applied sciences, state-run and private research departments or institutes. Private companies formed a rather small group. The relevance was only determined from the contents of the returned results. We are of course aware that we have not reached all relevant experts and that some were too busy to answer, but in addition to interviews and the workshop, the online survey was certainly very valuable and provided responses on the status quo and emerging technologies. With the results from this survey we refined our systematic technology list and

were able to collect data about research groups as well as their recommendations.

These five tasks resulted in an internal paper. The project partners then called for a workshop with external experts. There were around 20 attendees, discussing the results. More information about the workshop can be found in the annex. After that, adjustments were made based on the findings in the workshop and another internal workshop was held in order to define the roadmap and recommendations.

2 Interoperability Status Quo

This section concerns itself with technologies that are relevant to enable interoperability. From a conceptual perspective they build the base layer for emerging technologies. Moreover, this chapter aims at giving a general understanding of interoperability challenges and the current status quo. The outlined concepts introduced here are a result of the evaluation of the conducted expert interviews and literature research.

2.1 Technologies Relevant for Interoperability

This section discusses technologies that are relevant to interoperability which includes technologies such as networking, protocols, services and data structures. The following technologies and methods deal with interfaces and connection on a technical level, on a logical level including data structures used, and assignment of meaning.

An analysis of all the abstracts of publications that were identified as relevant for our study, revealed a technology list, from which we derived a hierarchical classification. Some obvious gaps were filled. This hierarchy was presented to researchers in an online questionnaire. This questionnaire was completed by 26 research organizations in Austria. These data are complemented by results from 15 interviews with experts in the field.

This chapter only presents the top level hierarchy. The corresponding examples for technologies can be found in the appendix. By no means is this list intended as an attempt to produce an exhaustive list. This list can serve as a guide that helps to determine the focus of a research group.

In order to evaluate possible regional focuses we split the Austrian institutes relevant for interoperability in two sectors: an east and a west sector. Details are thoroughly outlined in sub section 4.2 Interoperability Hotspots in Research in Austria. The split combines the cities Vienna, Graz and St. Pölten into the eastern region while Linz, Klagenfurt and Salzburg make the main contributors for the western region. The number of experts that filled out the questionnaire was nearly equal for both regions (west 12, east 13). There are, besides the usually differing focus of research organization no outstanding differences between the two regions.

In a first detailed view we evaluated the two main technologies ‘network technologies’ and ‘data structures’ which is depicted in Figure 2 for network below and Figure 3 under data structures. A clear main focus for the two defined regions cannot be found. Almost every mentioned technology is visible in both regions. Interfaces is the main area when it comes to network technologies, while semantics plays the major role in research related to data structure. Other topics are more or less evenly distributed in both regions.

2.1.1 Network[7]

A network is a number of autonomous units that can interact and/or exchange data with each other. The ability to do so and to enable cooperation between the autonomous units is the focus of this study.

[7] Compare with Wikipedia entry on network.

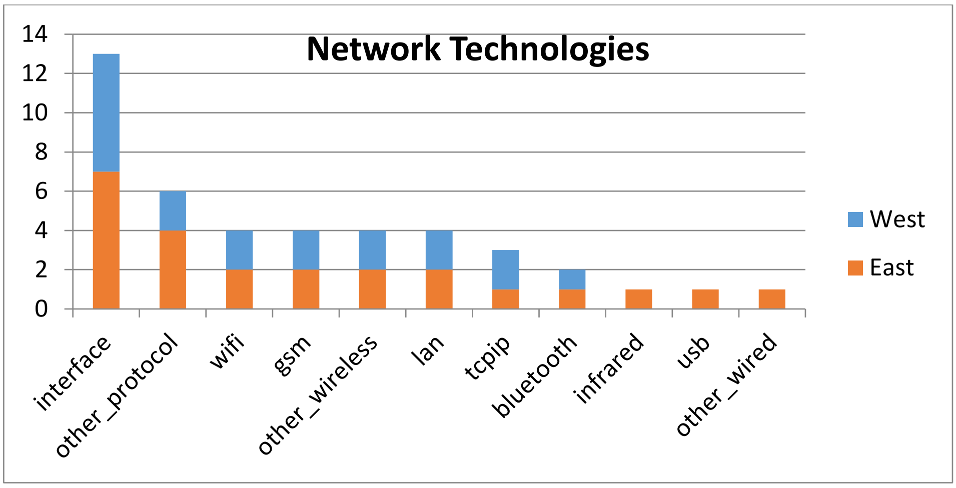


Figure 2: Number of activities in network technologies by research (questionnaire)

2.1.1.1 Wireless

Literally meaning "having no wires", there is no physical wired connection between sender and receiver. Many wireless technologies use electromagnetic waves, but that is not essential, any other physical effect like for example sound could be applied.

2.1.1.2 Wired networks

As opposed to wireless connections, senders and receivers are connected by wires.

2.1.2 Interface

An interface in our context is a shared boundary across which two components of a system exchange information. The exchange can be between software, hardware, persons or combinations of these.

2.1.3 Protocol

A protocol is a set of rules and instructions that allow two or more entities of a communications system to exchange information with each other. A protocol usually comprises syntax, semantics and synchronization of communication and possible error recovery methods. Protocols may be implemented by hardware, software, or a combination of both.[8]

[8] Wikipedia entry on protocol.

Protocol versus Standard

All protocols described here are standardized however, it has become a common practice to use the name of the protocol synonymously with the name of the standard. For example the TCP Protocol Standard is specified in the Request For Comments (RFC) 793[9]. The term TCP-Standard is commonly used instead of RFC 793. Accordingly the protocol name and the standard name are often used synonymously.

2.1.4 Service

Services are self-contained, loosely coupled units of functionality. Services implement a request/response mechanism that allows a client to remotely access/modify data. A service is designed to be accessed by other programs and to support interoperable machine-to-machine interaction over a network.

2.1.5 Application

A computer program specifically created to meet certain requirements.

2.1.6 Data Structure

Those are used to store and to share data. Data structures require special attention if they are used for data exchange between heterogeneous components.

2.1.7 Semantics

The term semantics refers to the meaning of languages, as opposed to their form (syntax). Semantics is about interpretation of an expressions, messages, data structures. In a closed system within one formal language, the semantics is usually well defined, but in a heterogeneous system especially in the context of conflicting information semantics poses a tremendous challenge.

The subject of ontology is the study of the categories of things that exist or may exist in some domain. The product of such a study, called an ontology, is a catalogue of the types of things that are assumed to exist in a domain of interest.[10]

[9] University of Southern California, 1981.
[10] Sowa, 2010.

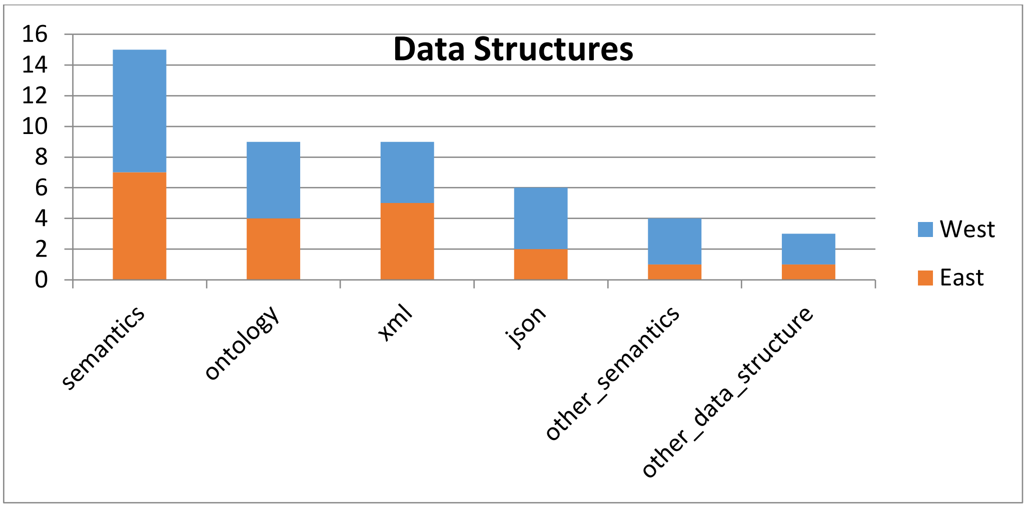


Figure 3: Number of activities regarding data structures by research (questionnaire)

2.1.8 Standards

Using standards can help to foster interoperability of products from different manufacturers. However standardization is a complex process. Standards evolve over time, some standards replace other standards, the outcome of the overall standardization process is difficult or even impossible to predict.

A large number of standards deal with interoperability to some extent.

2.2 Interoperability Domains

This section identifies the relevant domains of interoperability and provides a broad classification based on the conducted interviews. We identify interoperability mainly in four domains. The basic interoperability between hardware depicting physical entities (refer to 2.2.1), the domain of software covering all software related aspects (refer to 2.2.2), the domain of human interoperability with different facets (refer to 2.2.3) and the domain of conceptual interoperability (refer to 2.2.4).

One reason for the complexity of interoperability is the diverse nature of the entities under consideration. This study does not restrict the nature of these entities. However, a classification of possible scenarios is useful. Research groups usually do not have such a broad spectrum, they usually focus on certain scenarios and make various assumptions.

The scientific survey asked for specific technologies, domains and additional terms of the respective interoperability activities. The distribution between the two main technologies hardware and software is depicted in Figure 4 and Figure 5.

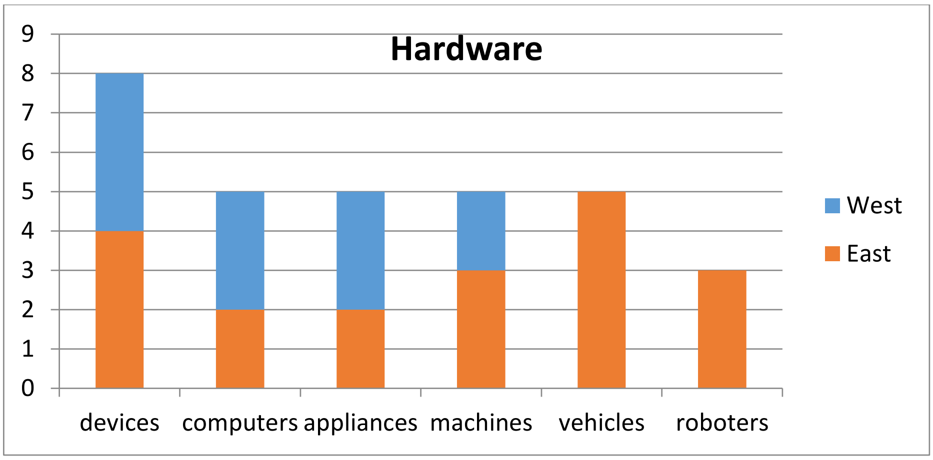


Figure 4: Number of activities regarding hardware by research (scientific survey)

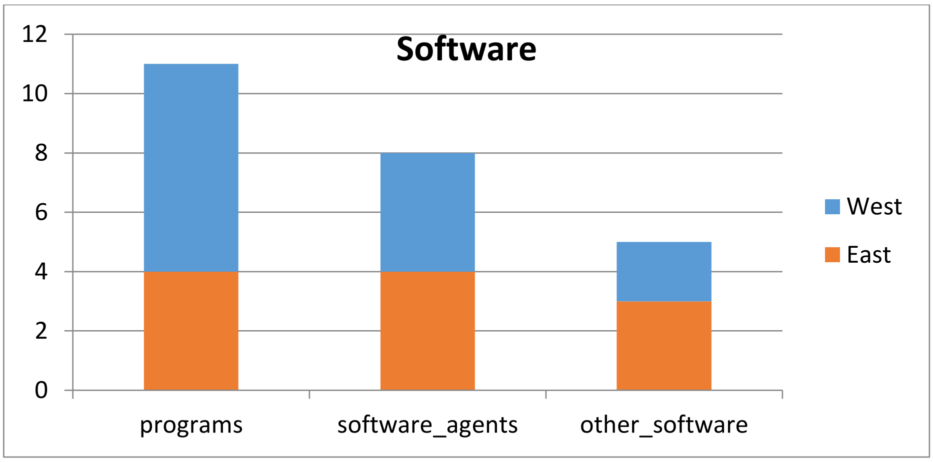


Figure 5: Number of activities regarding software by research (scientific survey)

The analysis shows that vehicles and robots are only reported in the east region. Robotics is certainly also a topic in the western part of Austria but apparently not seen as a main research topic as in the eastern part (like for example at the University of Technology in Graz). Research in software is almost homogenously split between west and east.

2.2.1 Interoperability between Appliances or Physical Objects

The first domain of interoperability to be described into more detail is interoperability between physical objects. It can be classified as follows:

Computers

A programmable electronic device designed to accept data, perform prescribed mathematical and logical operations and display the results of these operations.

Devices

An apparatus consisting of interrelated parts with separate functions, used in the performance of some kind of work.

Machines

An apparatus consisting of interrelated parts with separate functions, used in the performance of some kind of work.

Robots

In this context: A robot is a mechanical agent, usually an electro-mechanical machine that is guided by a computer program or electronic circuitry.[11]

Vehicles

A means of conveyance or transport. E.g. cars, aircrafts, ships, trains, but also infrastructure related to traffic.

Buildings or building parts

A structure with a roof and walls that is used as a place for people to live, work.

2.2.2 Interoperability between Software

Establishing a physical connection is a prerequisite for interoperability. Any software module that is supposed to use this connection needs to be equipped with capabilities for interoperability as well.

Programs

Interaction between different software programs is a very common requirement which was the top mentioned activity category in the research questionnaire.

Software Agents

Breaking larger programs into software agents is an advanced software design strategy. A software agent is a goal-oriented computer program that reacts to its environment and runs without continuous direct supervision to perform some task. Software agents can have user interfaces. A software agent is the computer

[11] Wikipedia entry on robots.

analogue of an autonomous robot. Some tasks can be accomplished very efficiently with the use of multiple identical agents working in parallel.

In addition to the mere technological topics ‘hardware’ and ‘software’ there are also the topics of interaction between persons and conglomerates of persons like organizations or companies.

2.2.3 Interoperability between Persons

The scope of this study is the interoperability between components or autonomous entities. Since persons can act as such autonomous entities, the interaction between a person and another entity or between two persons is a common scenario.

Some examples for this scenario are:

- patients,
- customers,
- citizens,
- etc.

2.2.4 Interoperability between Organizations

Many business or private activities involve interactions between organizations or interactions between organizations and other entities. So formalizing these interactions and providing systems that support the automation of parts of these interactions would be very advantageous. Some examples of organizations with a high demand for interoperability are:

- governmental organizations,
- utility companies,
- health care organizations,
- rescue organizations,
- scientific collections,
- touristic service providers,
- trade organizations.

3 Emerging Technologies

Emerging technologies are described as innovations that are currently developing or will be developed over the years, and which will substantially alter the business and social environment. These include for example information technology, wireless data communication, man-machine communication, on-demand printing, bio-technologies, and advanced robotics. Yet emerging technologies lack key foundational elements, namely a consensus on what classifies a technology as 'emergent' and a widely accepted definition of emerging technologies. Rotolo et al. (2015, p. 13) identify five attributes that feature in the emergence of novel technologies. These are: (i) radical novelty, (ii) relatively fast growth, (iii) coherence, (iv) prominent impact, and (v) uncertainty and ambiguity. Emerging technologies are radically novel, i.e. they fulfill a given function by using a different basic principle as compared to what was used before to achieve a similar purpose. Emerging technologies show relatively fast growth rates compared to non-emerging technologies. Coherence and its persistence over time distinguish technologies that have acquired a certain identity and momentum from those still in a state of flux and therefore not yet emerging. Emerging technologies exert a prominent impact on specific domains or more broadly on the socio-economic system by changing the composition of actors, institutions, patterns of interactions among those, and the associated knowledge production processes. Emerging technologies are characterized by uncertainty in their possible outcomes and uses, which may be unintended and undesirable, as well as by ambiguity in the meanings different social groups associate with the given technology. Emerging technologies have assumed increasing relevance in the context of policy-making for their perceived ability to change the status quo. This has spurred ad hoc governmental actions such as the "Future & Emerging Technologies" (FET) initiative funded by the European Commission[12].

This chapter describes emerging technologies that have been identified in a study on the Austrian IT service market by IDC[13] and that have been further prioritized in the study BEST AT[14], and adjusted in the frame of the “InterFuture” project through research and qualitative interviews with Austrian experts from economy and

[12] European Commission Website on, Emerging Technologies.
[13] IDC, 2015.
[14] Hötzendorfer et al., 2015.

science. For the Austrian market emerging technologies have different time scales. They are short-term (< 2 years), mid-term (2-6 years) and long-term (> 6 years). The following sub-chapters provide a definition or description of each identified emerging technology and its significance for the Austrian market. Also emerging technologies can have a significant impact on interoperability. Often, de-facto standards (refer to 1.2) arise within emerging technologies, which is due to the fast development of these technologies. In the following sections, emerging technologies are described and their relevance for the Austrian market and interoperability issues are discussed.

3.1 Short-Term Technology Innovations

Short-term technology innovations have a major impact on information and communication technology worldwide. They have high growth rates, have been implemented by a notable number of organizations, and have been hyped in the media. Short-term technology innovations refer to networked societies, cloud computing, mobility, and data-driven systems.

3.1.1 Networked Societies

The term “networked society” refers to applications that create a social network or online communities by using forms of electronic communication. Examples are YouTube, Facebook, Twitter, their counterparts in Asia, and other social media. What is special about networked societies is that users are the creators of the content, and a lot of political and social discourse has moved to these new communication channels.

3.1.1.1 Significance and Impact

There are several big social media players that share the Austrian market. For instance we count 3,4 Mio. Facebook users, 140.000 Twitter users and around 880.000 Instagram users (September 2015)[15].

Almost half of European companies adopt social media tools for business purposes. Adoption is high especially in vertical markets such as telecom/media, utilities/oil and gas, retail/wholesale. Early adopters and advanced companies

[15] Social Media Radar Austria Website.

undergo a process of improvement, while the majority needs to better understand the benefits of bringing innovation through social platforms.[16] Social media is not only a way to facilitate communication between corporations and individuals, but also an opportunity to enhance internal procedures, increase brand awareness, estimate consumer perception, and build a loyal customer base. The technology is still developing in some vertical markets, but markets will soon leverage such tools to become more advanced and competitive. However, not all these markets share the same perspective, and vendors should tailor their value propositions accordingly, focusing on improving more mature markets and educating those reluctant to go social.[17]

3.1.1.2 Interoperability challenges

Clearly, the trend is to connect everyone via social media. At the same time a great number of separate islands of communication are constructed and we see a drift towards silos of communication. On the one hand this can be explained by the technology itself that at an early stage was not able to support interoperability. On the other hand there has been little incentive to connect services together because maintaining ownership and control of a service's members has been key to the success of social media business models and valuation[18]. For social media platforms, it is typical that users generate a lot of data, for example by uploading videos on YouTube, status messages on Facebook, etc. Anyway, this data is not easy to access from other platforms. Such as vendor lock-in offers hardly any ways to connect with or engage between social media services from different providers.

3.1.1.3 Relevance for Austria

The study authors do not see any potential by providing a platform that avoids a vendor lock-in. There are no economic impacts or benefits for Austria. This was also not seen as a priority neither by the InterFuture workshop participants nor by the interviews with the domain experts. The study authors recommend to treat social media in connection with interoperability with a low priority.

[16] IDC 2014.
[17] Minonne and Vacca, 2015.
[18] Hinchcliffe, 2014.

3.1.2 Cloud Computing

Cloud computing is a term for Internet-based computing, where shared resources and information are provided to computers and other devices on demand. Cloud services are fundamentally about an alternative solution composition, delivery, and consumption model — one that can be applied to IT industry offerings but also, much more broadly, to offerings from many other industries, including entertainment, energy, financial services, health, manufacturing, retail, and transportation, as well as from government and education sectors.[19] IDC defines cloud services more formally through a checklist of key attributes. The cloud model goes well beyond prior online delivery approaches. It combines efficient use of multitenant (shared) resources, radically simplified "solution" packaging, self-service provisioning, highly elastic and granular scaling, flexible pricing, and broad leverage of Internet standard technologies and APIs — to make offerings dramatically easier and generally cheaper to consume (ibid).

