Description of Services and of Information and Communication Service Infrastructures

Prof. Dr. Herbert Weber
hweber@innovaberatung.com
hweber@cs.tu-berlin.de
Berlin, October 2014
Description of Services and of Information and Communication Service Infrastructures

Author:
Prof. Dr. Herbert Weber
INNOVA Beratungsgesellschaft mbH
Schopenhauerstrasse 47
14129 Berlin
Germany

Date:
October 2014
The following compendium of documents represents the introduction of a Description Methodology for what we call now Information and Communication Service Infrastructures. The descriptions, called profiles, are meant to be understood by professionals and nonprofessionals interested in the use and development of infrastructures. The description methodology, therefore, provides for coarse grain descriptions – primarily aiming at their suitability to non-ICT professionals – up to fine grain technical descriptions – primarily aiming at their suitability to ICT professionals within the same description framework.

Since the terms IT Infrastructures, ICT Infrastructures, Information and Communication Infrastructures have been overloaded in their day-to-day use with many different meanings, the introduction of the Profiling Methodology is started with an explanation what is meant by the different terms in the context of the explanation of the Profiling Methodology.

The Profiling Methodology was developed within the framework of the “Future Internet Public-Private Partnerships” supported by the European Union in the INFINITY Project (Contract Number 285192). It was used as an input to the development of a “Common Description Framework” when the methodology only existed in a rudimentary form at the beginning of the project.

At later stages of its development the Profiling Methodology gained attention in discussions with operators of large IT Infrastructures in enterprises and other organizations. For the lack of proper documentations for their installations the Profiling Methodology was considered an affordable means to retrospectively document their ICT Infrastructures and to use this documentation as a technical base for their maintenance and continuous development activities.

Along the same line discussions about the proper sourcing of Information and Communication Technologies and even more of ICT Services offered to an increasing extent on Service Marketplaces, the Profiling Methodology is seen as a means to evaluate offers to enable the discovery of side effects between existing and newly acquired components or of incompatibilities between existing and newly acquired components of the respective ICT Infrastructures.

The compendium encompasses different documents for different purposes:

I. A technical report introducing the Profiling Methodology.
II. A set of PowerPoint presentations used to explain the Profiling Methodology on different levels of detail (Attachment 1).
III. A set of PowerPoint presentations on a so-called “Conceptual Reference Framework for the Future Internet” as a sample abstract and coarse profile based on its description in terms of capabilities – a concept introduced in the methodology (Attachment 2).
IV. A taxonomy of terms used in the description of the Conceptual Reference Framework for the Future Internet to denote capabilities (Attachment 3).

The compendium is now published outside of the Future Internet Public-Private Partnership Community and beyond the INFINITY Project to receive feedback that would help to evaluate the Profiling Methodology.
Description of Services and of Information and Communication Service Infrastructures

Prof. Dr. Herbert Weber
hweber@innovaberatung.com
hweber@cs.tu-berlin.de
Berlin, October 2014
The subsequently provided monograph is a corrected and extended version of Task T3.2, Deliverables, “Methodologies for Infrastructure Profiling” of the Project “INFINITY – INfrastructures for the Future Internet CommuUNITY as part of the Future Internet Public-Private Partnership Contract Number 285192 of the European Community.

The Infinity Project
Infrastructures for the Future Internet Community
FI-PPP

Contract Number 285192

Partners in INFINITY
Table of Contents

Preface to the INFINITY Task T3.2, Deliverables, “Methodologies for Infrastructure Profiling” 5

1 Introduction 7

2 What is an Information and Communication Infrastructure and what is an Information and Communication Service Infrastructure? 11
2.1 Classification of Information and Communication Infrastructures 12
2.2 Actionable Artifacts as the Computing Model of Information and Communication Service Infrastructures 19

3 A Reference Schema for the Characterization of Information and Communication Service Infrastructures and Actionable Artifacts 24
3.1 Characterization of Infrastructures along the Virtualization Dimension 25
3.2 Characterization of Infrastructures along the Granularity Dimension 27
3.3 Characterization of Infrastructures Along the Virtualization and Granularity Dimension 29
3.4 Characterization of Infrastructures Along the Abstraction Dimension 31
3.5 Sample Classes of Actionable Artifacts 33