3.1.2.1 Significance and Impact

In 2014, spending around cloud delivery (public, virtual private, and private) in Austria recorded reasonable year-on-year growth. Cloud received considerable attention from CIOs and CEOs in Austria. The improved image of cloud in the Austrian market was due largely to vendors' efforts. By educating customers on the benefits of the cloud model, vendors were able to convince many organizations to deploy some form of cloud-based technology. More international cloud service providers are entering the Austrian market, increasing levels of competition for established players. To prosper (or even survive) in this more volatile market, service providers are advised to expand their portfolios to include cloud services, if they have not done so already, and to augment their capabilities on both the technical and promotional fronts in order to develop and push offerings that can distinguish them from competitors. Cloud has affected the IT industry in Austria significantly and in various ways. Many companies are trying to adopt new technologies such as self-service platforms, which is an important factor for cloud adoption. Enterprises are interested in the pay-as-you-go model, which is served effectively by cloud. Traditional outsourcing providers have begun to offer private

[19] IDC, 2015a.

cloud platforms[20] to compete with new players entering the market with public cloud services.[21]

3.1.2.2 Interoperability challenges

Interoperability challenges arise at different levels within the cloud domain. Basically, these challenges arise on each technology layer:

- Infrastructure as a Service (IaaS). Here, the question on interoperability between virtual machines is in question. A challenge is to move machines between different providers (e.g. from AWS to Microsoft or any other provider). Work has been carried out by the University of Linz, department of Tele-cooperation, on this topic[22].
- Platform as a Service (PaaS). Platform as a Service is an approach that is heavily service driven. This means that services need to provide some interoperability. However, the large service providers basically do not support this and built their own “de facto” standards. Work on that has also been carried out by the University of Linz.[23]
- Software as a Service (SaaS). SaaS is all about software that runs in the cloud. Often, IaaS or PaaS are used for that. Challenges refer to data interoperability (data format, data models, semantics, etc.), and how to bring data form one application to another.

3.1.2.3 Relevance for Austria

Cloud computing will shake up the Austrian market especially for independent software vendors (ISVs). Therefore, the impact from an economical point of view is very high. Even though there are no significant cloud providers originating from Austria, interoperability on this emerging technology is highly relevant. This was also confirmed by expert interviews and workshop participants. The study authors recommend to treat interoperability in connection with cloud computing with very high priority. Recommendations can be seen in chapter 5.

[20] Private Cloud are shared within a single enterprise or an extended enterprise, with restrictions on access and level of resource dedication, and defined/controlled by the enterprise, beyond the control available in public cloud offerings; Private cloud services are shared within a single enterprise or an extended enterprise, with restrictions on access and level of resource dedication, and defined/controlled by the enterprise, beyond the control available in public cloud offerings (IDC, 2015a).
[21] IDC, 2015b.
[22] Steinbauer, et al., 2013.
[23] Meir-Huber, n.d.

3.1.3 Mobile Devices

According to the US National Institute of Standards and Technology (NIST) the term "mobile device" is difficult to define but it can be described by a number of attributes. Mobile devices are equipped with a wireless network interface such as WIFI or Bluetooth, local storage, an operating system that is not a full operating system as in desktop PCs or notebooks, applications that are provided by different parties, a digital camera, and a microphone. Examples for mobile devices are tablet PCs, smartphones and smart watches.

3.1.3.1 Significance and Impact

Mobile devices are multifunctional and allow a great variety of applications. In the working environment it is mainly communication services such as e-mail, messenger tools, social media apps, etc., calendar management tools, or data and information management solutions that become more and more important. In addition, with smartphones we can make use of all kind of entertainment services such as games, music, video, camera, navigation services or payment services, and many more. According to a study by IDC on the Austrian IT service market in 2015[24] mobile services will continue to drive mobile device and software spending, and vice versa. Major Austrian telecommunication providers are challenged by users spending less on text messages that users replace with free web-based messaging (e.g. WhatsApp). The same may happen to voice calls, with users opting for free Internet calling. The future of the smartphone market worldwide is assured continued growth in the years ahead but with a constantly shifting mobile operating system landscape, with incumbents gaining ground and market followers struggling to keep up, and the average selling price going down[25]. A study conducted by the Applied University of St. Pölten in 2015 comes to the result that 85% of companies use mobile devices for their business activities. Half of them allow the concept of “bring your own device” to work, i.e. people do not use company hardware but private notebooks, phones, etc. blurring the boundaries between business and private.[26]

[24] IDC, 2015.
[25] IDC, 2015c.
[26] Reisinger, 2015, p. 59f.

3.1.3.2 Interoperability challenges

Interoperability challenges basically arise with the communication of the devices, either via the hardware stack (e.g. 4G) or the software stack (WhatsApp, iMessage, etc.). All of these challenges are driven by de-facto standards of the corresponding software or hardware manufacturers.

3.1.3.3 Relevance for Austria

No significant large hardware or software provider for mobile devices originate from Austria. Anyway, there is a growing number of startups and SMEs that design and develop applications running on mobile devices in Austria. Also the research sector is prototyping a great variety of mobile solutions. The study authors recommend interoperability in connection with mobile solutions to be handled with a medium to low priority.

3.1.4 Data-driven Systems

Data-driven systems is about discovering what data is important and what information can be taken from the data. As the amount of data is constantly growing the term “big data” came up. Data-driven systems can be characterized by the four Vs:

- Volume: enormous growths of the amount of data in the last years;
- Velocity: analysis of more data in a shorter amount of time;
- Variety: huge variety of data formats (arbitrary > relational > plain text);
- Value: generation of added value from data (with data to information, knowledge, and better decisions).

IDC describes big data as a new generation of technologies and architectures designed to economically extract value from very large volumes of a wide variety of data by enabling high velocity capture, discovery, and/or analysis“[27].

3.1.4.1 Significance and Impact

The amount of data that is available in today’s organizations is growing continuously. Forecasts talk about an average growth of 33,5% of turnover figures

[27] IDC, 2015d.

in the next four years. In Austria the big data market is expected to grow from 22 Mio. Euro in 2013 to 73 Mio. Euro in 2017.[28]

An online study by IDC in 2014 among almost 150 Austrian CIOs and IT managers collected and analyzed the status quo of big data in Austrian companies. 47% of respondents say that the implementation of big data solutions is seriously discussed within the company. For 39% big data is no issue at all. Anyway, a comparison with the previous year 2013 shows that big data is gaining attraction. In 2013 big data was not a topic to be discussed for 62% of Austrian enterprises. These figures are more or less in line with international trends, even though in countries such as Germany and USA the developments go much faster than in Austria.

3.1.4.2 Interoperability challenges

Compared to previously described technologies big data has some distinctive features. One of them is that most big data solutions are based on Apache Hadoop, which is an open source product. This platform is about to become the number one data handling platform, replacing other proprietary platforms. Hadoop has a high level of interoperability and standardization.

3.1.4.3 Relevance for Austria

Big Data is very important to the Austrian market. As of big data, it is not necessary to build a complex infrastructure (in comparison to mobile devices, where one needs to build the devices itself) but large amount of revenues come from IT-services. Research around this topic can help service companies gain attraction in the market. This will create jobs in the local market. However, standardization and interoperability are at a high level. Study authors recommend to focus on this topic with a medium to high priority. Recommendations are provided in chapter 5.

[28] Köhler and Meir-Huber, 2014.

3.2 Medium-Term Technology Innovations

Mid-term technology innovations are discussed widely but have not yet been implemented in many organizations. Nevertheless, it is expected that these technologies will play a major role for ICT all around the world in the next two to six years. Mid-term technology innovations are for example autonomous driving/cars, smart homes, smart cities, complex systems and smart industries.

3.2.1 Internet of Things

Internet of Things (IoT) is a term that describes the ability of devices to connect and communicate via the Internet from any location. IDC's definition of IoT is: „a network of networks of uniquely identifiable endpoints (or "things") that communicate without human interaction using internet protocol (IP) connectivity"[29]. The IoT taxonomy[30] provides the classifications and definitions for the major components that make up the IoT market. These components include:

- Intelligent, or enhanced traditional embedded systems
- Connectivity/service enablement
- Platforms: device, network, and application enablement
- Analytics and social business
- Applications
- Security

IoT is a paradigm shift of our society to actively use the Internet with specific devices (often mobile devices). Everyday objects turn into smart items that communicate and interact autonomously with their environment via the Internet. IoT is closely connected to and enriches topics such as big data, cloud as well as mobile and social applications. IoT is also a major factor in the development of smart cities, smart homes, and smart industries (refer to chapters 3.2.2., 3.2.3, 3.2.4, 3.2.5).

3.2.1.1 Significance and Impact

The reality of the Internet of Things market around the world is undoubtedly underway. Vendors are evolving their solutions in a supply-driven market on the edge of becoming a demand-driven market. Businesses are expanding their

[29] IDC, 2015e, p. 2.
[30] IDC, 2014a.

understanding of the efficiencies, business process transformations, and revenue implications that IoT solutions can generate. Consumers witness connected home, car2car, and other innovative concepts coming to life, changing the way they understand their daily activities and the world around them.[31] While the Internet of Things continues to evolve and expand, moving from the planning stage to execution, the momentum is quantifiable. According to a global IoT decision maker survey from 2015[32], 73% of respondents have already deployed IoT solutions or plan to deploy in the next 12 months. IoT awareness is gaining traction in the retail and manufacturing industries with 56% and 53% of respondents (respectively) showing high awareness of the IoT. In addition, a full 58% of respondents consider the IoT a strategic initiative, with a further 24% viewing it as transformative. The healthcare industry leads the field with 72% of respondents identifying IoT as strategic, followed by transportation and manufacturing at 67% and 66%, respectively. Government lags behind in overall awareness and often needs clarification around the IoT basics.

In general, we can say IoT is widely discussed, but has not yet reached a lot of practical implementation in the real world. The Austrian Computer Emergency Response Team CERT points out to the rapid developments until 2020 and asks for proactive measures to avoid risks regarding security and interoperability in its annual report[33].

3.2.1.2 Interoperability challenges

IoT is challenging to interoperability and might be one of the best examples for the importance of interoperability. With IoT, we have a large number of sensors, that might have proprietary protocols and alike. Also, different “things” might come with individual APIs that will challenge the interoperability and standardization process. Without interoperability, lights would not work with switches, sensors could not be read by smartphones, and devices could not use the networks around them. Devices that operate on their own without human supervision need to automate all their operations. As a result, it is important that the devices can not only connect to the appropriate radio and IP networks, but they also need to work well with others with regards to transport and application protocols, security, and data that they pass

[31] ibid.
[32] IDC, 2015f.
[33] CERT, 2015, p.34f.

around. A big issue is on semantic interoperability, relating to standardising the formats and semantics of data that is carried in IoT applications. Anyway, interoperability is not yet mature; the work on data formats (in the form of data models and information models) has not seen the same level of consistency throughout various standardization groups.[34]

3.2.1.3 Relevance for Austria

The IoT market is still young and immature. However, Austria has a large and active IoT community, as well as industry production that works together with the research sector on pilots in different domains such as traffic optimization, industry 4.0, home automation, etc. The study authors see that Austria could play a leading role in this market by working with international institutions on the provision of standards. The authors recommend to invest in this sector and give it a very high priority. Recommendations are provided in chapter 5.

3.2.2 Autonomous Driving

Autonomous means having the power for self-government[35]. Autonomous systems can be systems that perform tasks or deliver goods or services with a high degree of independence. Some characteristics of autonomous systems are a range of environmental sensors (e.g. electromagnetic spectrum, sound, touch, temperature, range to various objects, and altitude) to perform the required task, and to navigate (indoor/outdoor). A prominent example are autonomous cars – or self-driving cars – that can sense its environment and navigate without human input and that have gained a lot of attention for the public in the last years due to several technology providers, companies, research organizations and government regulations that allow tests in real life conditions.

3.2.2.1 Significance and Impact

In Austria the automobile industry is primarily located in the area of the City of Graz. The first test track for autonomous vehicles will be established already in 2016. These are either sections of newly constructed roads prior to their opening or

[34] Internet Engineering Task Force (IETF), 2016.
[35] Antsaklis, et al., 1991.

sections of already existing roads. Experts estimate that autonomous cars will be ready for the Austrian market in the next 15-20 years.[36]

3.2.2.2 Interoperability challenges

Several challenges on autonomous driving arise with communication between vehicles and with infrastructure. Vendors must apply standards in order to ensure security of vehicles. The main activity here is seen in the communication standard between cars and infrastructure by the study authors. This means the development of a communication protocol.

3.2.2.3 Relevance for Austria

In Austria, there is high interest by the industry. Especially in Graz, where Magna and AVL List are situated. The study authors see great potential for the Austrian market and suggest to give this a high priority. Recommendations are given in 5.4.2

3.2.3 Smart Homes

The term smart home refers to the automation of the home and household activity in order to provide comfort, efficiency and security. A home automation system integrates electrical devices in a house with each other. According to IDC home automation is a subset of IoT which involves devices associated with individuals for use in and/or around the home or related to personal needs. Examples of these devices include but are not limited to appliances (refrigerator, etc.), utility meters (electric, water, etc.), security systems (burglar alarm, etc.), and wearable devices (Fitbit, glucose monitors, etc.).[37] Some further applications are control of lighting, temperature (heating, ventilation, air conditioning), access (locks and opening of doors and gates), etc. Increasing smartphone and tablet connectivity play a major role in the growths of smart home solutions.

The smart home concept is closely related to active & assisted living (AAL). AAL is understood as to extend the time people can live in their preferred environment by increasing their autonomy, self-confidence and mobility, to support maintaining health and functional capability of the elderly individuals, to promote a better and healthier lifestyle for individuals at risk, to enhance the security, to prevent social

[36] Sulzbacher, 2015.
[37] IDC, 2015g.

isolation and to support maintaining the multifunctional network around the individual. It also includes to support carers, families and care organizations, and to increase the efficiency and productivity of used resources in the ageing societies.[38]

3.2.3.1 Significance and Impact

Smart Homes have the chance of become a major market around the globe. As of now, it is still a niche player but chances are high that they will enter the mass markets and thus will become commodity.

In Austria a number of AAL pilot projects, living labs, test regions, show rooms/apartments, or similar have been designed and tested by users. Future living is the key topic for example for the West-AAL test region where ICT-supported living has been actively tested for a longer period in more than 70 households. The focus has been on innovative and user centered smart home and smart service solutions that are based on information technologies.

3.2.3.2 Interoperability challenges

The smart home environment is highly characterized by heterogeneity with many systems that need to interoperate and perform their tasks efficiently. With rapid growth of services, applications and devices, the interoperability aspect seems still unsolved. This is due to the nature of smart home as distributed architecture that needs certain degree of interoperability for managing heterogeneous systems. As of now, large vendors create their own de-facto standards. While the Austrian research sector is very strong in smart homes and AAL, the big challenge of the past years has been to succeed in the transformation of research prototypes to market ready solutions. Currently, there are several standards present, which are shown in the following table.

Name	**Description**
Z-Wave	Z-Wave is a communication standard maintained by the Z-Wave alliance. The focus on Z-Wave is high communication security and energy efficiency for home automation systems. Currently, there are about

[38] European Active & Assisted Living Program.

	330 members in the Z-Wave alliance, making it a leading standard for smart home systems.
KNX	KNX is a standard for home automation that relies on wired connections. This makes the implementation rather expensive, since a bus system has to be implemented (which is hardware and installation intense).
ZigBee	ZigBee is another communication standard made for smart home systems. The focus of ZigBee is on the communication in wireless networks with a low number of data sent. ZigBee is maintained by the ZigBee alliance, which is supported by 230 companies.
Enocean	Enocean was developed by a Siemens Spin-Off and is now maintained by the Enocean Alliance. The focus of Enocean is on wireless communication and very low energy consumption. Often, it is possible to operate devices without battery (e.g. by using the kinectic energy).
AALIANCE 2	AALIANCE2 is a standard built by the European union to make standards for AAL. AALIANCE2 now is a collection of standards relevant to AAL.

Table 1: Smart Home Standards

Also refer to study TAALXONOMY that was conducted by the FFG and provides a comprehensive analysis of existing standards in AAL (www.taalxonomy.eu).

3.2.3.3 Relevance for Austria

In this market, Austria could play a leading international role and fill a gap. In upper Austria, the company “Loxone” is already internationally recognized for smart home solutions. The market could benefit from interoperability of smart home solutions, and additional jobs could be created. The study authors suggest this topic to give a medium to high priority. Recommendations for further interoperability research are given in 5.4.3.

3.2.4 Smart Cities

A smart city is a place where the traditional networks and services are made more efficient with the use of digital and telecommunication technologies for the benefit of its citizens and businesses. Smart cities aim to make better use of resources, be energy efficient, and reduce emissions. For example smart cities invest in intelligent urban transport networks, upgraded water supply and waste disposal facilities, and more efficient ways to light and heat buildings. Also a smart city can encompass a more interactive and responsive city administration, provide safer public spaces and meet the needs of an ageing population.[39] The concept of smart city is cross-sectional, covering all areas of life, work and leisure activities in equal measure, and includes everything from infrastructure, energy and mobility to all aspects of urban development.[40] There are different definitions of smart city, and cities put different foci on what the concept means to them. IDC highlights the use of ICT as a key aspect for smart cities.[41]

3.2.4.1 Significance and Impact

Local governments around the world are under pressure to improve their infrastructure, liveability, sustainability, and economic opportunities for residents as well as to transform the end-to-end citizen experience. Third platform technologies such as big data, social, mobile and cloud, and innovation accelerators such as IoT, sensors, robotics, etc., offer unparalleled opportunities to deliver new government capabilities that influence all of government verticals while sustaining budget levels even as urban populations increase. External political, economic, social, environmental, legal, and business-related forces are reaching crucial tipping points and have the potential to dramatically alter the ecosystem of multiple industries, including government. Main drivers for smart cities are digital transformation, urbanization, shifting global economic power, the societal impacts of climate extremes, social and mobile as well as sensor technology, and cloud computing.[42] In Austria the concept of smart city is widely discussed among the public, research as well as private sector mainly supported by the Austrian Federal Government (Ministry for Transport, Innovation and Technology, Ministry of Agriculture, Forestry, Environment and Water Management), the Austrian

[39] Digital Agenda for Europe, 2020 Initiative.
[40] Smart City Vienna.
[41] IDC, 2015h.
[42] IDC, 2015h.

Research Promotion Agency (FFG) and the Climate and Energy Fund. On local level a number of Austrian cities have put the concept of smart cities on their agenda. For example the City of Vienna developed a Smart City Strategy Framework[43], i.e. a milestone in the future development of the Austrian capital with the goal to ensure high quality of life for all citizens. Smart cities is also a topic for other Austrian regional capital cities such as Graz as well as a number medium-sized towns. Most of these initiatives relate to the European 2020 goals to reduce CO2 emissions. In smart cities digital technologies translate into better public services for citizens, better use of resources and less impact on the environment is also what the European Union addresses in their digital agenda for Europe[44] and invests in ICT research and innovation to improve the quality of life of citizens and to make cities more sustainable in view of Europe's 20-20-20 targets[45].

3.2.4.2 Interoperability challenges

Interoperability basically occurs on the data exchange between cities and within cities as well as sensors in cities. However, due to the fact that this is public sector driven, de-facto standards are not seen as a major standard here but a number of committees and focus groups on European and national level are working on the development of standards for smart and sustainable cities and communities and the integration of information- and communication technologies in urban processes.[46]

3.2.4.3 Relevance for Austria

Interoperability of solutions is highly relevant to the Austrian administration and the public sector and closely related to IoT technologies. However, the study authors see that this should not be driven by Austria itself but developed in line with international and European initiatives. To succeed in this, it is relevant to support cross-border efforts in this area. As of interoperability, this should have a medium to high priority.

[43] City of Vienna, n.d.
[44] European Commission Website, Smart cities.
[45] European Commission Website, Europe 2020 targets.
[46] Austrian Standards Website.

3.2.5 Smart Industries

In 2013 a discussion started in the German speaking countries as well as all across Europe about an industrial change that is also called the „fourth industrial revolution“[47]. Industrialization can be divided into four main phases. They are:

- Industry 1.0: Introduction of mechanic production facilities using water or steam power instead of human power;
- Industry 2.0: Introduction of shared work processes that led to mass production using electrical power;
- Industry 3.0: Automatization of production using information technology;
- Industry 4.0: Introduction of cyber physical systems[48] and using connectivity with Internet technology.

Smart industries, smart factory or Industry 4.0 target on novel sensors, service architectures and control methodologies being given to add-ons and upgrades to existing machines and systems, which will help to improve the performance of existing equipment and to extend its useful life[49]. Industry 4.0 is strongly connected to cyber physical systems, virtualization of processes, online networking and communication of people, organizations and machines, and the Internet of Things, meaning the clear identification of physical objects in an Internet-like structure (refer to chapter 3.2.1)[50].

3.2.5.1 Significance and Impact

Recently, the first Industry 4.0 pilot factory opened its doors in Austria. It is the place for industry and research to bring the Austrian industry sector on a next level. After the automatization of manufacturing facilities, facilities are now linked via the Internet and upgraded to smart machines. This has tremendous impact on the overall production process: stronger cooperation with vendors and partners, changing number and types of employees, machines, new products and business models. In the pilot factory enterprises can design, develop and test new ways of production in collaboration with the research sector. Currently, around 20 enterprises are involved in the Austrian pilot factory.[51]

[47] Behrendt et al., 2013.
[48] Industrial machines can be on the one hand physical and on the other hand virtual (on the web) (see Behrendt, et al., 2013); cyber-physical systems is a system of collaborating computational elements controlling physical entities (see Khaitan et al., 2014).
[49] European Commission Website.
[50] Refer to Behrendt et al., 2013.
[51] Drucker, 2015.

The cooperation in Industry 4.0 between Austrian research organizations and the private sector is at the beginning, and will be central for the industry in the upcoming years. Anyway, the implementation of initiatives depends on how new concepts can support cost savings, automatization, management of product complexity, and the response to new requirements.[52] Even though there have been a lot of discussions about the chances that come with digitalization and connection of industrial units, the technology has not yet reached the Austrian market on a big scale. According to a survey by Gallup, only 47% of 200 local companies have heard about the term Industry 4.0. Around 25% still need further information about this topic. One fifths believes Industry 4.0 is just a hype that will pass and 8% assumes that the topic applies more to Asia or USA than to Europe.[53]

3.2.5.2 Interoperability challenges

Industry 4.0 is basically driven by the Internet of Things. Challenges on this are basically the same as with IoT and refer to the large number of sensors, different “things” and APIs.

3.2.5.3 Relevance for Austria

Austria has an important industrial production. All developments made in this section should be done via the IoT paradigm. Therefore, the study authors see this as a subgroup to IoT and no special priority is assigned to smart industry itself.

3.3 Long-Term Technology Innovations

Long-term technology innovations are still far away from implementation in day-to-day businesses and procedures. Even though there are some notable research activities, a wide usage is not expected for the next ten years. Further fundamental research on these technologies and their interoperability with other systems is required to reach higher adoption rate on the market. Long-term technology innovations are for example wearables with integrated nanotechnologies and robotics.

[52] IDC Event, 2015 on Industry 4.0.
[53] Drucker, 2015a.

3.3.1 Wearables

Wearables are computer technologies that can be worn by the user on the body to support activities in the real world. Examples are smart watches, smartphone bracelets, wrist worn gadgets, data eyeglasses, programmable cloths, etc. A wearable computing device must have a microprocessor, is capable of logic and computing, can be worn only on the body, and connects to a network either directly (cellular or Wi-Fi) or indirectly (through a smart computer device, such as a smartphone or tablet). This allows the research to focus on the new market of wearable computing devices (eyewear, watches, and bands) and away from the old market (digital watches and basic Bluetooth headsets). It also allows the research to distinguish which devices are truly capable of computing and which ones are extensions of a smart compute device (headphones and head-worn displays).[54]

3.3.1.1 Significance and Impact

The overall wearables market is still in its initial stages but continues to show signs of steady progress. Pushing the market forward is a combination of major vendors becoming more active in the market and a list of start-ups and market pioneers launching second- and third-generation devices, applications, and experiences to the market. While there has been some definite progress from a vendor and device perspective, consumer awareness and interest have yet to match it. IDC surveys have pointed to a myriad of reasons why adoption has yet to reach the mass market. Chief among them is the belief that wearables pose little use to users, that their value proposition has yet to be clarified, and that users do not know enough about them. Again, we remind users that the market is still in its initial stages, and as vendors address these pain points as well as purchase drivers, adoption of wearables is expected to increase in the years ahead. IDC expects that by the end of 2015, a total of 76,1 million wearable devices will ship worldwide, making for a 163,3% increase from the 28,9 million units shipped in 2014. From there, we anticipate a total of 173,4 million units shipped worldwide in 2019, resulting in a five-year compound annual growths rate of 43,1%. Given this growth trajectory, there will be plenty of opportunity for tech suppliers in terms of hardware

[54] IDC, 2014b.

development, processor development, materials, and building partnerships with key members of the wearables ecosystem.[55]

Key drivers within the wearable computing devices market will be sensors and connectivity. Wearable devices will be laden with a myriad of sensors, collecting a range of data from both the user and the nearby environment. At the same time, wearables will require connectivity to transmit and receive data, whether directly through a wireless network or tethered to a smart device. For simpler devices, near-field communications or Bluetooth low energy will suffice, but for longer and larger data streams, Wi-Fi or cellular is preferred. In addition, development in power management and capacity will help drive wearables' adoption as will evolution of cultural norms. Applications will also play a key role for the wearable computing devices market. Developers will be faced with challenges far different from those found when developing applications for smartphones or tablets, ranging from different product categories, form factors, and user interfaces. Consequently, operating systems — most ostensibly, Android Wear, Apple, Tizen, and Pebble — will seek developer loyalty to build a thriving application ecosystem.[56]

3.3.1.2 Interoperability challenges

As of now, each vendor provides its own standards for wearables. This means that there is a high risk of a vendor lock-in. There are no standard APIs available right now.

3.3.1.3 Relevance for Austria

In Austria, there has not been a significant market for wearables yet. The technology itself is yet to take off and might not even take off. The study authors suggest to treat this emerging technology with a low priority.

3.3.2 Robotics

Robotics is the branch of technology that deals with the design, construction, operation, and application of machines capable of carrying out a complex series of actions automatically, especially one programmable by a computer[57].

[55] IDC, 2015i.
[56] IDC, 2014b.
[57] Oxford Dictionary on robotic.

3.3.2.1 Significance and Impact

The development in robotics show notable progresses in the last years. Beside the industry sector, there are more and more areas of application for robots at home, e.g. service robot Asimo. Robotics is one of the core areas of Horizon 2020, especially due to its potentials for the industry sectors such as health, manufacturing, logistics, etc.

3.3.2.2 Interoperability challenges

Interoperability with robotics basically occurs on the communication between such devices. However, robotics is a very long-term topic and still there is not enough information available.

3.3.2.3 Relevance for Austria

Due to the long-term effects of robotics, high relevance for the Austrian market cannot be seen at the moment.

4 Interoperability Outlook for Austria

4.1 Interoperability Heat-Map

ICT is in almost every device. Deep integration of ICT into every aspect of our life and the increasing interaction of devices make it more and more difficult to handle the enormous complexity of the systems involved. Hence, interoperability is becoming a key aspect for a lot of research areas which are described in the following sub-chapters.

Our starting point was a search for scientific articles in the field of interoperability. We chose two portals for this purpose, the IEEE and the Scopus article search portals because they host large databases, they support searching by keywords and they support export of article data to CSV-files (Character Separated Values). We retrieved all the scientific papers that were published in the last 18 months and that where tagged with the keyword “interoperability” and imported them to a local database. This database contains, among other fields, the title, the authors and their affiliations, the keywords and most importantly the abstract of the article. With the help of this database we were able to do the following:

- Rule out articles that were falsely tagged or used “interoperability” in a sense outside the scope of this study.
- Estimate the relevance of the remaining articles on a five-point scale from “definitely relevant” to “probably not relevant”.
- With the affiliated institutions we were able to determine if the author or one of the authors is part of an Austrian research group. More weight was given to the affiliation of the first and second author.
- Together with the post code of the institutions and a database with geocoded Austrian post codes we were able to show the regional distribution of published relevant articles on an Austrian map. Furthermore, by filtering the articles by different criteria we were able to analyze regional research foci.
- A technology list was produced, that contains every technology name, standard, method or other relevant technical term mentioned in the abstracts.
- From the technology list mentioned above a classification was produced that comprises three parts. They are:
  - Hierarchical ontology of technologies used by the research groups.
  - Hierarchical ontology of domains in which interoperability is investigated by these groups.
  - Structured list of additional topics.
- So we could create a list of institutions and experts relevant for this study. The database was complemented with the contact information of the authors because this information was not part of the article data retrieved. More institutions and experts were added from other sources.

Personal interviews with more than 15 experts were conducted all over Austria using a guided questionnaire asking general questions and using structured check lists. The same questionnaire and checklists were also sent via an online tool to more than 130 scientists. In total 42 experts from different research institutions have participated in the interview and the online questionnaire. Answers from all Austrian universities as well as from applied universities and non-university research institutions were delivered.

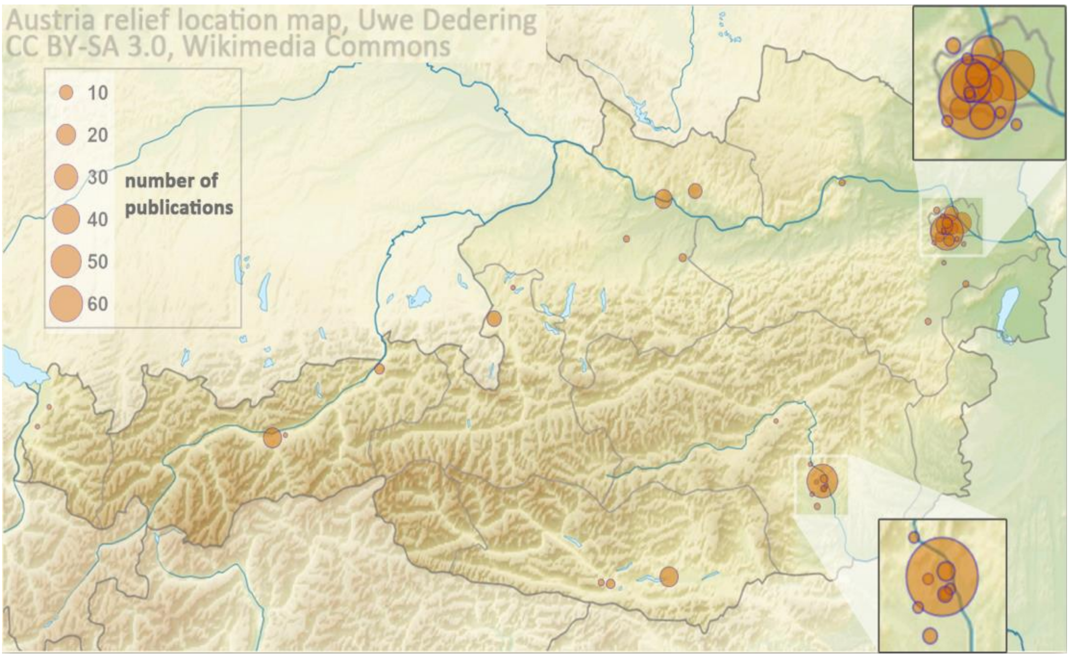


Figure 6: Hotspots area in the Austrian research community

Figure 6 shows the scientific expert regions which we identified through our desktop and Internet research and where they are located in Austria. The bigger the circle the more experts are working in the field of interoperability. This is a preliminary depiction of the hot-spots in Austria. A discussion in relation to the field of interest will follow.

Due to the thorough desktop and Internet research we identified more than 130 scientific experts whose research fields are connected to interoperability questions. In the next chapter the research areas related to interoperability of the different institutes are outlined followed by a summary of challenges which the experts identified for the near future.

4.2 Interoperability Hotspots in Research in Austria

An online questionnaire was answered by 26 researchers, one contained only comments but no answers. In order to evaluate possible regional focuses the remaining responses were split in two regions (east and west) based upon the location of the research institution in Austria, trying to balance the number of contributions:

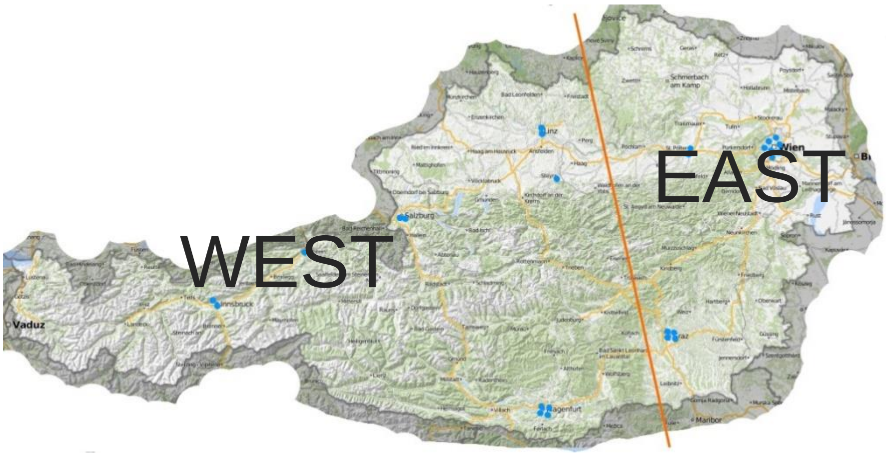


Figure 7: Research regions from questionnaire answers

This resulted in 13 answers from the east region vs. 12 answers from west region. In the east region following research institutes are included:

- Vienna University of Technology
- University of Vienna
- Austrian Institute of Technology (AIT)
- Joanneum Research
- Graz University of Technology
- Know Center in Graz
- Austria Tech
- St. Pölten University of Applied Sciences (FH St. Pölten)
- University of Natural Resources and Life Sciences

while the west region of Austria is covering:

- University of Salzburg
- Johannes Kepler university of Linz
- University of Innsbruck
- Alpen Adria University in Klagenfurt
- Kufstein University of Applied Sciences (FH Kufstein)
- Salzburg University of Applied Sciences (FH Salzburg)
- Profactor GmbH

First the number of activities for the top categories was evaluated by summarizing the sub-areas into their top categories:

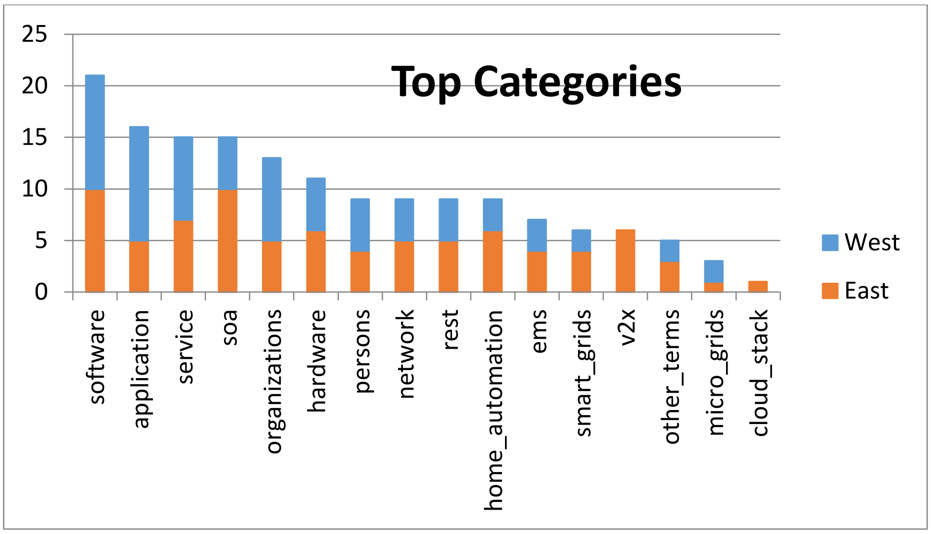


Figure 8: Top categories of research activities (questionnaiare)

The main five categories are software, applications, services, service oriented architecture (SOA) and organization. They are distributed among west and east very homogenously, except application which is more dominant in the west region of Austria and SOA which has an eastern dominance. Two categories, v2k and cloud stack, are only mentioned within the east region.

A summary of the activities and research topics which were mentioned in the research questionnaires are shown in Annex 7.3. Semantic web and security play a big role in both areas, the other topics overlap in part reflecting the activities of the different research institutions.

In the following, the research institutions and its experts are described in more detail to present a comprehensive image about the main players in the field in Austria.

4.2.1 East Austria in Detail

At the University of Technology in Graz the group around Professor Slany is focussed on the analysis and testing of distributed systems. One of the crucial issue in its research area is the interaction between all components and environments of the whole system. Here the institute is elaborating such challenges in several industrial projects: The project 3ccar deals for example with the implementation of combinatorial testing in automotive systems. Another co-operation with industry aims to analyze autonomous intelligent systems.

One of the scientific questions is how to generate adaptive systems which are a learning system within a system. Such self-adaptive systems should on the one hand be reliable but on the other hand fulfil safety requirements. Questions arise like „What do we allow the system?“ or „Which boundaries do we set?“

Social Network analysis will be a very important field of research in the near future. The Institute of Knowledge Technology at the University of Technology in Graz has one of its foci laid at this research field.

The Institute for Technical Informatics at the University of Technology in Graz is analyzing in several departments questions around embedded automotive systems, networked embedded systems or smart systems. The research groups investigate the implementation and testing of sensor networks and have a special emphasis on the networking and software engineering aspects regarding Internet of Things and/or cyber-physical systems.

The Institute of Applied Information Processing and Communications of the University of Technology in Graz has an outstanding reputation in e-governmental basic services and in the field of secure systems in general. This implies cryptography architecture, design as well as the construction of correct systems.

The University of Technology in Vienna is covering a wide range of research regarding interoperability. The distributed system group at the Institute of Information Systems has one of its focus on service oriented computing which is a new emerging paradigm for distributed computing processes. Research topics include model-driven service engineering, development methods for web services workflows, web services workflows and verification and dynamic web services registries. Services are autonomous, platform independent computational elements.
The Faculty of Computer Science of the University of Vienna has one particular research area based on multimedia information systems. The main topics cover interoperability in semantic web, linked data, clouds, big data, etc. dealing with distributed databases, object-oriented databases and/or databases for the Internet (e.g. unstructured, semi-structured and structured).

The cyber physical system group at the Institute of Computer Engineering under the lead of Professor Grosu has its research activities focus on the area of cyber physical systems and dependable embedded systems. In this sense it is a core enabling technology leading to a decisive contribution to societal challenges. In future more than 7000 billion embedded devices will exist and there must be an easy going feature for plug and play of such devices in order to achieve an emergent behaviour of the system.

The biggest non-university research institution in Austria – the Austrian Institute of Technology (AIT) – has several research topics related to interoperability. Especially at the Energy Department a group is working on smart grids and the interoperability of distributed energy resources (DER), remote control, and SCADA integration, etc.
Another team in the Digital Safety and Security Department is working on wireless communication systems and automation and control algorithms for autonomous driving or flexible production environments with a focus on secure information access in distributed systems. The three pillars of this department are future networks and services, intelligent vision systems and highly reliable software and systems.

Big Data analysis and data integration are the main foci at the Know-Centre lead by Professor Lindstaedt. Data integration is meant over the chain of economic value added as well as data types. Another important aspect is the needed granularity of the data in order to be able to derive the correct conclusions depending on the applications used. For each domain there must be a specific standard established for enabling a smooth data exchange.

The Institute for IT Security at the Applied University in St. Pölten generally focuses on industrial security with relevant applications for smart phone security, smart meter intrusion detection security, and security of cyber physical systems. Analysis of malware systems are done at the Josef Ressel Centre. Interoperability in cars are one of the most challenging applications. The interaction as well as the security of the microprocessors have not yet been solved.

The group for Digital Healthcare in St. Pölten has specializations on patient empowerment, health literacy, digital media and technologies in health care systems.

4.2.2 West Austria in Detail

At the University of Innsbruck two institutes are strongly involved in research areas regarding interoperability: first the Semantic Technology Institute of Professor Fensel and second the Institute of Quality Engineering of Professor Breu.

The Semantic Technology Institute is mainly focussed on research in the field of smart data. The scientific questions are related to enable execution environments for design, dynamic interoperation of empowered services. Projects deal with solutions of design and implementation of semantic web services and are applied to several industrial sectors like transport, health, AAL, smart buildings, security and tourism. One cooperation with the Health and Life Sciences University in Hall in Tirol is putting the focus towards new developments in health systems. In the near future services which can make autonomous decisions based on semantic and structured data will become important. In general this research field will move from a fundamental research area more and more towards applied research.

The research group around Professor Breu from the Quality Engineering Department is dealing with model-based quality management with a focus on inter-organizational systems and with security engineering. Challenges in these areas are to ensure the quality of IT systems that are composed of manifold services across organizational and platform boundaries as well as to ensure the security of an assembly of services.

The Alpen Adria University (AAU) in Klagenfurt has determined two excellence fields of research topics. One of the two is networked autonomous systems. The Institute for Networked and Embedded Systems comprises four departments. They are mobile systems, pervasive computing and embedded communication systems and smart grids.
The university has established an international reputation in the research of smart micro grids. The team is working on new modelling, methods and analysis of

solutions for future energy applications. Since renewable energy is hardly steerable the end devices have to become intelligent in order to be adjustable of actual energy needs.
Professor Tonello from the embedded system group is dealing with the question how two devices on one physical layer can talk and understand each other. A higher level of self-organization — such as self-configuration, self-awareness, self-healing, and self-adaptiveness — holds the promise of a paradigm shift for the design and the evolution of ICT systems and may help to master complexity challenges.