4 Profiling of Information and Communication Service Infrastructures and Actionable Artifacts 37
4.1 Functional View at Information and Communication Service Infrastructures and Actionable Artifacts 40
4.2 Profiling Methodology 47
4.2.1 Terms and Concepts 47
4.2.2 Infrastructure-Driven Refinements of Terms and Concepts 57
4.2.3 Architecture-Driven Refinements of Terms and Concepts 62
4.2.4 Service-driven Refinements of Terms and Concepts 66
4.2.5 Rules of Conduct 72

5 Elements of the Extendable Profile Description Language 74
5.1 Description of Profiles of Information and Communication Service Infrastructures and of Actionable Artifacts in Terms of Capabilities 75
5.1.1 Architectural Classification of Capabilities 83
5.1.2 Capability Description 87
5.2 Actions of Information and Communication Service Infrastructures and of Actionable Artifacts 89
5.2.1 Actions of Actionable Artifacts 91
5.2.2 Composition and Decomposition of Actions 91
5.2.3 Common Actionable Artifacts, Common Capabilities and Common Actions 94
5.3 Action Attributes 95
5.3.1 Attribute Relationships 96
5.3.2 Attribute Instances 100
5.3.3 Attribute Refinements 101
5.3.4 Processes and Process Hierarchies 103
6 Infrastructure Description Frameworks

7 Autonomous and Semi-Autonomous Systems as an Extended Computing Model for Information and Communication Service Infrastructures

7.1 Control Flow between Actions
7.2 Data Flow between Actions
7.3 Data Dependencies between Actions

8 Profiling Procedures

9 Conclusion

Attachments

Attached to this monograph are four PowerPoint presentations prepared for audio-visual, in-classroom explanations of their contents:

Attachment 1 Profiling of Information and Communication Service Infrastructures and their Application Environment (Parts 1-3)

Attachment 2 Conceptual Reference Framework for the Future Internet (Parts 1-4)

Attachment 3 Taxonomy of Concepts for the Future Internet of Services
Preface to the INFINITY Task T3.2, Deliverables, “Methodologies for Infrastructure Profiling”

Prior investments into the development of infrastructures in Europe funded either nationally or within the framework programs of the European Union may be exploited in the FI-PPP. They represent maybe valuable assets that can create a much greater impact than currently known. Making the capacities that they represent available to wherever there may be an interest in their use is the task of capacity building. For that purpose existing infrastructures need to be analyzed to reveal their capacities and to describe them uniformly to enable their proper understanding and to enable their reuse wherever and whenever possible.

Capacities are, in our view, of different kinds:
- Concepts: i.e., models, designs, architectures, terminologies, taxonomies, ontologies, etc.
- Data: i.e., unstructured, semi-structured or structured information, geo data, business data, health care data, etc.
- Systems: i.e., software systems, hardware systems, communication systems, etc.
- Infrastructures: i.e., communication infrastructures, information management infrastructures, service management infrastructures, etc.

Capacities may also be of different values:
- Business Value: i.e., it enables the reduction of costs for the acquisition of essential business information
- Operational Value: i.e., it enables an increase in the availability of a computing resource
- Technical Value: i.e., it enables an increase of the performance of an infrastructure or of a component

Derived Capacities:
Capacities that may be resulting from the analysis and profiling of infrastructures like
- differences and/or commonalities between infrastructures
- transfer opportunities
- standardization opportunities
- reuse opportunities
- customization opportunities
  etc.

The great variety of capacities that may be of benefit to Europe is demanding a systematics of the capacity building process and the description of capacities embedded in developed infrastructures that is formal enough to enable the correct
analysis and understanding of infrastructures and is informal enough to allow non-ICT professionals to make use of them.