The Institute of Information Technology, Department Multimedia Communication around Professor Hellwagner has its focus on the transfer of multimedia data. In this area essential standards like packaging of data, standardization of network protocols, etc. are required. His group was part of a consortium of an EU project aiming to improve the technical and organizational support of rescue teams in catastrophic scenarios. Interoperability was a major topic to ensure a smooth transfer of data from one to another team and country. Interoperability of devices, protocols and software is essential for mobile ad-hoc networks which will be certainly a remaining research field. One considerable problem is the huge dominance of the big companies like Google, Apple, IBM, etc. which are manifesting standards only on their business interests.

The Institute of Information and Communication Systems lead by Professor Eder has research areas in enterprise interoperability, (inter-organizational) business processes and information systems for medical research. Challenging topics are data quality, semantic data transformation, evolution of information systems, privacy, and anonymization.

At the Johannes Kepler University in Linz the Institute of Pervasive Computing under the lead of Professor Ferscha is an important player regarding embedded systems, Internet of Things, context computing, distributed multi-user environments and wireless or ad-hoc networks. A key challenge towards such systems as manufacturing systems based on ICT is the confluent and collaborative cooperation and communication between man and machines. The research group works on a reference implementation of attentive machines based on formal models of human attention, multisensory recognition architectures and embedded subtle assistive support mechanisms. Results of this work are improved product quality assurance, and significantly advanced worker safety.

The Institute for System Software lead by Professor Mössenböck is mainly concerned with compiler programming. There is an emphasis in cross-language interoperability between programming languages, memory-safe execution of C code and compiler construction as well as virtual machine construction. The institute works on a programming-language-agnostic system that can combine different programming languages as JavaScript, Ruby, C, and Java. However, future work needs to integrate more programming languages in their system. Further, the Institute for Integrative Circuits from Professor Hagelauer is dealing with modelling, simulation and programming of highly complex integrative circuits.

At the Applied University of Kufstein several research topics have been established in the last years. Software defined networking (SDN) for example is one focus. There are already standards defined for SDN but key players like Cisco are promoting their own standards for their business. This hampers the development of a standardized switch interface. Open Source solutions are supporting the trends towards the right direction. Another research area is the development of document management systems. There exists a content management interoperability service based on a web service which is supported by Microsoft via Sharepoint. Machine-Human interface is another dominant research field. Interoperability between machine and human becomes a more and more challenging task in different industrial applications. Questions like „How is the user dealing with information?“ or „How are decisions being made on the basis of information?“ are in the focus of the researchers.

Last but not least interoperability for data is of big importance especially related to specific applications. Specifically open government data are an issue since the interoperability of open data are asymptotically going to zero. Standardization is still missing. One key player in the research of Information and Communication Systems is the Software Centre in Hagenberg. Topics as embedded systems, near field communication, and secure information systems are in the focus of the research groups. Real-time monitoring data transfer into a sensor observation service with different data formats is one of the fields of the Geoinformatics Institute at the University of Salzburg. Big data processing and tailoring data for (real-time) decision support are the most challenging issues.

4.2.3 Re-considering the West / East Division

The west/east division was a first tentative approach to reveal a possible clustering. The results obtained showed that the justification for such a classification is limited. However, by geo-locating all our search results we obtained a more detailed view that revealed four possible clusters:

- Health: Wien, Graz, Linz, and others
- Robotics: Wien, Graz, and others
- Automotive: Wien, Graz, Klagenfurt, and others
- Aircraft: Wien, Innsbruck, Kufstein, Salzburg, Linz

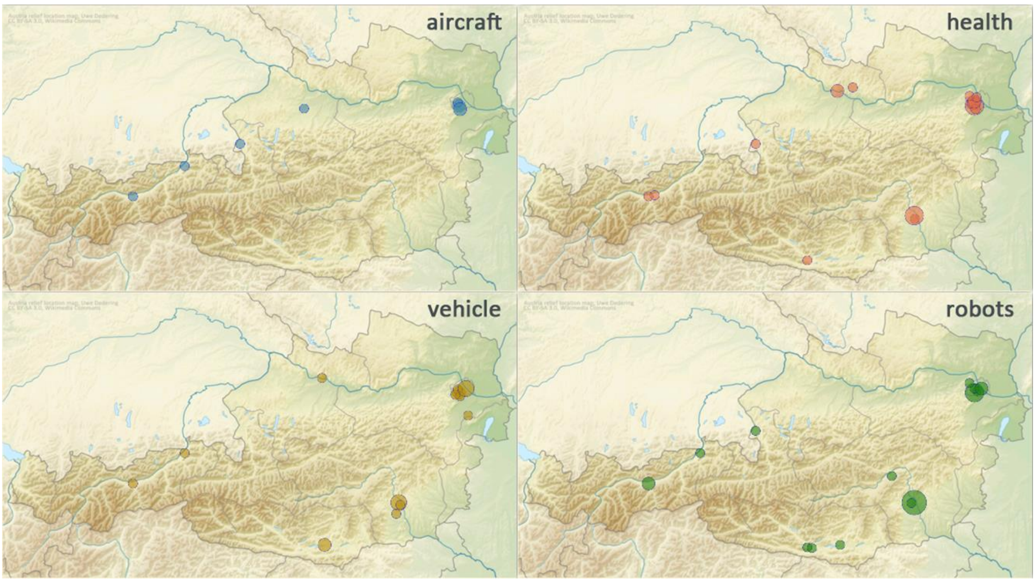


Figure 9: Clusters revealed by geo-locating publications

Looking at the data from this point of view we can see some strong players who are active in all clusters. Examples are Vienna and Innsbruck.

4.3 Business Impact of Interoperability

The online survey „Interoperability of Systems in Austria“ was conducted in October 2015 among Austrian end users. It provides insights about the importance of interoperable solutions in businesses, the challenges users are facing in case solutions are not interoperable with existing systems, and gives suggestions what needs to happen to further push interoperability. The "technology user's voice" served as input for the recommendations and roadmap in chapter 5. The call for participation at the survey happened via IDC's network and targeted companies in different industries, their CIOs and IT managers. In total 158 respondents completed the questionnaire. 61% of respondents are from the private sector (industry, commerce, banking and insurance, service sector) whereas 34% are from the public sector. 45% of all responding organizations have more than 500 PC workplaces. The survey shows clearly that in all areas interoperability and standards are seen as important and IT managers pay attention to interoperability and standards whenever they buy new solutions. Most respondents see great potential of interoperability for their organizations. Therefore, respondents prefer offers that support interoperability and standards to offers that do not; also they recommend their clients or partners to use standards. Anyway, even though interoperability and standards are seen as highly important in Austrian industries, organizations still face major problems in regard to interoperability and standards. Main obstacles are problems with interoperability, missing standards for software, hardware, data, organizational and administrative aspects. Most problems occur with mobile solutions. The most important drivers for interoperability of systems in organizations are clear standards that are independent from suppliers and manufacturers. The following sub-sections present the detailed results.

4.3.1 Importance of Interoperability

The first question is about the importance of interoperability and standards for hardware, software and services. Possible answers range from 1 (not important) to 10 (very important). The results show that in all areas interoperability and standards are seen as important and answers range on the scale from 7,3 minimum (i.e. organizations with less than 200 PC seats and referring to hardware) to 8,7 maximum (i.e. public organizations in referring to software).

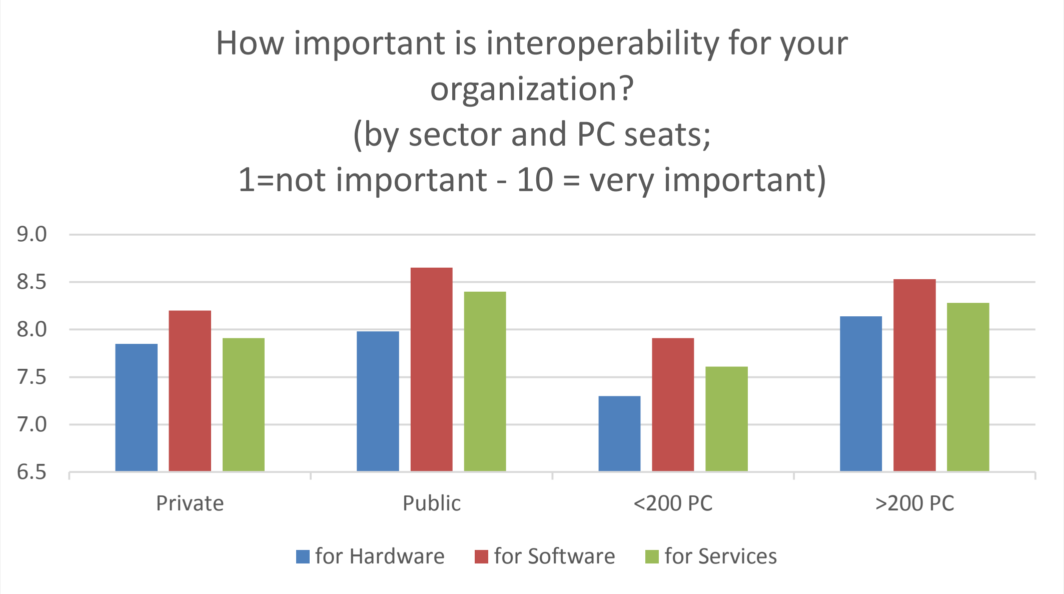


Figure 10: Importance of interoperability by sector and PC seats

The average value is 7,9 for hardware, 8,3 for software and 8,1 for services. Companies with more than 200 PC workplaces rank the importance of interoperability higher than companies with less than 200 PC workplaces. A comparison between public and private organizations shows the same result. Public organizations rank the importance of interoperability slightly higher.

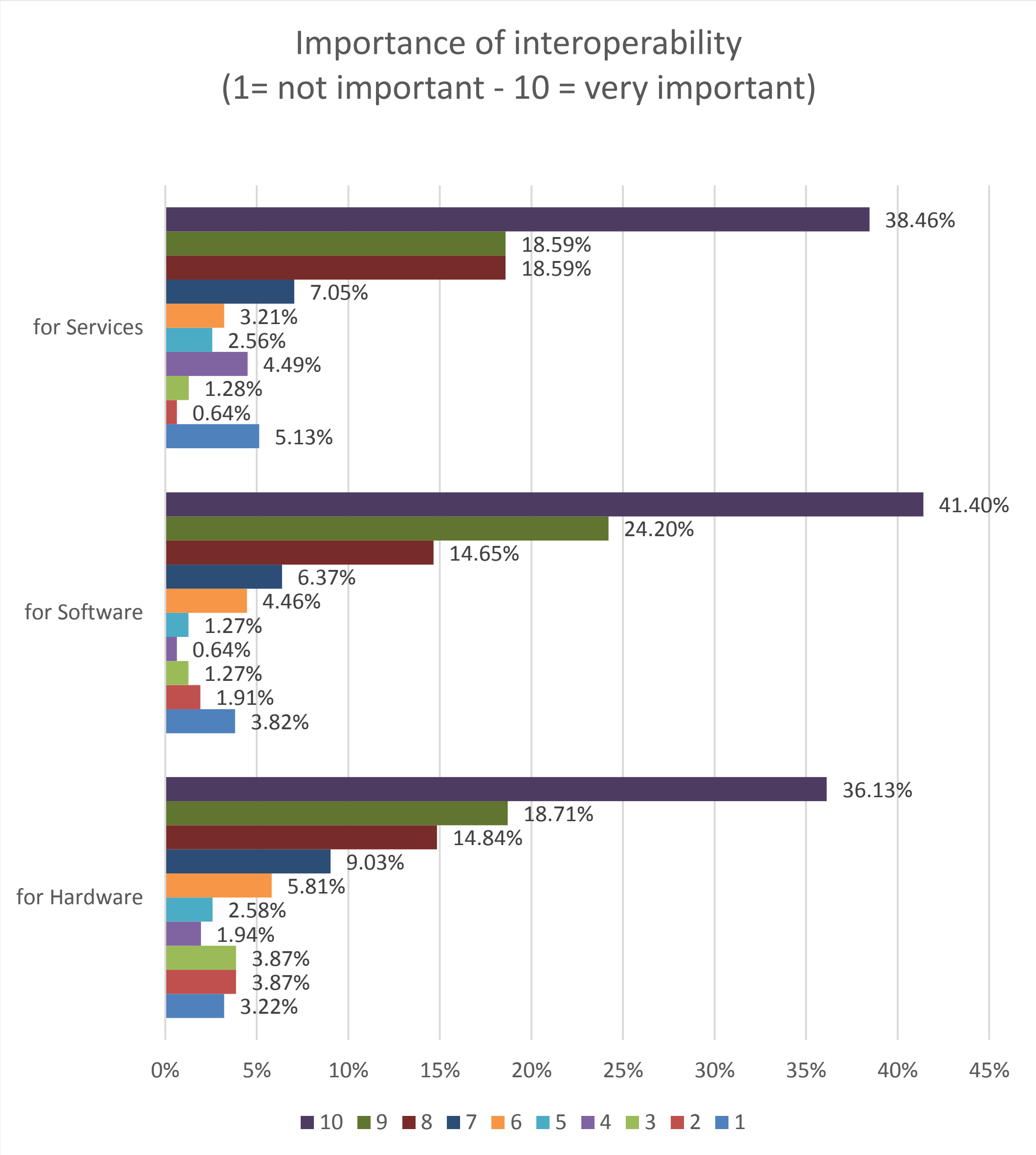


Figure 11: Importance of interoperability and standards in organizations in regards to services, software and hardware

4.3.2 Influence on Decision-making

The second question asks if organizations pay attention to interoperability and standards when they buy new solutions. A clear majority answers the question with yes. In regards to hardware 92% pay attention to interoperability, for software it is 97% and for services 88%. The result shows clearly that the majority of respondents pay attention to interoperability when they purchase new hardware, software or services. There has been hardly any difference between public and private organizations or between organizations with more or less than 200 PC workplaces.

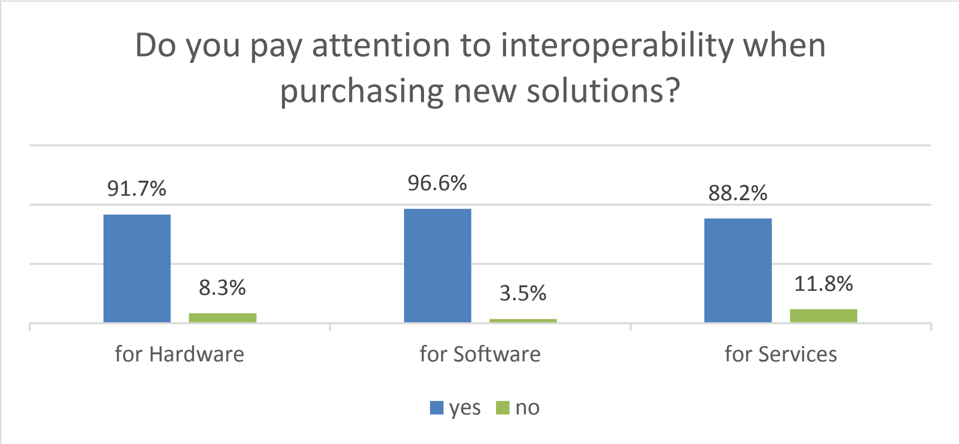


Figure 12: Purchasing new hardware, software or services

Question three shows similar results as question two. The question asks if respondents prefer offers that support interoperability and standards to offers that do not, taking into account that both have the same costs. The majority of respondents answer this question with a clear "yes". Breaking this further down the results show that in terms of hardware 98% of respondents prefer solutions that support interoperability and standards, in terms of software it is 99% and in terms of services 97%. Similar to the previous questions, there are no relevant differences between the public and the private sector or between organizations with more or less than 200 PC workplaces.

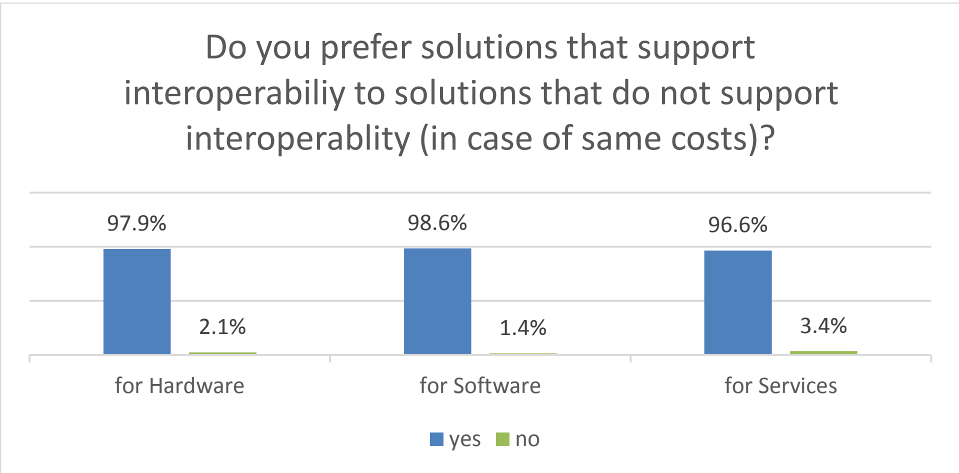


Figure 13: Solution preferences

In most cases respondents recommend their clients or partners to use standards. In regard to hardware this is 88%, in regard to software 93% and in regard to services 90% of respondents.

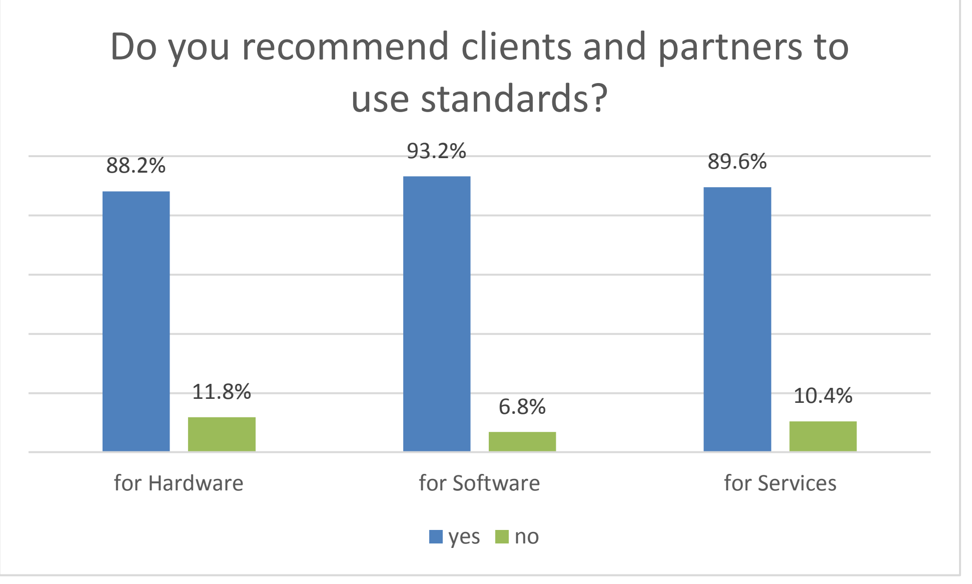


Figure 14: Recommendation of standards

Focusing on software we can see that public organizations (96%) and organizations with more than 200 PC workplaces (96%) recommend the use of standards more often than private companies (92%) and organizations with less than 200 PC workplaces (87%).