The FI-PPP is not interested in capacities that may be gathered from infrastructures in the broadest possible meaning of the term but primarily from “Information and Communication Infrastructures”, and the methodology that is developed for the analysis and description of information and communication infrastructures will be called “Profiling”. For their use in INFINITY these two terms will have to be explained in detail to enable their correct and unambiguous use. This is especially important since different communities of expertise have to be addressed with the methodology. It may, in fact, be the case that the methodology will be needed to play the role of a lingua franca between these communities.
1 Introduction

Profiles and Profiling

Profiles will be a means of providing descriptions of Information and Communication Service Infrastructures in terms of a common base language. It is called “base language” since it is not really a language defined by its concrete syntax, but it rather introduces a collection of “language concepts” defining what descriptions of computing artifacts should comprise and how these descriptions should be constructed. In this sense it is also meant to be a “Common Base Language” since it should be the basis for different languages – each defined by means of its own concrete syntax. The purpose of introducing it is two-fold:

It seems to be very unlikely that a standard description language for Information and Communication Systems or Information and Communication Service Infrastructures will ever be available and universally used. But unified descriptions across numerous Building Blocks of Information and Communication (Service) Infrastructures of different origin would be required to make them available as Tradable Artifacts in open marketplaces.

The second motivation for introducing yet another language is based on observations that show that currently used description techniques like object-oriented descriptions do not adequately support the description and understanding of very high-scale computing systems by both, professionals and nonprofessionals. Any description in a modelling language like UML that extends beyond 10-15 objects and 10-15 interrelationships of different kinds are already hard to understand by experts and even more so by nonprofessionals.

The common base language will be used to define Information and Communication Service Infrastructures as compositions of their constituent Artifacts. These Artifacts are meant to be building blocks and as for physical systems like automobiles we introduce Information and Communication Service Infrastructures as hierarchic compositions of building blocks represented as “Bills of Materials”.

The common base language for the profiling of Information and Communication (Service) Infrastructures is, hence, used more to analyze and retrospectively describe computing systems or to prospectively describe them for their planning, architeciting and designing.

Descriptions of Information and Communication (Service) Infrastructures with the common base language will, in the end, be delivered as structured data that supports the proper detection of side effects between different Building Blocks and the tracing of impacts caused by changes of the Building Blocks and the interrelationships between them.
Profiling is meant to start out with simple linguistic concepts and is intended to enable their transition into solid technical specifications of the constituent Artifacts. Profiles are, hence, meant to be – for their initial stage – easily understandable and used by both, professionals and nonprofessionals. For later stages in the transition of the initial stage to subsequent stages the profiling language will get extended to incorporate engineering terms and concepts that nonprofessionals may have difficulties to understand and master. However, any description in terms of profiles at the early stages will be kept valid throughout the rest of the transition up until the formal specification of the Artifacts.

Profiles are hence developed in an outside-in fashion starting with the from “outside” observable characteristics of Information and Communication Service Infrastructures and they will be successfully refined to capture their internal workings. This corresponds to the “profiling” of automobiles by looking at their bodies and their functioning with steering wheels, brakes, interior designs before looking at their electronic supports like ABS or by looking “under the hood”.

Based on these rules of conduct profiles will start out as “light-weight” technical descriptions and will end up as “heavy-weight” engineering-driven descriptions that possess the necessary degree of formality to express engineering requirements posed onto Information and Communication Technology Artifacts to enable their reliable implementation and evaluation.

Information and Communication Service Infrastructures

We look at infrastructures as “Shared Resources” that provide on-demand societal, economic or technical “services” to its communities of users. In many cases infrastructures are societal, economic and technical artifacts at the same time since they do have a societal, an economic and a technical function and existence and, hence, require the simultaneous analysis of all three aspects for their full understanding. This obviously leads to the need to look at and to understand a great variety of Building Blocks of infrastructures and it requests for a multidisciplinary effort for their full understanding and documentation. To still enable a “common understanding” will not be possible without the ability to uniformly describe them. This will be achieved with the introduction of a unifying computing model for all kinds of Building Blocks of Information and Communication Service Infrastructures called “Actionable Artifacts”.