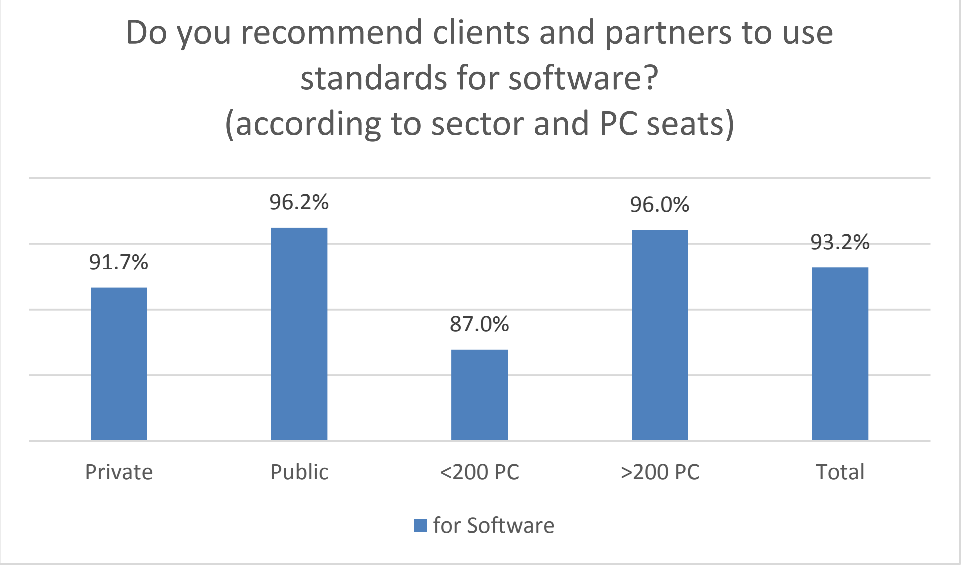


Figure 15: Recommendation of standards for software

4.3.3 Challenges

Questions five and six aim at identifying the challenges that organizations are facing. Notable 60% of respondents have problems with proprietary software, hardware or services that could have been avoided in case of better support of standards. This refers to public organizations (60%) as well as private companies (59%) likewise. There is a correlation between interoperability problems and the number of PC workplaces. 63% of respondents with more than 200 PC workplaces claim that they have problems with interoperability, whereas this applies only to 52% of organizations with less than 200 PC workplaces. Only 40% of all respondents do not have any problems at all with interoperability.

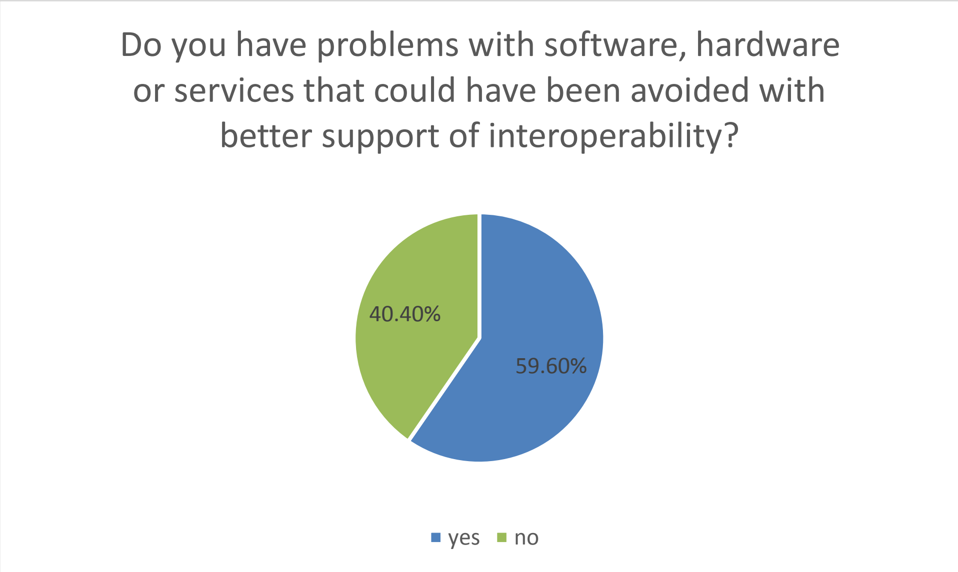


Figure 16: Problems due to lacking support of interoperability

In an open question respondents name various obstacles regarding to software, hardware or services. Main obstacles are problems with interoperability, missing standards for software, hardware, and data, and organizational and administrative aspects. Especially data exchange, non-standardized data formats, problems with compatibility and the threat of information loss when transferring data from one system A to a system B are mentioned several times. Missing interfaces between systems, unclear specifications and related complex programming and maintenance are also highlighted. In terms of cloud solutions, e.g. online calendar applications, problems exist with synchronization and delays of data transfer. Respondents also mention organizational challenges, e.g. restructuring of departments requires restructuring of existing workflows. Isolated solutions ("islands") in different company departments make collaboration more difficult. Missing are know-how and an overview of the tremendously broad spectrum of possibilities in IT to identify the best solution for the organization. Moreover, security related aspects, scalability of applications and high costs (e.g. for software updates) are rated as problematic.

Question six asks for technologies with deficits regarding interoperability and standards. Respondents could select from a list of 22 technologies, and could add additional ones. Mobile solutions are listed on top with 39%. According to the respondents mobile solutions are the technologies where most deficits in terms of interoperability and standards can be found. This is followed by workflow-solutions (33%), content and document management (29%), and enterprise resource planning (ERP) solutions (27%).

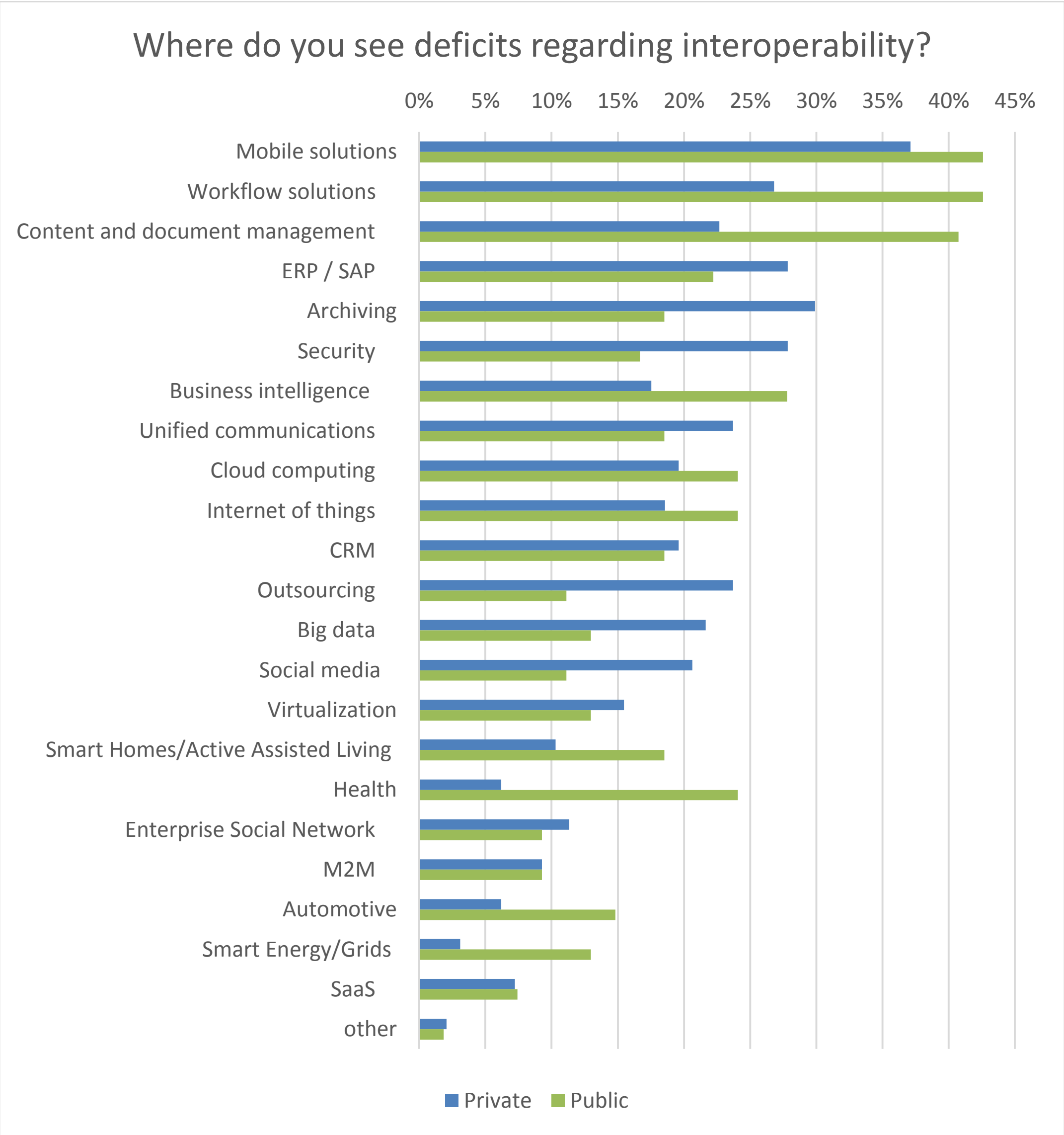


Figure 17: Technologies with deficits regarding interoperability

When we distinguish between private and public organizations we see different results. The top three technologies with the most deficits for public organizations are mobile solutions and workflow solutions (both 43%) as well as content and document management (41%). Private organizations on the other hand rank mobile solutions (37%) before archiving (30%), security and ERP (both 28%).

The respondents point out different challenges in terms of interoperability. Main challenges are the interaction between products, platforms and devices, data exchange and data merge especially when it comes to big datasets. In this regard security issues are highlighted. Also the interconnection of locations (e.g. distributed offices, departments) and interfaces with systems outside of the organization is seen as a key challenge in terms of interoperability. Within the organization challenges are time and costs for workarounds, the establishment of an internal IT strategy, and the consolidation of knowledge from different sources (e.g. departments). A clear intention to implement standards within an organization is often missing. Standardization of processes, data formats, interfaces, etc. is hard to achieve without any loss of flexibility.

4.3.4 Potentials

The question regarding drivers for interoperability could be answered by giving values from 1 (not important) to 10 (very important). Standards are the most important drivers for interoperability of systems in organizations (average 8,3), followed by processes (average 8), technologies and strategies (average 7,7 for both), and management (average 7.3).

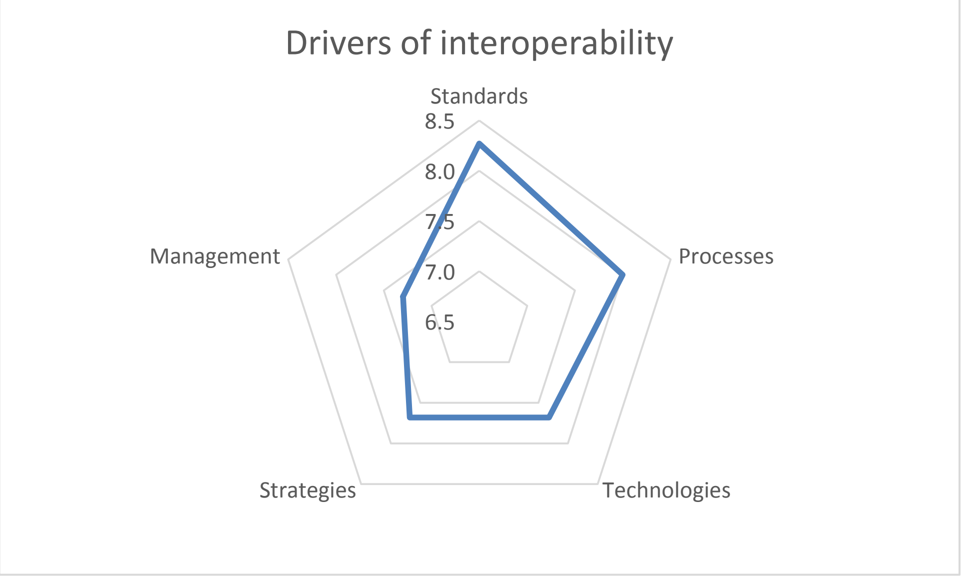


Figure 18: Key drivers of interoperability in organizations

In addition, an open question asked what needs to happen to push interoperability and standards. According to the survey respondents positive factors for interoperability are:

- Standards that are independent from suppliers and manufacturers (standards for interfaces, APIs, data formats, etc.)
- Simplicity of standards and compliance with standards
- International or European standardization bodies
- Legal specifications that regulate the implementation of standards
- Norms and standards such as ISO 14001, 27001, 45001 and cost reduction for standardization
- Clients, governments and research organizations need to put higher pressure on ICT providers
- Awareness raising and communication of the benefits of interoperability
- Efficient collaboration and partnership between suppliers
- Success stories and good practices (e.g. standard power cable for smartphones)
- Open source solutions

Some respondents doubt that standards will become fully accepted, as standards can contradict with the interests of solution providers. Market leaders might slow down the introduction of standards that are supplier-independent. Of primary interest are economic factors and unique selling propositions (USPs). This means interoperability needs to become interesting from an economic perspective. Enterprises require incentives, and need to be able to achieve competitive advantages through standardization and interoperable solutions.

Most respondents see great potential of interoperability for their organization. In an open question efficiency, cost and time savings, optimization of processes, and the reduction of redundancies are highlighted. Standards and formats that are independent from the technology provider (producer, manufacturer) make internal communication, administration and documentation easier. This also refers to communication and exchange of data and information with third parties (clients, providers, vendors, etc.). Standards allow to better connect distributed locations (e.g. departments), and to create mobile and flexible work places – work anytime, anywhere, on any device. Interoperability allows to cross borders, to use synergies, to implement new and neat technologies with high usability in a fast and efficient way, and to have all required data including metadata linked to each other. Eventually, the activities in the field of interoperability might lead to national or EU-wide regulations for the protection of data privacy as well as a global exchange and transfer of knowledge in this field. Interoperability is seen as a basic requirement for cooperation by the survey respondents – without cooperation there is no potential for economic growth.

5 Roadmap and Recommendations

This section provides the roadmap and general recommendations for the future of interoperability in Austria, and for further actions by the BMVIT (see also figure 19).

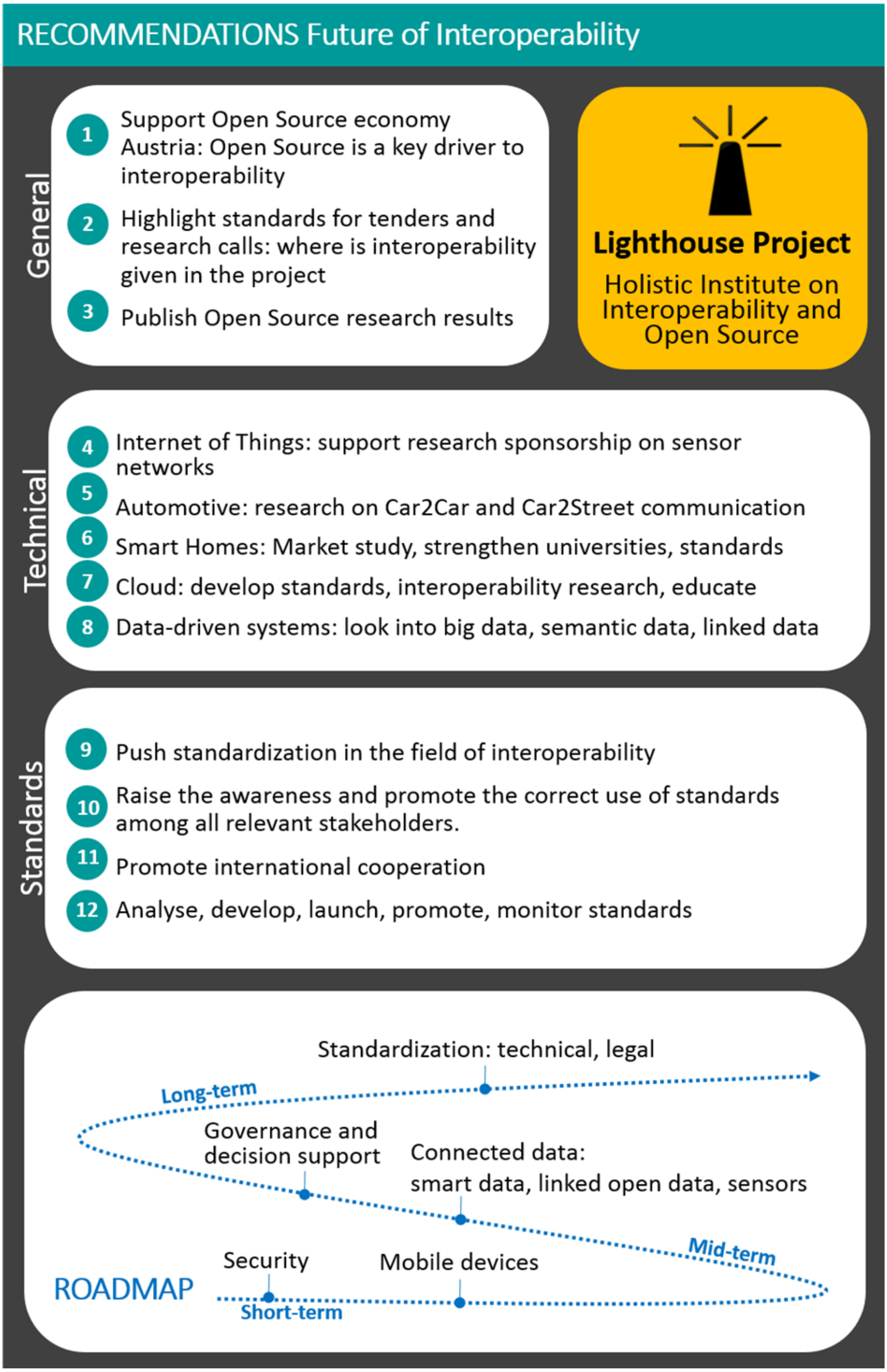


Figure 19: Overview on the recommendations for the future of interoperability

5.1 Lighthouse Project

Interoperability spans many areas and domains, and is multidisciplinary by nature. An important issue is the enormous complexity of the subject, and that it is not obvious how a direct intervention could be carried out. Therefore, a primary goal should be for Austria to create a favourable environment for innovations in the field of interoperability. The consortia recommends several forms of implementation of a lighthouse project, which can be selected based on the available funding and priorities of the BMVIT.

Austrian Holistic Competence Centre on Interoperability and Open Source/Standards

Interoperability is not a single research item. The challenge with interoperability is that it is (or ideally should) be in all IT domains. Interoperability is cross-sectorial, which basically means that there is no single institution dedicated to it so far. In order to improve interoperability, a holistic institute should be established. This institute can run in the form of a comet centre and addresses different interoperability challenges. The institute focuses on the development and implementation of standards throughout different technologies. It also emphasizes on open source systems and might be sponsored by companies that promote open source software (e.g. Red Hat). The target of this institute is to establish a community with researchers and enterprises in Austria that apply standards, interoperability and open source technologies. During the runtime of this institute, different projects that are required to improve interoperability can be implemented. Recommendations for such research projects are given in the following sub-chapters. Strengths of a comet centre are to coordinate, provide leadership, promote best practices, research, support and/or train in the focus area. The institute has dedicated and skilled personnel, which requires higher funding, but can lead to bigger impact. The entity should be established in Austria, and actively corporate with other European countries and EU-level initiatives.

Interoperability is a cross-border issue, i.e. should be tackled on EU-level with strong input and positive drive from Austria. Some efforts on interoperability and especially standardization make no sense on national level alone. One of the keys to interoperability will be to know and to understand what is done internationally and to break down these efforts to a national level. A major document is the

European rolling plan for ICT standardization[58]. It provides an overview of the needs for preliminary or complementary ICT standardisation activities to be undertaken in support of EU policy activities. It is drafted by the European Commission in collaboration with the European Multi-Stakeholder Platform (MSP) on ICT standardisation and is updated annually. National level efforts will be to monitor and adopt initiatives of European or international level. All national measures should be in harmony with European and international initiatives, and no measures should be in conflict.

Austrian Interoperability Platform

Alternatively a platform could be developed that serves as a network to exchange general information, publications, and events between members. The platform is a suitable way to build a network of relevant stakeholders concerned about pushing and promoting interoperability in Austria, and beyond. A good example is the Austrian AAL Platform[59]. For the success of the interoperability platform it is important to have human resources available who have the time and the commitment to focus on the development of the platform. Not having dedicated personnel and strong contributors who can steer platform activities is a potential risk for the platform's success and impact.

Anchor interoperability issues in existing platforms and communities

In addition, it is recommended to position the issue of interoperability in existing centres, platforms and communities. Some examples are the Austrian Open Data Portal[60], the Austrian AAL Platform, EuroCloud Austria[61], or IoT Vienna[62]. Such platforms focus already on the technology itself such as the Internet of Things and cloud computing, or on specific sectors such as health. Interoperability – similar to the topic of security – needs to find its place and gain a strong position in each of these platforms and communities. The previously mentioned interoperability institute or platform could interlink the multiple domain-specific and technology-specific activities on a meta-level.

[58] European Commission, 2016.
[59] Active & Assisted Living Platform Austria.
[60] Open Data Portal Austria Website.
[61] EuroCloud Austria Website.
[62] IoT Vienna Website.

Incentives, Award

Incentives could be a way to stimulate work in that field. Examples are to award the best work in the field of interoperability such as:

- diploma thesis, doctoral thesis, book, (peer reviewed) publication,
- outstanding products, projects, initiatives.

Professorship

Establish a professorship dedicated to interoperability. The professorship should be at a faculty, which focuses on one or ideally more of the five selected emerging technologies. The person that receives this professorship should research interoperability and standards in his/her fields and drive interoperability questions in Austria and internationally. This person should play a vital role in the Austrian interoperability community and network with different stakeholders.

5.2 General Recommendations

5.2.1 Stimulate a healthy open source economy in Austria

Open source is a key driver to interoperability. Open source software incorporates open standards and thus improves overall interoperability. The authors recommend the stimulation of a healthy open source economy in Austria by stronger regulations on project implementations for the public sector. Many IT companies lobby at ministries to drive their proprietary solutions. Whenever possible, open source software should be preferred instead of closed source software. If closed source solutions are implemented, it should be necessary to the providing company to at least implement open standards. A good sample on that would be Microsoft's Office solution which can store their documents under the two most common document formats (ODF and OpenXML). During the workshop and interviews the role of industry leading open source solution providers, such as Hadoop for big data, was discussed and that open source solutions and interoperability should be mandatory for public tenders.

5.2.2 Make the use of standards necessary for future tenders

Each applicant for a tender (e.g. Horizon 2020 or other local research projects) should fill out a mandatory section that asks for what communication between systems (e.g. sensors) are used. It should be stated if interoperability is given at any point in the project. The applicants should acknowledge where they use interfaces and if they follow open standards. Samples could be:

- Database systems: do the database systems allow standard procedures for access? If the database does not expose a standard (e.g. SQL) or if the standard is not implemented well, this should be avoided.
- Backend Systems: does the backend system expose a standard API such as REST or SOAP? If there is no standard API available, this piece of system should be avoided.

If the applicant uses systems, tools or applications that do not follow interoperability requests, the applicant should explain in detail why this is necessary.

5.2.3 Project output should be made available as open source

For project evaluation, the quantitative measures should be extended by the fact that a system developed should be made available as open source system. This should strictly include all necessary systems that are necessary to run the developed system. If a project uses a proprietary software, this would conflict with that point. A sample might be: „The results of project X are available open source. In order to run the software, you need to have a valid licence of Y which is proprietary“. A more concrete sample would be a software that is developed on Microsoft Windows. Windows is not open source and it must be licenced properly. The availability of open source results should change the evaluation of a project. If this is guaranteed, more points are given in the evaluation. If this is not done, fewer points are given.

5.3 Selection of Emerging Technologies for this Study

In section 3 several emerging technologies are described. The following table prioritizes these technologies according to their relevance to interoperability, and in respect to their potential for the Austrian market. High priority technologies were selected during the stakeholder workshop, and an internal workshop.

Emerging Technology	Relevance
Networked Societies	**Low –** Networked societies was not seen as a priority for interoperability. For a detailed description please refer to 3.1.1.3.
Cloud Computing	**High –** Cloud computing is not only a trend, it becomes more and more reality within Austrian enterprises. Interoperability is still an issue here, so investments should be undertaken in this area. For a detailed description please refer to 3.1.2.3.
Mobile Devices	**Low –** There is no significant industry for mobile devices in Austria. In the workshops nobody saw this as a priority. For a detailed description please refer to 3.1.3.3.
Data Driven Systems	**High –** Data driven systems (or big data) will be applied in a majority of companies within Austria. Therefore, a high priority is given. For a detailed description please refer to 3.1.4.3.
Internet of Things	**High** – IoT is highly relevant for several industries, especially manufacturing, transport, or government. For a detailed description refer to 3.2.1.3.
Autonomous Driving	**High –** There is a strong automotive cluster in the south of Austria. The companies employ a large number of people and stimulate the Austrian economy. Also, several research institutions corporate with these companies. For a detailed description refer to 3.2.2.3.
Smart Homes	**High –** Smart homes and AAL are a sector that has potential in Austria. There is also a European market leader originating from Austria. For a detailed description refer to 3.2.3.3.
Smart Cities	**Medium –** Smart cities are closely related to IoT with medium to high relevance for the Austrian market. For a detailed description please refer to 3.2.4.3.
Smart Industries	**High –** Smart industries is seen as part of IoT. For a detailed description please refer to 3.2.5.3.
Wearables	**Low –** Wearables have no significant impact on the market at the moment and are not seen as relevant by the stakeholders. For a detailed description refer to 3.3.1.3**Error! Reference source not ound.**.

Robotics	**Medium –** Robotics will reach more priority for the Austrian market only on long-term. For a detailed description refer to 3.3.2.3**Error! Reference source not found.**.

Table 2: Selection of high priority technologies for the roadmap

The following chapters describe the emerging technologies with “high” relevance for the Austrian market. Furthermore, the project consortia recommends another evaluation of those emerging technologies that are marked as “medium” within 3-5 years.

5.4 Technology Recommendations

Technology users point out they do have problems with proprietary software, hardware or services that could have been avoided in case of better support of standards (refer to chapter 4.3). The importance of interoperability is also underlined by the circumstance that users pay high attention to interoperability when they purchase new software, hardware or services. Users require clear interfaces, specification and standards for software, hardware, services and data, especially for data exchange. This refers to a broad number of technologies. Mobile solutions have most deficits in terms of interoperability and standards, followed by workflow-solutions, content and document management and enterprise resource planning solutions. Providers and vendors should keep these facts in mind when designing and developing new solutions.

5.4.1 IoT: Sensor Networks

A key challenge that was often stressed in interviews, was the high complexity of future IT systems. This is often driven by sensor networks that are present in different scenarios. The study authors recommend the implementation of a research sponsorship that deals with challenges in sensor networks. In order to achieve high impact, this research should not focus on dedicated domains but should address the communication with sensors in general. An output of this project should be a standard that can be implemented for IoT sensor networks.

5.4.1.1 Short-term Term research recommendations

Short-term research might affect medium and long-term research recommendations.

- **IoT Interop study.** Develop a study that outlines all research questions in detail for IoT and interoperability. This roadmap should be used to have detailed insights on questions in this field. The study should deliver additional research projects and shape the topic for future projects.

5.4.1.2 Medium-term research recommendations

- **IoT Platforms.** Develop an IoT Platform as part of a research project. The platform should focus on the following aspects: (a) technologies used in each aspect of the automated fabric and each process step and (b) information exchange and communication between services, applications and processes in each step of the automated fabric. The project should deliver insights into platforms and technologies that are currently available for IoT and the status of interoperability within each of them. Another important output are standard recommendations for services, applications and processes.

5.4.2 Autonomous Driving: Car2Car, Car2Street, Car Devices

The automotive sector is heavily driven by changes. This is also visible when we look at new cars. They are getting more and more autonomous and we can now see first trial routes where cars can actually drive autonomously.

The study authors see several major elements and interoperability challenges. Sensors itself (e.g. how they work and exchange information) are not of primary interest, since a lot of research and work on this was already conducted [63][64]. The focus should be on the information exchange protocols. However, only elementary research on the later point was conducted, which makes it necessary to create a study on that (as described in the following recommendations). The following recommendations will focus entirely on the information exchange. Safety isn't part of this, as this needs to be done from a holistic security & safety study on this topic.

5.4.2.1 Short-term research recommendations

- **Study.** Create a study on current standards and future aspects necessary for the automotive industry. This study should create a comprehensive

[63] http://link.springer.com/article/10.1007%2Fs00502-015-0343-0

[64] http://ieeexplore.ieee.org/xpl/login.jsp?tp=&arnumber=5948952&url=http%3A%2F%2Fieeexplore.ieee.org%2Fxpls%2Fabs_all.jsp%3Farnumber%3D5948952

overview on standards available and involved companies in the Austrian economy.

5.4.2.2 Medium-term research recommendations

- **Car2Car communication:** in order to make cars more secure for autonomous driving, cars need to communicate with each other. Therefore, it is necessary to implement a standard for communication that car manufacturers can then use. This focuses on the format of the communication (exchange of data and information), not on how the communication works.
- **Car2Street communication**: cars also need to communicate with the street or even with the city. The street could forward speed limits, road situation (e.g. if the road is slippery because of cold weather, etc.) and other topics. It is also necessary to communicate with the city or street operator (e.g. Asfinag). There are several options, including traffic jam prediction. In order to enable this, standards have to be established. This focuses on the format of the communication (exchange of data and information), not on how the communication works.
- **Car Devices:** there are many devices available nowadays within cars. These devices need to communicate with each other. Each car has a large number of sensors now that need to be built with open APIs. This focuses on the format of the communication (exchange of data and information), not on how the communication works.

5.4.3 Smart Homes

Austrian companies are globally in a very good position when it comes to Smart Homes. An example of that is Loxone[65], located in upper Austria with great international reputation. As the Austrian situation for this emerging market is already at a good level, the study authors suggest to improve interoperability in this market. This could lead to a key role for Austria in this specific section. There are already some standards in place (as described in 3.2.3.2) but none of them addresses the complexity of Smart Homes. Smart Homes deal with a large number of sensors, devices and objects typical for a house. Standards on the

[65] Loxone Website.

communication between these things should be evaluated. A description of Smart Homes was provided in 3.2.3.

5.4.3.1 Short-term research recommendations

- **Market study** on the relevance. This study should outline the market potentials on a global scale. Next, it should evaluate current and upcoming standards in the Smart Home market. Eventually, concrete recommendations should be given for further development. This study is necessary as there has not been much research around the topic yet.

5.4.3.2 Medium-term research recommendations

- **Professorship**. Establishment of a “Smart Home” Institute/Professorship at an Austrian university. This institute/professorship should work on different aspects of Smart Homes, like interoperability and security.

5.4.3.3 Long-term research recommendations

- **Standard**. Create and agree on a standard for smart homes. Some work was already carried out in Austria on this. The study authors recommend that a consortium should be formed that works towards agreeing on a dedicated standard for smart homes. As a starting point, standard recommendations given in the document “Accepting Smart Homes – 823585” should be further evaluated. Findings in the short-term recommendations also serve as input and the Institute/Professorship should play a leading role for that.

5.4.4 Cloud Computing

Cloud computing is a key technology for the Austrian and European market. The challenges were described in the chapter 3.1.2. In addition, expert interviews, the interoperability workshop and the market research showed that cloud computing is one of the key “battlegrounds” for interoperability. There is a major risk of running into vendor lock-ins.

5.4.4.1 Short-term research recommendations

- **Study.** Create a study on standards for common cloud computing providers and list the status quo on them. The study should serve as educating the

Austrian society, economy and public on what standards vendors implement for cloud computing.

5.4.4.2 Medium-term research recommendations

- **Interoperability research.** On the JKU, work has been done on interoperability for cloud platforms. During this work, a generic library to switch between cloud platform vendors was developed. This work should be intensified to create interoperable platforms in the cloud.
- **Educate.** Educate the Austrian society, economy and public by providing events, workshops and trainings on open source platforms in the cloud such as Fi-Ware. No respondents in the market research nor in expert interviews nor any workshop participants knew the platform. There is a significant gap that needs to be closed.
- **Support research on Fi-Ware.** Fi-Ware is not well known in Austria and no significant research is happening on this platform. The European Union tries to place Fi-Ware as an alternative to other platforms. The study authors suggest that research on Fi-Ware should be supported. A specific research should be done on how it is possible to move from closed platforms (such as AWS) to Fi-Ware with little effort.
- **PaaS Standards.** Create a study or research on standards in advanced topics for cloud computing. This is, as by the study authors, seen as Platform as a Service (PaaS). Currently, PaaS Solutions are highly customized and harder to standardize, which is due to the nature of PaaS solutions. To get a better understanding of standards for PaaS solutions, a comprehensive study for PaaS solutions is necessary.

5.4.4.3 Long-term research recommendations

- **Create a PaaS standard.** Based on short- and medium-term research recommendations and their implementation, a standard for PaaS solutions should be implemented. This could either be a specific part of PaaS solutions (e.g. for middleware solutions) or cover a broad aspect (e.g. for application development).

5.4.5 Data-driven Systems

With the aim to economically extract value from very large volumes of a wide variety of data by enabling high velocity capture, discovery, and/or analysis big data technologies gain importance and we recommend applied research and pilot projects on linked (open) data initiatives in the Austrian private and public sector.

5.4.5.1 Medium-term research recommendations

- **Data access.** Create a standard for data access in big data systems. In traditional systems, there is SQL. However, most big data systems do not implement SQL or only implement something similar to SQL. A research project should focus on creating a standardized access to data, similar to SQL.
- **Data by verticals.** Create standard processes for different verticals. Each vertical requires different processes for data-related topics. These processes should focus on the following verticals: banking, manufacturing, retail, tourism and utilities.

5.5 Standardization Recommendations

Standards are the most important drivers for interoperability of systems in organizations. According to the survey results standards should be independent from suppliers and manufacturers, simple, and supported by legal specifications that regulate the implementation of standards and supported by international or European standardization bodies who develop and control standards (refer to chapter 4.3). Main goals as expressed by the majority of the experts during the workshop are:

- Push standardization in the field of interoperability,
- Raise the awareness and promote the correct use of standards among all relevant stakeholders,
- Promote international cooperation.

Recommended measures can be divided in more detail into three phases. They are the analysis phase, intermediate phase, and advanced phase.

Analysis phase:

- Study and follow European Commission (EC) recommendations (for example the annual "Rolling plan for ICT standardization")
- Monitor EC positions and activities on interoperability

- Conduct a survey to determine other member states' initiatives, resources and positions on interoperability
- Analyze all other available member states' work plans and strategies on interoperability
- Analyze short- and long-term economic factors of interoperability (costs for implementing interoperable solutions)
- Monitor international efforts outside the EC

With the results of the analysis phase:

Intermediate phase

- Participate in EC programs (for example "Joinup"[66], a collaborative platform funded by the EC)
- Participate in joint programs or networks of other member states
- Launch a platform for suggestions and the reporting of problems connected to interoperability
- Launch a platform for the exchange of best practices
- Promote a regular dialogue on interoperability involving members from all stakeholder groups
- Host a conference with participants from industry, government, science both national and international
- Launch a multidisciplinary experts group that assembles in regular intervals and reports on its findings
- Organize a series of workshops on interoperability issues
- Investigate on suggestions for further improvements of standards and specifications

With the results of the above:

Advanced phase

- Contribute and get involved in European and international standardization activities
- Initialize first smaller and then increasingly larger pilot projects

[66] Joinup platform.

- Propose and contribute to a European interoperability framework
- Provide guidelines for selected stakeholders groups
- For procurers on how to mention standards
- For representatives from industry on standards conformance and the standardization process
- For researchers on standards conformance and the standardization process
- Ensure that existing interoperability standards are properly used
- Encourage IT suppliers to implement favored interoperability standards in their products or services
- Produce a report annually or in regular intervals on the activities and status of the national interop activities.

5.6 Roadmap

Future aspects and challenges with respect to interoperability are based on expert interviews and research questionnaires. Near-term challenges have a time horizon of up to one year, mid-term challenges a horizon between 2 and 6 years and long-term challenges are expected to apply for 6 and more years.

Near-term challenges

Near-term challenges are emerging from the existing and ever increasing complexity of interoperating systems, the created security issues and concerns how such systems can be properly designed, thoroughly tested against specifications and standards, and how complexity can be managed and the systems can be maintained.

- Future systems must be reliable, safe and secure within a system which itself is influenced by its surrounding. The main question here is how this can be dealt with already in the beginning of the design phase. There is a need for more flexible methods to define system specifications, which should be self-adjusting to changing assumptions. There is the question of how such systems can be configured? Therefore, methods must be established for constructing autonomous and self-adapting systems which fulfil reliability as well as safety and security aspects. Another issue is to proof if a software is working properly.

- A big challenge is to assure the security of the overall system. This will be more and more problematic due to the increasing connection of things with each other. Some studies predict that in 2020 50B of devices are connected worldwide. Here the question is who will pay the increasing effort for keeping the systems secure? The control of the complexity – it means interoperability in a scale of 10^6 or even 10^7 – will be a major challenge already in the near future.
- Security of trust in the systems and privacy protection in the face of interoperability/integration are also major topics. They include to ensure the quality of IT systems that are composed of manifold services across organizational and platform boundaries and to ensure the security of an assembly of services.
- Due to the enormous dynamic of end devices, mobile security will become a significant value in future designs. Cross platform developments will increasingly be important. Software development currently undergoes a switch from traditional environments towards mobile devices.
- Topics for the near future are distributed simulation development processes and simulation model description languages that help to avoid interoperability problems. Challenges are the integration of several programming languages into a system, cross-language debugging, cross-language inheritance, and multi-language concurrency models.

All this requires skilled people, toolkits and e-learning platforms that support the process of observing and maintaining interoperable states in flexible and adaptive systems.

Mid-term challenges

On mid-term level challenges arise from the increasing complexity and amounts of connected data and the problem how to make best use of it.

- The size and complexity of data and its metadata are growing rapidly. The more data are available the more we have to think about the structure of the data and methods how to connect data in an intelligent way. This means new integration systems like linked (open) data. An important role will be the development of added value services and systems with more flexibility. The synonym smart data is covering such features. An example is the combination of data that is needed to steer production lines (e.g. sensor data) with data that is needed to steer the company itself (e.g. data for the ERP system).

- One big challenge is to develop a unified concept which can handle discrete-continuous data, space-time, multi-linguality, uncertainty, limited resources, and failures.
- An important aspect is the combination and integration of structured and unstructured data. The so called „human in the loop" approach enables the interaction of humans, e.g. data analysts and application experts, in order to achieve high quality analyses.
- Interoperability on legal and organizational level: as part of overcoming organizational restrictions (changing governance structures) a framework of "trust" needs to be established. This means we need to trust our neighboring system as well as service operators, and we need to be willing to share data, services and knowledge. The aim is to identify an organizational framework where several actors and decision-makers can be in the driving seat who are willing to invest in cooperation which is the basis for interoperable solutions.
- Promising are the semantic web and Internet of Things, streaming data in real-time from large-scale heterogeneous sources and tailoring data for (real-time) decision support. Challenges are to implement practicable solutions for semantic interoperability (e.g. through linking via knowledge graphs) and big data processing (present systems have hardly been capable of handling millions of data records).
- Also in applications like geoinformatics standardization is an important topic: it is essential to implement a ruleset definition on datasets for decision support (multi-purpose use of environmental information) and further the integration of data (with the rulesets) into web processing services. The European INSPIRE Directive[67] – the Infrastructure for Spatial Information in the European Community – has set ground rules for geospatial data harmonization, sharing and access. The directive's implementation is still

[67] INSPIRE defines a number of implementing rules, data specifications for metadata, data harmonization, sharing and monitoring etc. through web services. The INSPIRE directive came into force on 15 May 2007 and will be implemented in various stages, with full implementation required by 2019 (Inspire Website).

on its way and requires further strong efforts on national, regional and local level.

- Inclusion of radically new systems that have not been part of the data and content value chain so far e.g. human brain (brain-machine direct interface), advanced semantic services and business processes to reach global interoperability at business level. Leveraging simulation model interoperability from plain technical and syntactical interoperability to semantic and conceptual interoperability will be a key feature in the next years.

Long-term challenges

It is commonly agreed that standardization is a major ingredient for interoperability. Standardization however, although necessary right now, is a time consuming process and therefore a long-term challenge which also needs to tackle the upstream harmonization of different and diverging sub-standards.

- The lack of common standards in many domains and technologies, e.g. in the field of smart grid technology, is still one of the most challenging topics. According to which specifications can/should devices or objects communicate with each other? Anyway, the fact that there has still been a huge and remaining diversity among end devices makes it not easier for establishing a common standard. The need for common ICT interfaces and common protocols is increasing. Referring to the energy sector intelligent energy management system and demand response systems are required.
- The European Union is an important player. Standardization of coding, data compression, cryptography, especially with respect to data transfer and data storage, are crucial topics on European level. There must be standards on European/international level that are independent of the big influence from the industry. E.g. web and IT security standards in IoT, automotive and manufacturing.

Interoperability is not an issue that needs to be solved at a particular time, but rather needs to develop itself further as involved systems do the same. Also, interoperability needs not only to be considered from a technical viewpoint but also from a legal and organizational perspective.

6 List of References

Active & Assisted Living Platform Austria, online: http://www.aal.at (accessed 13.03.2016).

Antsaklis, P. J., Passino, K. M., Wang, S.J., 1991. An Introduction to Autonomous Control Systems. IEEE Control Systems 11 (4): 5–13.

Austrian Standards Website, Smart Cities and Communities, online: https://www.austrian-standards.at/infopedia-themencenter/infopedia-artikel/smart-cities-and-communities/#c2569 (accessed 23.11.2015).

Behrendt, W., Güntner, G., Reich, S., 2013. Industrie 4.0 Menschen, Maschinen und Organisationen im World Wide Web.

CERT, 2015. Jahresbericht 2014.