This monograph starts with a characterization of Information and Communication Technology Artifacts of concern: It distinguishes Information and Communication Infrastructures (frequently called Corporate Information and Communication Infrastructures) from Information and Communication Service Infrastructures. This part of the monograph, hence, reflects on the paradigm shift taking place in the use of Information and Communication Technologies towards the use of services provided by Information and Communication Technology Infrastructures.
For the great variety of infrastructures in place in modern societies the monograph presents later on a schema for their categorization and classification based on their characterization along a number of dimensions. These dimensions will later on in the monograph be used to also introduce different categories and classes of profiles used to describe Information and Communication Service Infrastructures for different stakeholders.

The Profiling Language

Subsequently, the monograph introduces the linguistic concepts used to describe Information and Communication Service Infrastructures: Terms and Concepts. These two notions have been heavily debated in the area of knowledge representation and information modelling. Terms are meant to be words in spoken and commonly understood (natural) languages. They do represent abstract or concrete things addressed in descriptions and conversations. Terms may not just be single words but combinations of words in accordance with given particular combination prescriptions.

Whereas terms “denote” abstract or concrete things, the concept behind a term is meant to refer to the meaning of the term, i.e., its semantics. Both concepts are needed to cope with the ambiguities of natural languages. The monograph will show how terms and concepts may serve to nonambiguously describe Information and Communication Service Infrastructures in a pragmatic fashion up to the point of the respective clarity and precision.

Based on “terms” and “concepts” as the basis for the description of Information and Communication (Service) Infrastructures, the monograph then introduces a Profile Description Language. The language is meant to be in conformance with the Actionable Artifact-based computing model and will, therefore, restrict the use of terms and concepts to denote functions an infrastructure is able to perform. This functional view at Information and Communication Service Infrastructures introduces “Services” and “Platforms” as their “Functional Building Blocks”, and terms and concepts will only be used to denote different services and different platforms.

The monograph then introduces a number of language elements for pragmatic reasons: Instead of demanding a complete description of a service or a platform as required to correspond to the Actionable Artifact computing model, the language also allows their partial description in terms of “Capabilities”. They are meant to only name services and/or platforms and do not specify anything about their characteristics. With them nonprofessionals should be enabled to express their intuitive understanding of the function of a service or platform that may subsequently be completed to their full description with the aid of a professional.

Finally, the Profile Description Language will be defined with the “Action Model” of the language that provides a visual representation of the language definition as it is
assumed that formal definitions of languages by means of a grammar and a semantic denotation are not the common ground for the different stakeholders interested in profiles as descriptions of Information and Communication Service Infrastructures.

Profiling and profiles as introduced below to describe Information and Communication Service Infrastructures are meant to be employed in different tasks: They may be employed to “retrospectively” develop a documentation for an existing Information and Communication Service Infrastructure or they may be used to successively develop a requirements specification for a new development in an incremental fashion with the advantage of enabling the tracing of impacts resulting from changes of prior specifications for the rest of the specification. It is hence a basis for continuous revisions and refinements and for their impact management.

In the end, profiles are descriptions of Information and Communication Service Infrastructures that aid in their continuous adjustments and for their continuous (re)engineering to meet new demands and requirements. Profiles may be seen as a “knowledge base” that may be used at all stages during the existence of an Information and Communication Service Infrastructure. In order to serve in that capacity, profiles can be represented as “structured data” in a conventional database that offers intelligent query and evaluation capabilities to act as an engineering tool to enable the reliable operation of Information and Communication Service Infrastructures.

The profiling methodology is – in conclusion – meant to fill in a gap existing between mostly used natural language descriptions and (semi-) formal methods used to characterize computing artifacts. It represents a retreat to simplicity for the sake of uniformity and wide acceptance.
2 What is an Information and Communication Infrastructure and what is an Information and Communication Service Infrastructure?

The term “infrastructure” is used in quite a number of communities and not necessarily with the same meaning: Even in the IT communities some of them do think primarily of computer communication (network) infrastructures, others think of (distributed) information management infrastructures, and yet some others think of enterprise ICT infrastructures etc. The meaning of the term is broad enough to enable the denotation of many different kinds of infrastructures.