City of Vienna, n.d. Smart City Wien. Framework Strategy, online: https://smartcity.wien.gv.at/site/files/2014/09/SmartCityWien_FrameworkStrategy_english_onepage.pdf (accessed 23.11.2015).

Digital Agenda for Europe, 2020 initiative, online: https://ec.europa.eu/digital-agenda/en/smart-cities (accessed 23.11.2015).

Drucker, W., 2015. Industrie 4.0. Der lange Weg zur Pilotfabrik. Wirtschaftsblatt vom 25.08.2015, online: http://wirtschaftsblatt.at/home/nachrichten/oesterreich/4805728/Industrie-40_Der-lange-Weg-zur-Pilotfabrik (accessed 13.10.2015).

Drucker, W., 2015a. Industrie 4.0 bleibt für österreichische Betriebe ein Fremdwort. Wirtschaftsblatt vom 10.04.2015, online: http://wirtschaftsblatt.at/home/nachrichten/oesterreich/4704603/Industrie-40-bleibt-fur-osterreichische-Betriebe-ein-Fremdwort (accessed 13.10.2015).

EuroCloud Austria Website, online: https://www.eurocloud.at/ (accessed 13.03.2016).

European Active & Assisted Living Programme, online: http://www.aal-europe.eu/about/objectives/ (accessed 23.11.2015).

European Commission, 2016. Rolling plan for ICT standardization, online: http://ec.europa.eu/newsroom/dae/document.cfm?doc_id=14510 (accessed 13.03.2016).

European Commission Website on Emerging Technologies, online: https://ec.europa.eu/programmes/horizon2020/en/h2020-section/future-and-emerging-technologies (accessed 19.11.2015).

European Commission Website on Europe 2020 initiative, online: https://ec.europa.eu/digital-agenda/en/smart-factory (accessed 23.11.2015).

European Commission Website, Smart Cities, online: https://ec.europa.eu/digital-agenda/en/smart-cities (accessed 23.11.2015).

European Commission Website, Europe 2020 targets, online: http://ec.europa.eu/europe2020/targets/eu-targets/index_en.htm (accessed 23.11.2015).

European Commission Website, The Rolling Plan on ICT Standardisation, https://ec.europa.eu/digital-single-market/en/news/rolling-plan-ict-standardisation-0

Hinchcliffe, D., 2014. Where is interoperability for social media? Published on 28.02.2014 on ZDNET, online: http://www.zdnet.com/article/where-is-interoperability-for-social-media/ (accessed 13.03.2016).

Hötzendorfer, W. et al., 2015. BEST AT Roadmap, Vertrauen rechtfertigen: sichere Systeme.

IBM WebSphere MQ information center, 2016. Coexistence, compatibility, and interoperability from 09.03.2106, online:

https://www.ibm.com/support/knowledgecenter/SSFKSJ_7.5.0/com.ibm.mq.mig.doc/q006320_.htm (accessed 12.03.2016)

IDC, 2015. Austria IT Services Market 2015–2019 Forecast and 2014 Analysis.

IDC, 2015a. Worldwide IT Cloud Services Taxonomy.

IDC, 2015b. Austria Cloud Services Market 2015–2019 Forecast and 2014 Analysis.

IDC, 2015c. Worldwide Smartphone Forecast Update, 2015–2019.

IDC, 2015d. Worldwide Big Data Taxonomy.

IDC 2015e. Worldwide Internet of Things Taxonomy.

IDC, 2015f. New Global IoT Decision Maker Survey Quantifies the IoT Opportunity, press release from 22 Sep 2015, online: http://www.idc.com/getdoc.jsp?containerId=prUS25923515 (accessed 30.11.2015).

IDC, 2015g. U.S. IoT-enabled, Home Automation “Outsourced-Managed” Services Study: Consumer Service Provider Preferences and Requirements (Part 3).

IDC, 2015h. FutureScape: Worldwide Smart City 2016 Predictions.

IDC, 2015i. Market Analysis Perspective: Worldwide Wearables.

IDC Event, 2015. Industry 4.0., online: http://www.cvent.com/events/idc-directions-industrie-4-0-2015-germany/event-summary-16282e14ec1447d18f35f1a22781026b.aspx (accessed 13.10.2015).

IDC, 2014. European Vertical Markets Survey.

IDC, 2014a. Worldwide and Regional Internet of Things (IoT) 2014–2020 Forecast: A Virtuous Circle of Proven Value and Demand.

IDC, 2014b. IDC's Worldwide Wearable Computing Devices Taxonomy.

IEC 61499 Website, online: http://www.iec61499.com/ (accessed 30.11.2015).

Inspire Website, online: http://inspire.ec.europa.eu/ (accessed 15.12.2015).

Interoperability Working Group Website, 2015, online: http://interoperability-definition.info/en/ (accessed 18.12.2015).

Internet Engineering Task Force (IETF), 2016. An Interoperable Internet of Things, posted in IETF on 14.01.2016, online: https://www.ietf.org/blog/2016/01/an-interoperable-internet-of-things/ (accessed 13.03.2016).

IoT Vienna Website, online http://www.iot-vienna.at (accessed 13.03.2016).

Joinup platform, online: https://joinup.ec.europa.eu/ (accessed 13.11.2015).

Khaitan, S.K., 2014. Design Techniques and Applications of Cyber Physical Systems: A Survey, IEEE Systems Journal.

Köhler, M., Meir-Huber, M., 2014. #Big Data in #Austria: Österreichische Potenziale und Best Practice für Big Data.

Loxone Website, online: http://www.loxone.com (accessed 12. 11. 2015).

Meir-Huber, M., n.d. Towards Cloud Computing Interoperability and Transportability for Services on the Platform as a Service Layer / Tier Master Thesis co-supervised with Prof. Dr. Gabriele Anderst-Kotsis.

Minonne, R., Vacca, A., 2015. Enhancing Digital Transformation in Europe Through Social Media Tools: A Vertical Market Perspective research analyst, IDC European Industry Solutions, online: http://www.idc.com/getdoc.jsp?containerId=DTS53X (accessed 15.11.2015).

National Instruments Website. Introduction to LIN, online: http://sine.ni.com/np/app/main/p/ap/icomm/lang/en/pg/1/sn/n17:icomm,n21:17/fmid/2837 (accessed 1.11.2015).

Open Data Portal Austria Website, online: https://www.opendataportal.at/ (accessed 13.03.2016).

Oxford Dictionary, Robotic, online: http://www.oxforddictionaries.com/definition/english/robotics#m_en_gb0714530 (accessed 23.11.2015).

Plexxi, 2013. The subtleties of Open: Interoperability vs. interchangeability, posted on 08.07.2013, online: http://www.plexxi.com/2013/07/the-subtleties-of-open-interoperability-vs-interchangeability/ (accessed 12.03.2016).

Reisinger, R., 2015. Informationssicherheit in Deutschland, Österreich und der Schweiz 2015, Diplomarbeit, FH St. Pölten.

Rotolo, D., Hicks, D., Martin, B., 2015. What is an emerging technology? SPRU Working Paper Series (ISSN 2057 – 6668), online: https://www.sussex.ac.uk/webteam/gateway/file.php?name=2015-06-swps-rotolohicksmartin.pdf&site=25 (accessed 30.11.2015).

Social Media Radar Austria Website, online: http://socialmediaradar.at/ (accessed 28.10.2015).

Sowa, J.F. 2010. Ontology, online: http://www.jfsowa.com/ontology/ (accessed 30.11.2015).

Smart City Vienna, online: https://smartcity.wien.at/site/en/ (accessed 23.11.2015).

Steinbauer, M., Khalil, I. and Anderst-Kotsis, G., 2013. Building an On- Demand Virtual Computing Market in Non-Commercial Communities, in proceedings of The 28th Symposium on Applied Computing, 2013, Coimbra, Portugal.

Sulzbacher, M., 2015. Österreich bekommt 2016 Teststrecke für selbstfahrende Autos, in derStandard vom 27.08.2015, online: http://derstandard.at/2000021354958/Oesterreich-bekommt-2016-Teststrecken-fuer-selbstfahrende-Autos (accessed 30.11.2015).

Techtarget Website. Definition of Interoperability, online: http://searchsoa.techtarget.com/definition/interoperability (accessed 12.03.2016).

University of Southern California, 1981. Transmission Control Protocol, Darpa Internet Program Protocol Specification, online: https://tools.ietf.org/html/rfc793 (accessed 01.11.2015).

Wikipedia entry for 3G, online: https://en.wikipedia.org/wiki/3G (accessed 30.11.2015).

Wikipedia entry for CAP, online: https://en.wikipedia.org/wiki/Common_Alerting_Protocol (accessed 30.11.2015).

Wikipedia entry for communications protocol, online: https://en.wikipedia.org/wiki/Communications_protocol (accessed 13.03.2016).

Wikipedia entry for computer network, online: https://en.wikipedia.org/wiki/Computer_network (accessed 13.03.2016).

Wikipedia entry for EN 13606, online: https://en.wikipedia.org/wiki/EN_13606 (accessed 30.11.2015).

Wikipedia entry for fieldbus, online: https://de.wikipedia.org/wiki/Feldbus#Normung (accessed 01.11.2015).

Wikipedia entry for interoperability, online: https://en.wikipedia.org/wiki/Interoperability (accessed 12.03.2016).

Wikipedia entry for network, online: https://en.wikipedia.org/wiki/Computer_network (accessed 12.03.2016).

Wikipedia entry for OWL, online: https://en.wikipedia.org/wiki/Web_Ontology_Language (accessed 30.11.2015).

Wikipedia entry for protocol, online: https://en.wikipedia.org/wiki/Communications_protocol (accessed 13.03.2016).

Wikipedia entry for RDF, online: https://en.wikipedia.org/wiki/Resource_Description_Framework (accessed 30.11.2015).

Wikipedia entry for robots, online: https://en.wikipedia.org/wiki/Robot (accessed 13.03.2106).

Wikipedia entry for SNOMED CT, online: https://en.wikipedia.org/wiki/SNOMED_CT (accessed 30.11.2015).

Wikipedia entry for telecommunications network, online: https://en.wikipedia.org/wiki/Telecommunications_network (accessed 12.03.2016).

7 Annex

7.1 List of Figures

7.2 List of Tables

7.3 Scientific online Survey

Interop Survey

Please also share this survey with other researchers working in the field of interoperablitiy **in Austria**.

Dear Participant

Please fill in the information and press submit.
Thank you very much in advance!

☐ correction (only use this for corrections of previous submissions)

your name:

email:

your institution:

city: post code:

Please answer these questions:

In what areas of research are you active ? (project, ...)

What topics of interoperability are actively investigated at your institution?

What are the greatest challenges in the **near future?**

What do you think are the future issues around interoperability?

Who are your national / international partners?

national

international

Online survey continued

Categorization

Please specify the technologies, domains and additional terms of your interoperability activities.
Please add items, that you are missing (in the 'other' input box).

I Technologies

- [ ] Network
  - [ ] Wireless
    - [ ] WIFI
    - [ ] Bluetooth
    - [ ] GSM
    - [ ] Infrared
    - other (please use ',' to separate multiple items)
  - [ ] Wired
    - [ ] LAN
    - [ ] USB
    - other (please use ',' to separate multiple items)
- [ ] Interface
- [ ] Protocol
  - [ ] TCP/IP
  - other (please use ',' to separate multiple items)
- [ ] Service
- [ ] Application
- [ ] Data Structure
  - [ ] XML
  - [ ] JSON
  - other (please use ',' to separate multiple items)
- [ ] Semantics
  - [ ] Ontology
  - other (please use ',' to separate multiple items)

Remarks for Technologies

Online survey continued

II Domains

Interoperability between:

- ☐ Hardware
  - ☐ Computer
  - ☐ Appliances
  - ☐ Devices
  - ☐ Machines
  - ☐ Roboters
  - ☐ Vehicles
    - ☐ Cars
    - ☐ Aircrafts
    - other (please use ',' to separate multiple items)
- ☐ Software
  - ☐ Programs
  - ☐ Software Agents
  - other (please use ',' to separate multiple items)
- ☐ Persons
- ☐ Organizations
  - ☐ Utility companies
  - other (please use ',' to separate multiple items)

Remarks for Domains

III Additional Terms

- ☐ V2I Vehicle to Infrastructure, V2V Vehicle to Vehicle, V2X both
- ☐ Cloud Stack
- ☐ Service-oriented architecture (SOA)
- ☐ REST
- ☐ Smart Grids
- ☐ Micro Grids
- ☐ Home Automation
- ☐ Energy Management Systems

other (please use ',' to separate multiple items)

Remarks for Terms

General Remarks

Submit

Active areas

Survey respondents named the following activity areas: Smart grids, ICT for smart grids, power utility automation, ultra-reliable wireless communication systems, linked data, clouds, big data, cloud computing, intelligent transport systems, mobility technologies, crowdfunding, crowdsourcing, crowdbusiness, innovation management, multimedia analysis, multimedia metadata, digital preservation, patient empowerment, health literacy, digital media, technologies in health care, networked embedded systems, industrial automation, building automation, information retrieval, machine learning, network analytics, agricultural engineering, solar energy, identity management, IT security, model-based quality management with a focus on inter-organizational systems, security engineering, spatial/georeferenced data, harmonization of soil datasets across Europe, harmonization of nature conservation datasets across Europe, enterprise interoperability, (inter-organizational) business processes, information systems for medical research, education and process modelling/management, semantic web, semantic web services, semantic technology, smart data, data and content economy, application of semantics in energy efficiency, mobile communications, tourism, media, parallel and distributed simulation; interoperability of simulation models, performance analysis of computer systems, energy, smart metering, smart home, cross-language interoperability between programming languages, memory-safe execution of C code, compiler and virtual machine construction, enterprise interoperability, simulation based design and optimization of production systems, manufacturing research.

Research topics

Survey respondents named the following research topics: Interoperability of distributed energy resources (DER), remote control, SCADA integration, wireless communication systems and automation and control algorithms for autonomous driving or flexible production environments, model driven, scalable, semi-automatic interoperability of mobility systems, customer oriented production, integration of customers in production processes, metadata for multimedia preservation and archiving, visual content description, automation systems integration, data synchronization and exchange (interoperability on technical and semantic level), linked data, interoperability between agricultural machines, interoperability of European eID, electronic documents, cross-border services, security aspects of interoperability, integration testing, geospatial data and services interoperability, real-time monitoring data into a sensor observation service with data formats observations and measurements, data quality and interoperability, semantic data transformation, evolution of information systems and interoperability, privacy and anonymization, interoperability from the viewpoint of complex adaptive systems/systems, theory/systems-of-systems, interoperability with respect to evolutionary development and emergent behavior, research and development to bring information and communication technologies of the future into today's world, applying semantics to make the content interoperable, interoperability of simulation models, smart home and smart grid, different areas of compiler and virtual machine construction, enterprise interoperability.

7.4 Expert Interview Questionnaire

Datum: xx-xx-2015, Ort: Telefon

Teilnehmer:

- In welchen Forschungsgebieten sind Sie aktiv?! (Projekt, …)
  ➔ …

  Laufende bzw. abgeschlossene Projekte:

  ➔ …
- Welche Schwerpunkte sehen Sie an ihrer Universität im Gebiet Interoperabilität?
  ➔ …
- Was sind ihrer Meinung nach Zukunftsthemen rundum Interoperabilität?
  ➔ …
- Was sind die größten Herausforderungen in der nahen Zukunft?
  ➔ …
- Wer sind ihre nationalen/internationalen Kooperationspartner?
  ➔ Nationale:
    - …

  ➔ International:
    - …
- Kategorisierung

- In welchen Gebieten sind Sie aktiv (bitte um Ergänzung falls Ihnen etwas fehlt)

I Technologies

- Network
  - Wireless
    - WLAN
    - Bluetooth
    - GSM
    - Infrared
  - Wired
    - LAN
    - USB
    - …
- Interface
- Protocol
  - TCP/IP
  - ...
- Service
- Application
- Data Structure
  - XML
  - JSON
  - ...
- Semantics
  - Ontology
  - ...

II Domains

Interoperability between:

- Hardware
  - Computers
  - Devices
  - Machines
  - Roboters
  - Vehicles
    - Cars
    - Aircrafts
    - …
- Software
  - Programs
  - Software Agents
- Persons

- Organizations

III Additional Terms

V2I: Vehicle to Infrastructure, V2V: Vehicle to Vehicle, V2X: both
Cloud Stack
Service-oriented architecture
…

7.5 Online Business Survey

The online survey „Interoperability of Systems in Austria“ was conducted in October 2015 and targeted companies in different industries, their CIOs and IT managers in Austria. In total 158 respondents completed the questionnaire. Language was German.

Interoperabilität: Potenzial und Herausforderungen für die Zusammenarbeit von Systemen in der IT

Als Interoperabilität bezeichnet man die Fähigkeit zur Zusammenarbeit von verschiedenen Systemen, Techniken oder Organisationen. Dazu ist in der Regel die Einhaltung gemeinsamer Standards notwendig. Dadurch sollen Informationen auf effiziente und verwertbare Art und Weise austauschbar bzw. für den Benutzer verfügbar werden, ohne dass dazu gesonderte Absprachen zwischen den Systemen notwendig sind.

Wie wichtig sind Interoperabilität und die Einhaltung von Standards in Ihrem Unternehmen? (1 – 10; 10=hoch)

Für Hardware
für Software
für Services

Achten Sie bei Angeboten auf Interoperabilität und Standards? (ja/nein)

Für Hardware
für Software
für Services

Würden Sie bei gleichen Kosten Angebote vorziehen, wenn diese Interoperabilität und Standards besser unterstützen? (ja/nein)

Für Hardware
für Software
für Services

Empfehlen Sie Ihren Kunden und Partnern Standards einzusetzen? (ja/nein)

Für Hardware
für Software
für Services

Haben Sie derzeit Probleme mit proprietärer Software/Hardware oder Services, welche durch bessere Standardunterstützung nicht entstanden wären? (ja/nein)

Für Hardware
für Software
für Services

Bei welchen Technologien sehen Sie Defizite hinsichtlich Interoperabilität und Standards?

- Archivierung
- Business Intelligence
- Cloud Computing
- Content & Document Management
- CRM
- ERP / SAP
- Outsourcing
- Enterprise Social Network
- Security
- M2M
- SaaS
- Unified Communications
- Virtualisierung
- Big Data
- Mobile Lösungen
- Workflow Lösungen
- Internet of Things
- Social Media
- Smart Energy/Grids
- Smart Homes/Active Assisted Living
- Automotive

- Health
- Anderes:..................

Was müsste passieren, um Interoperabilität und Standards voranzutreiben?

- 1. ....
- 2. ....
- 3. ....

Wie bedeutend sind die folgenden Aspekte, um Interoperabilität in Ihrem Unternehmen voranzutreiben? (1 – 10; 10=hoch)

- Technologien
- Standards
- Prozesse
- Strategien
- Management

Was sind für Ihr Unternehmen die größten Herausforderungen in der nahen Zukunft im Bereich Interoperabilität?

- 1...
- 2. ....
- 3. ....

Worin sehen Sie für Ihr Unternehmen die größten Potentiale in der nahen Zukunft im Bereich Interoperabilität?

- 1. ....
- 2. ....
- 3. ....

7.6 Stakeholder Workshop

The InterFuture workshop took place on November, 30 2015 in Vienna with around 20 participants. Below is the invitation to the workshop including the workshop agenda. The workshop started with impulse statements from the project consortium. Project partners provided a short introduction to the project, an overview on technologies for interoperability as well as emerging technologies, the presentation of the highlights of the study on the research landscape on interoperability in Austria as well as the presentation of the key results of the market study on the role of interoperability in Austrian enterprises. The second part of the workshop emphasized on the involvement of experts through round table discussions on two different topics. The first round table focused on research related questions and technologies for interoperability. The second round table had emerging technologies and business aspects in the centre of its discussion. The round tables were organized in a way that all workshop participants had the chance to join each of the round tables. A final roll-up session summarized the key results of each discussion. Participants had a great variety of professional background, including sociology, economy, IT, etc., and came from the private, public, non-profit and research sector. Active contributors to the workshop were for example representatives from companies such as ATOS, Wiener Netze, from the research sector such as TU Wien, AIT, Joanneum Research, the Bundesrechenzentrum and Austrian Standards, etc. The interdisciplinary group absolutely reflected the interdisciplinary topic of interoperability.

Wir laden Sie herzlichst zu unserem

Experten Workshop zum Thema Interoperabilität

am Montag, den 30. November 2015, von 15-18 Uhr,
in den Räumlichkeiten der OCG ein.

Vorläufige Agenda:

15:00 – 15:15	Einführung in das Projekt
15:15 – 15:25	Technologien für Interoperabilität
15:25 – 15:40	Emerging Technologies
15:40 – 15:55	Forschungslandschaft zu Interoperabilität
15:55 – 16:10	Wirtschaftliche Auswirkungen und Bedeutung von Interoperabilität
16:10 – 17:10	3 Diskussionen (Dauer jeweils 20 Minuten) in 4 Gruppen *(20 Minuten Pause nach der zweiten Diskussionsrunde)*
17:30 – 18:00	Zusammenfassung der Ergebnisse

Die vier Diskussionsgruppen beschäftigen sich mit folgenden Fragestellungen:

Gruppe 1: Interop-Technologien. Validierung der Technologien, wo Interoperabilität eine Rolle spielt. Auffinden von weiteren Technologien sowie Forschungsschwerpunkten für Österreich

Gruppe 2: Emerging Technologies: Validierung der Ergebnisse; Auffinden von weiteren Technologien und Forschungsanreize in Österreich

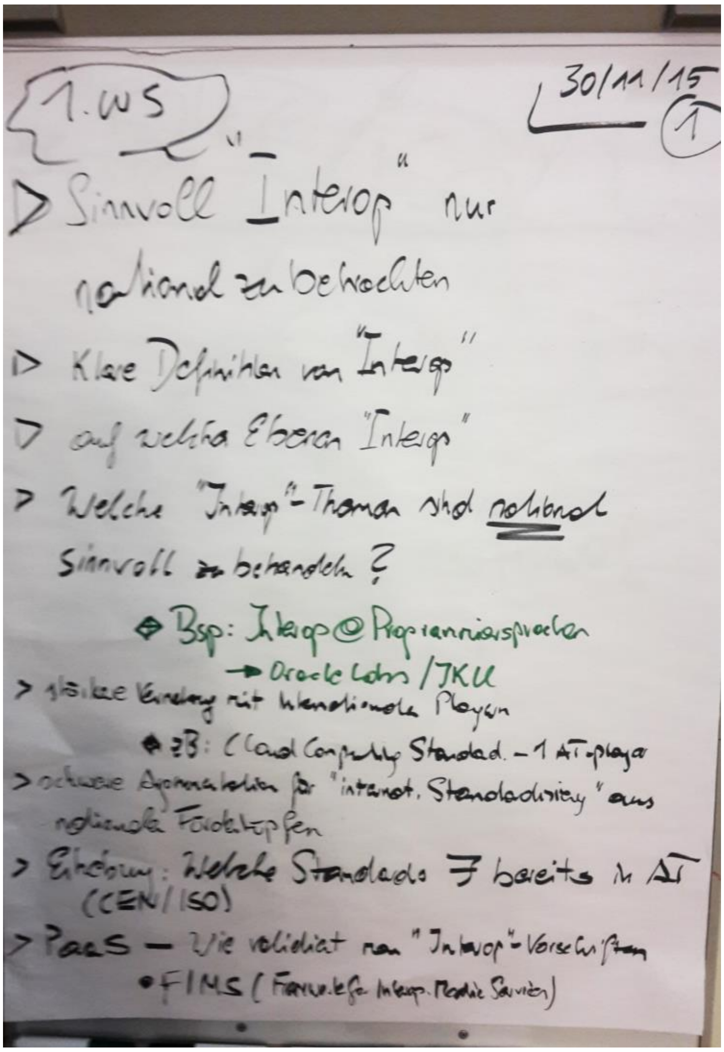
Gruppe 3: Forschungslandschaft in Österreich: Auffinden von Forschungs-Gaps und weiteren Möglichkeiten in diesem Umfang. Welche Forschungsanreize müssen geschaffen werden?

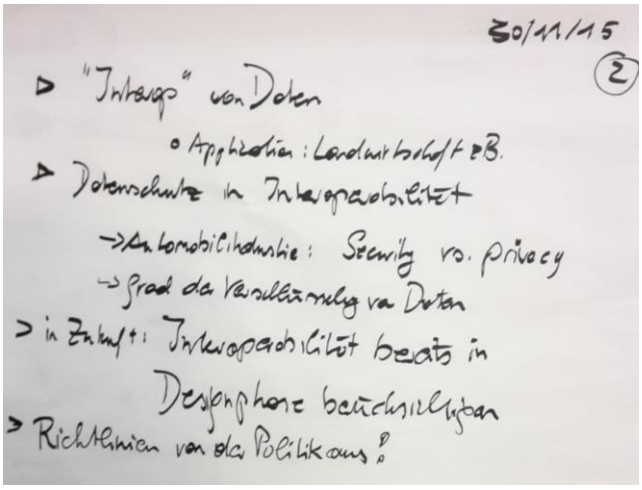
Gruppe 4: Wirtschaftliche Bedeutung von Standards, Interoperabilität und Open Source. Diskussion von weiteren Möglichkeiten und Forschungsschwerpunkten

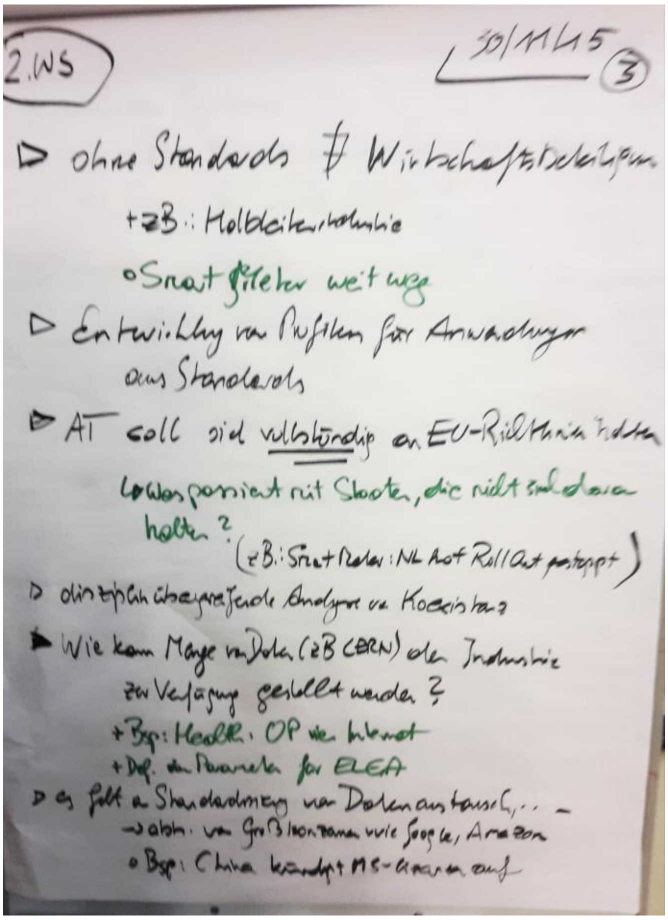
Wir freuen uns auf Ihr Kommen!

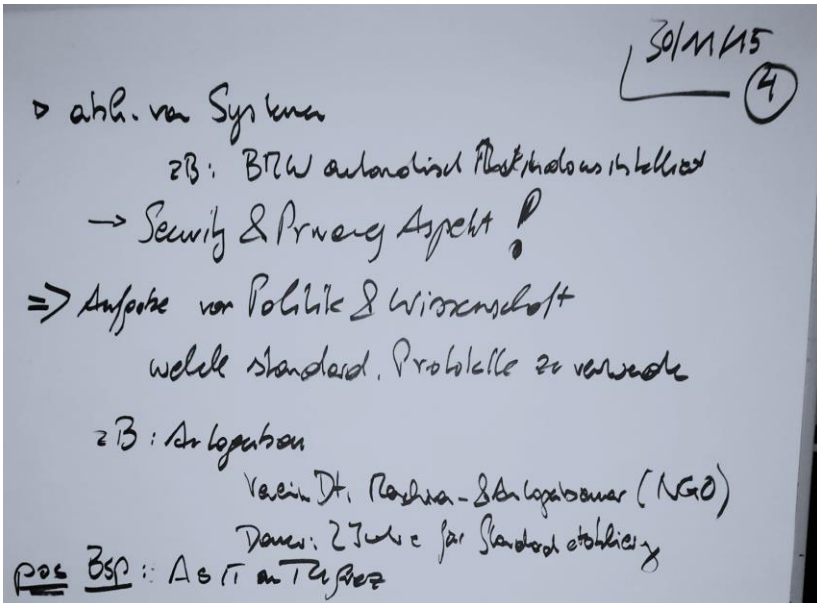
Veranstaltungsort
Österreichische Computer Gesellschaft
Wollzeile 1, 1010 Wien

Anmeldung bitte bis spätestens 23. November unter *www.ocg.at/ws-interoperabilitaet*


1. WS
30/11/15
1
Sinnvoll "Interop" nur
national zu betrachten
Klare Definition von "Interop"
auf welchen Ebenen "Interop"
Welche "Interop"-Themen sind national
sinnvoll zu behandeln?
Bsp: Interop @ Programmiersprachen
→ Oracle Labs / JKU
stärkere Vernetzung mit internationalen Playern
zB: Cloud Computing Standard. – 1 AT-player
schwere Argumentation für "internat. Standardisierung" aus
nationalen Fördertöpfen
Erhebung: Welche Standards ∃ bereits in AT
(CEN/ISO)
PaaS – Wie validiert man "Interop"-Vorschriften
FIMS (Framework for Interop. Media Services)


30/11/15
2
"Interop" von Daten
Applikation: Landwirtschaft zB.
Datenschutz in Interoperabilität
→ Automobilindustrie: Security vs. privacy
→ Grad der Verschlüsselung von Daten
in Zukunft: Interoperabilität bereits in
Designphase berücksichtigen
Richtlinien von der Politik aus?





The pictures above show the whiteboards that were used in the workshop to summarize the key results of the round tables. These results are integrated in various parts of this report.

7.7 Technologies relevant for Interoperability from Chapter 2 and some example representatives

7.7.1 Network

7.7.1.1 Wireless

IEEE 802.11, WLAN

A set of specifications for implementing wireless local area network (WLAN) computer communication. Also known as Wi-Fi.

IEEE 802.11p

An approved amendment to the IEEE 802.11 standard to add wireless access in vehicular environments (WAVE), a vehicular communication system. It defines enhancements to 802.11 required to support Intelligent Transportation Systems (ITS) applications. This includes data exchange between high-speed vehicles and between the vehicles and the roadside infrastructure.

Bluetooth

Bluetooth is a wireless technology standard for exchanging data over short distances from fixed and mobile devices and building personal area networks (PANs).

GSM (Global System for Mobile Communications)

Default global standard for mobile communications.

Mobile Internet

Mobile Internet technologies are of special significance for interoperability both as an example for various successful interoperability use cases and as a possible connection layer. A new generation of mobile standards has appeared approximately every ten years since the first introduction of 1G systems around 1981. Each generation is characterized by new frequency bands, higher data rates and non–backward-compatible transmission technology[68].

- **3G**: 3G networks support services that provide an information transfer rate of at least 200 kbit/s. Members of this standard generation are: Universal Mobile Telecommunications System UMTS, High Speed Packet Access HSPA, Long-term Evolution (LTE), WIMAX.
- **4G:** According to the International Telecommunication Union (ITU), a 4G network requires a mobile device to be able to exchange data at 100

[68] Wikipedia on 3G.

Mbit/sec. LTE-Advanced, a major enhancement of the Long-term Evolution (LTE) standard. It was formally submitted as a candidate 4G system to ITU-T in 2009.

- **5G:** 5G operates with a 5Ghz signal and will offer speeds of up to 1 Gb/s for tens of connections or tens of Mb/s for tens of thousands of connections. Planned launch is ca. 2020.

IrDA (Infrared Data Association Standard)

A standard for communication between devices (such as computers, PDAs and mobile phones) over short distances using infrared signals. Needs a direct line of sight between sender and receiver. This characteristic is seen as an advantage by some from a security standpoint, because the signal cannot be intercepted as easily as Bluetooth or Wi-Fi.

IEEE 802.15.4

IEEE 802.15.4 is a standard which specifies the physical layer and media access control for low-rate wireless personal area networks (LR-WPANs).

ZigBee

Based on IEEE 802.15.4, ZigBee is a specification for a suite of high-level communication protocols used to create personal area networks built from small, low-power digital radios. ZigBee is based on an IEEE 802.15.4 standard. Though its low power consumption limits transmission distances to 10–100 meters line-of-sight.

6LoWPAN

Based on IEEE 802.15.4, providing Internet connectivity at lower data rates for small, low power devices. 6LoWPAN is an acronym of IPv6 over Low power Wireless Personal Area Networks and also the name of a working group within the Internet Engineering Task Force (IETF).

ANT

A proprietary (but open access) multicast wireless sensor network technology to form wireless personal area networks (PANs). It is conceptually similar to Bluetooth low energy, but is oriented towards usage with sensors. ANT is primarily incorporated into sports and fitness sensors (heart rate monitors, watches, cycling power meters, cadence meters, and distance and speed monitors, etc.), but it may additionally be used for other purposes.

Ethernet (TCP/IP)

Also known as the “Internet protocol suite”, TCP/IP is the computer networking model and set of communications protocols used on the Internet and similar computer networks. TCP/IP stands for “Transmission Control Protocol / Internet Protocol”.

7.7.1.2 Wired networks

Fieldbus, IEC 61158[69]

Fieldbus is the name of a family of industrial computer network protocols used for real-time distributed control.

- **Controller area network (CAN bus):** A vehicle bus standard designed to allow microcontrollers and devices to communicate with each other in applications without a host computer. CAN is a message-based protocol, designed at first for multiplex electrical wiring within cars, but is also used in many other situations.
- **TTP/A:** A time-triggered real-time fieldbus protocol, provides a low-speed (below 1 MB/s), low-cost protocol suitable for non-critical applications like car body electronics (SAE class A).
- **LIN Bus:** See Local Interconnect Network under protocols.

Universal Serial Bus USB

An industry standard that defines the cables, connectors and communications protocols used in a bus for connection, communication, and power supply between computers and electronic devices.

7.7.2 Interface

7.7.3 Protocol

OPC Unified Architecture (OPC UA)

An industrial Machine2Machine (M2M) communication protocol for interoperability.

LIN (Local Interconnect Network)

A serial network protocol used for communication between components in vehicles. The Local Interconnect Network (LIN) bus was developed to create a standard for low-cost, low-end multiplexed communication in automotive networks. Though the Controller Area Network (CAN) bus addresses the need for high-bandwidth and

[69] Wikipedia entry for Fieldbus.

advanced error-handling networks, the hardware and software costs of CAN implementation have become prohibitive for lower performance devices such as power window and seat controllers. LIN provides cost-efficient communication in applications where the bandwidth and versatility of CAN are not required. You can implement LIN relatively inexpensively using the standard serial universal asynchronous receiver/transmitter (UART) embedded into most modern low-cost 8-bit microcontrollers."[70] We can conclude, that while CAN is technologically more advanced, LIN is cheaper and can be used where CAN would be too expensive.

Health Level-7 (HL7)

Health Level-7 or HL7 refers to a set of international standards for transfer of clinical and administrative data between software applications used by various healthcare providers. These standards focus on the application layer, which is "layer 7" in the Open Systems Interconnection (OSI) model. HL7 specifies a number of flexible standards, guidelines, and methodologies by which various healthcare systems can communicate with each other.

OpenID

Is an open standard and decentralized protocol by the non-profit OpenID Foundation that allows users to be authenticated by certain co-operating sites (known as Relying Parties or RP) using a third party service. This eliminates the need for webmasters to provide their own ad hoc systems and allowing users to consolidate their digital identities. In other words, users can log into multiple unrelated websites without having to register with their information over and over again.

Common Alerting Protocol (CAP)[71]

An XML-based data format for exchanging public warnings and emergencies between alerting technologies. CAP allows a warning message to be consistently disseminated simultaneously over many warning systems to many applications. CAP increases warning effectiveness and simplifies the task of activating a warning for responsible officials.

IEC 61850

A standard is a set of open communication protocols commonly used in electrical utilities. Supervisory control and data acquisition (SCADA) systems use IEC 61850

70 National Instruments website.

71 Wikipedia entry for CAP.

to communicate between a master station, remote terminal units, and intelligent electronic devices.

Modbus

An open protocol that has become a standard communications protocol in industry, and is now the most commonly available means of connecting industrial electronic devices. Modbus is typically used to transmit signals from instrumentation and control devices back to a main controller or data gathering system, for example a system that measures temperature and humidity and communicates the results to a computer. Modbus is often used to connect a supervisory computer with a remote terminal unit (RTU) in supervisory control and data acquisition (SCADA) systems. Versions of the Modbus protocol exist for serial lines (Modbus RTU and Modbus ASCII) and for Ethernet (Modbus TCP).

7.7.4 Service

7.7.5 Application

7.7.6 Data Structure

XML

(EXtensible Markup Language) is a widely used format for data, introduced by the W3C in 1998. Hierarchical data can be represented in a structured form. It is a human-readable as well as a machine-readable format. Since its introduction XML was quickly adopted as a technology for program intercommunication.

- **Security Assertion Markup Language SAML:** An XML-based, open-standard data format for exchanging authentication and authorization data between parties, in particular, between an identity provider and a service provider.
- **Resource Description Framework (RDF)[72]:** A family of World Wide Web Consortium (W3C) specifications originally designed as a metadata data model. It has come to be used as a general method for conceptual description or modelling of information that is implemented in web resources, using a variety of syntax notations and data serialization formats. It is also used in knowledge management applications.

[72] Wikipedia entry for RDF.

JSON

JavaScript Object Notation (JSON) is an open standard format that uses human-readable text to transmit data objects consisting of attribute-value pairs. Although originally derived from the JavaScript scripting language, JSON is a language-independent data format. Code for parsing and generating JSON data is readily available in many programming languages. JSON is quickly replacing XML because it has all the advantages of XML but is more lightweight.

- **JSON-LD:** A set of W3C standards track specifications for representing Linked Data in JSON. It is fully compatible with the RDF data model, but allows developers to work with data entirely within JSON.

Industry Foundation Classes (IFC), ISO 16739:2013

A data model to describe building and construction industry data. It is a platform neutral, open file format specification that is not controlled by a single vendor or group of vendors. It is an object-based file format to facilitate interoperability in the architecture, engineering and construction (AEC) industry, and is a commonly used collaboration format in building information modelling (BIM) based projects.

7.7.7 Semantics

SNOMED CT[73]

SNOMED CT (Clinical Terms) is a systematically organized computer processable collection of medical terms providing codes, terms, synonyms and definitions used in clinical documentation and reporting. SNOMED CT is considered to be the most comprehensive, multilingual clinical healthcare terminology in the world. The primary purpose of SNOMED CT is to encode the meanings that are used in health information and to support the effective clinical recording of data with the aim of improving patient care. SNOMED CT provides the core general terminology for electronic health records. SNOMED CT comprehensive coverage includes: clinical findings, symptoms, diagnoses, procedures, body structures, organisms and other etiologies, substances, pharmaceuticals, devices and specimens.

Web Ontology Language (OWL)[74]

A family of knowledge representation languages for authoring ontologies. Ontologies are a formal way to describe taxonomies and classification networks,

[73] Wikipedia entry for SNOMED CT.
[74] Wikipedia entry for OWL.

essentially defining the structure of knowledge for various domains: the nouns representing classes of objects and the verbs representing relations between the objects. Ontologies resemble class hierarchies in object-oriented programming but there are several critical differences.

7.7.8 Standards

A few examples for standards related to interoperability:

- **ISO/IEEE 11073:** The ISO/IEEE 11073 Medical / Health Device Communication Standards are a family of ISO, IEEE, and CEN joint standards addressing the interoperability of medical devices. The ISO/IEEE 11073 standard family defines parts of a system, with which it is possible to exchange and evaluate vital signs data between different medical devices as well as remotely control these devices.
- **Electronic Health Record Communication, EN 13606, Europ. Standard[75]:** The goal of this standard is to define a rigorous and stable information architecture for communicating part or all of the Electronic Health Record (EHR) of a single subject of care (patient). This is to support the interoperability of systems and components that need to communicate (access, transfer, add or modify) EHR data via electronic messages or as distributed objects.
- **openEHR:** An open standard specification in health informatics that describes the management and storage, retrieval and exchange of health data in electronic health records (EHRs). The openEHR specifications include an EHR extract specification but are otherwise not primarily concerned with the exchange of data between EHR-systems as this is the focus of other standards such as EN 13606 and HL7.
- **IEC61499[76]:** The IEC61499 architecture represents a component solution for distributed industrial automation systems aiming at portability, reusability, interoperability, reconfiguration of distributed applications. The IEC 61499 standard provides a generic model for distributed systems. This model includes processes and communication networks as an environment for embedded devices, resources and applications. Applications are built by networks of function blocks.

[75] Wikipedia entry for EN 13606.
[76] IEC 61499 Website.