Information and communication technology developments have led to the creation of quite a number of different artifacts named, for instance, as information and communication systems, hardware/software components, applications, services etc. The term information and communication infrastructure is used next to names like “information and communication technology infrastructure”, “service infrastructure” or “application infrastructure”.

“IT Infrastructures”, “ICT Infrastructures” or “Information and Communication Infrastructures” are used in this monograph as the collective names of all hardware and software constituents of an electronic computing environment of an enterprise or of any other type of organization.

In order to understand the common sense of the term “infrastructure” we make use of a very general definition of the term in the Merriam Webster’s dictionary:

“The system of public works of a state, country or region; the resources (as personnel, buildings or equipment) required for an activity.”

By interpreting this definition, we conclude that an infrastructure is (I) public or “open” to be used by an extended community of users like “company”, “state”, “country”, “region”; (II) is required to support activities (of its users) and is (III) built to be a “system”.

Following this definition we further characterize Information and Communication Infrastructures as follows:

- Infrastructures will have been built with a particular objective and their use will be of value to the users.
- Infrastructures serve a community of users and members of the community of users will share the infrastructures as a common resource.
- Infrastructures will be able to handle the “concurrent” use by the members of the community.
- Members of the community of users may get served by enabling their access to the infrastructures, by enabling their (temporary) use of the infrastructures, and
by enabling the acquisition of assets – as, for example, data – that the infrastructures maintain and are able to provide.

This first definition will be refined later on with the introduction of some other terms and concepts.

2.1 Classification of Information and Communication Infrastructures

The definition above is still too general to enable us to distinguish between infrastructures of very different natures. A first, more elaborate characterization will look at infrastructures for three different purposes: (a) technical infrastructures as technical systems built up of technical artifacts like “tools”, “machines”, “programs”, “buildings”, etc.; (b) economic infrastructures as economic systems built up of “enterprises”, “businesses”, “service providers”, etc.; and (c) societal infrastructures as societal systems built up as “healthcare systems”, “taxation and revenue service systems”, etc.

Even though this separation between views at infrastructures helps to characterize infrastructures by a first classification, it is not intended to suggest that the three types of infrastructures may be independent. It is in fact very likely that technical infrastructures exist within an economic infrastructure and that economic infrastructures exist within a certain societal infrastructure.

Building Blocks and Structure of Information and Communication Infrastructures

This differentiation above is not yet helpful to distinguish between infrastructures and other man-made artifacts. The identification of the common characteristics
that identify infrastructures will be introduced in the subsequent sections on infrastructures and their building blocks and on infrastructures and the dimensions along which infrastructures may be characterized.

A refined definition of information and communication infrastructures is related to their structure, to the building blocks that constitute them and to the relationships between the different building blocks.

**Corporate Information and Communication Infrastructures**

Traditionally, Information and Communication Infrastructures are structured as depicted with the following graph (source: OMG).

In this graphic representation Information and Communication Infrastructures are seen as a collection of adjacent layers. The layers are meant to encompass different building blocks of a similar kind. The different layers represent a categorization of the building blocks in accordance with a particular criteria.

The depiction above separates between layers that represent different “virtualizations” of physical entities that constitute the Information and Communication Infrastructure.
Internet-based Information and Communication Infrastructures

A possible structure for an Internet-based Information and Communication Infrastructure may be depicted as follows:

We have become used to thinking of the Internet not just as a technology that enables access to different information sources, but that is also capable of running different applications that help users to perform a certain task. Applications like “healthcare applications”, “business applications” or “scientific applications” will all be based on common or different information sources accessible over the Internet.

Information and Communication Service Infrastructures

It seems to be commonly accepted by now that applications may best be constituted of a selection of services that can be reused across as many applications as possible, with “compound services” built of a proper selection of services that get used in a proper order to fulfill a particular task or with “constructed services” that may take base services as components and use their deliveries as input for their own delivery. This leads to the concept of a structure that positions a service level between the application and the communication level.
This structure is meant to express the fact that applications use (generic) services provided at the service level S which, in turn, use services provided at the infrastructure level HW/SW Units.

The service level in this structure gains the role of a “mediator” between applications and information and communication technology capabilities. The services are seen as value-added services and are meant to become assets in their own right. The service level assumes, at the same time, the role of a separator between applications and information and communication technology capabilities in the sense that applications will be made “independent” of changes in the information and communication technology capabilities by providing for stable interfaces to the information and communication technology capabilities. It may also act as a “mediator” in the sense that not each new application with unforeseen requirements may demand for changes on the information and communication technology capability level but rather at the service level.

**Cloud-based Information and Communication Service Infrastructures**

An extension to the concept of an Information and Communication Service Infrastructure will be achieved with the option to use services of different origins provided by different service or HW/SW clouds.

With the service level the structure may now also support the vertical segmentations of Information and Communication Service Infrastructures by enabling applications to use services of different service sets: “Service Clouds” on
the service level and on the information and communication technology capability level as indicated with the following picture:

Both, the horizontal and the vertical segmentation of the structure corresponds to a structuring of infrastructures in terms of “building blocks” and in terms of layers.

Recent developments reflect demands resulting from new levels of cooperation in the society as a whole and especially in enterprises: Concentrating on core competences and on the division of labor between different corporations lead to the need to interrelate enterprises and to ultimately establish dynamic business ecosystems with highly distributed Information and Communication (Service) Infrastructures that interrelate numerous devices, software systems, services and service providers and users of different enterprises. Devices may now not only be computers of different kinds but, for example, NC machines, robots, 3D printers, printers, storage devices, but also routers, scanners, copiers, electronic door locks and even antennas, sensors and actuators etc. Software may be operating systems for different kinds of devices, data and content management systems, workflow systems etc. that all enable different kinds of services provided by the different Building Blocks of Information and Communication (Service) Infrastructures. This great variety of Building Blocks with their many characteristics, however, need to be described uniformly to enable their interconnection, their interoperability and interworking. We, therefore, introduce now a model that is meant to enable their unified characterization. This now demands for a different picture for its characterization: As a network of Information and Communication (Service) Infrastructures.
These kinds of Information and Communication (Service) Infrastructures reach a level of complexity that cannot be mastered any longer without their precise description. This will be achieved with the introduction of Actionable Artifacts as a unifying computing model.

**Building Blocks and Bills of Materials for Building Blocks**

As indicated above, Information and Communication (Service) Infrastructures comprise hardware and software systems, communication networks, peripheral devices like storage devices, printers/scanners etc. as their constituent Building Blocks. They, however, only constitute an infrastructure if they are properly integrated to enable their interoperation to deliver the kinds of services their users expect.

More recently, the term “Building Block” is used with an extended meaning by also looking at services as being constituent Building Blocks without even looking at the devices that are capable of delivering the services. Looking at the services provided by an Information and Communication (Service) Infrastructure and suppressing the look at the hardware/software devices that are needed to provide the services is usually called “virtualization”. In this capacity virtualization enables the “separation of concerns” for different stakeholders interested in different views at infrastructures. This monograph will, hence, understand the term “Building Block” as either a hardware/software device or as virtual concepts like “Services”, “Actions”, “Applications” etc. This will be reflected in the definition of classification.
dimensions for Information and Communication (Service) Infrastructures later on in this document.

As in the colloquial use of the term “Building Block” it is intended to also look at Building Blocks in the context of Information and Communication (Service) Infrastructures as being “composable”. Compositions are intended to enable the use of (basic) Building Blocks to construct new (composable) Building Blocks that encompass the basic Building Blocks as their constituents. In the profiling concept introduced in this monograph this “self-reference concept” will be seen as the means to cope with the size and complexities of today’s and tomorrow’s Information and Communication (Service) Infrastructures.

In order to cope with the complexities of existing Information and Communication (Service) Infrastructures, and even more though with the increasing complexities of future infrastructures with myriads of active or passive micro devices as Building Blocks of infrastructures, profiling must be based on proven engineering practices.

Large composed physical Artifacts like automobiles, airplanes, bridges etc. are treated in their engineering as compositions of Building Blocks that will be mirrored in schemata called “Bills of Materials”, representing a breakdown structure for the Artifact. The hierarchical breakdown structure, frequently also called “parts explosion” schema, may be represented by a directed graph with the nodes representing the “wholes” and the “parts” that constitute the “whole” and the arcs representing the “is-part-relationship” between the whole and its parts. A “Bill of Materials”, hence, enables the complete description of complex physical Artifacts down to the last little bolt and screw. In its use in engineering, manufacturing and maintenance different versions of a “Bill of Materials” may be set up to reflect the specific needs in these activities.

Bills of Materials will now also be used to represent Information and Communication (Service) Infrastructures in terms of both, physical and virtual Artifacts as Building Blocks of the infrastructure. Following this concept Information and Communication (Service) Infrastructures may be described as Bills of Materials for their constituent physical devices, as Bills of Materials for their constituent virtual concepts like Services or as Bills of Materials that combine both, physical and virtual constituents.

At first glance it may seem to be necessary to also differentiate between Building Blocks of Information and Communication (Service) Infrastructures in accordance with their “Function” in the infrastructure, like in physical Artifacts where automobiles encompass “breaks”, “airbags”, “engines” etc. In the profiling of Information and Communication (Service) Infrastructures this differentiation will be neglected and all artifact descriptions will be based on a common, more abstract
concept called “Actionable Artifact”. Actionable Artifacts are introduced as the common denominator for all types of Building Blocks of Information and Communication (Service) Infrastructures. With Actionable Artifacts Information and Communication (Service) Infrastructures and all their possible constituent Building Blocks are meant to be uniformly described as Actionable Artifacts.

2.2 Actionable Artifacts as the Computing Model of Information and Communication Service Infrastructures

The unified characterization of Building Blocks of Information and Communication (Service) Infrastructures will be achieved with the introduction of Actionable Artifacts. They will be their constituents and all their constituents together with all the interrelationships between the constituents are again seen as an Actionable Artifact. This self-referentiality will be the dominant concept throughout the introduction of the profiling concept.

A complete definition of Information and Communication Service Infrastructures will also demand for a characterization of their behavioral properties. Since we assume that they will be able to perform tasks, we need to explain how infrastructures will be enabled to do this.

Since Information and Communication (Service) Infrastructures encompass many different types of Building Blocks, the description of the infrastructure would normally request for different notions for the different Building Blocks. This would, for the description of Information and Communication (Service) Infrastructures, lead to an unbearable complexity. We, therefore, introduce “Actionable Artifacts” as a uniform computing model for the description of all kinds of Building Blocks.

In Information and Communication Service Infrastructures all Building Blocks and the infrastructure itself are considered to enable “computations”. Profiling is looking only at this computation capability, independent of as to whether these Building Blocks may be able, for instance, to “print” or to “deliver” or to “scan” documents or to “access” databases.

In subsequent parts of this monograph we will, therefore, talk about both, “Building Blocks” – whenever we intend to refer to an implementation of an Information and Communication Service Infrastructure in terms of hardware/software – and about “Actionable Artifacts” – whenever we intend to refer to the denotation of the computing provided by a Building Block.

We assume Actionable Artifacts to be capable of conducting Actions. In order to conduct an Action, an Actionable Artifact is expected to accept a “Stimulus” that would start an Action. The Action can be conducted to its end and delivers then a “Response”. This may be depicted as follows:
Looking at computations in terms of stimuli, actions and responses is not new even though it is not necessarily seen by all experts as a “unification concept” for different kinds of Actionable Artifacts. In fact, the concept corresponds to the functional view of computations that have traditionally been used in the characterization of software where the formula

\[ f(s) = r \]

indicates that a function \( f \) applied to the stimulus \( s \) delivers the result \( r \). Using the notation of a function is, however, a departure from traditional characterizations of computing devices and of computing infrastructures.

Actionable Artifacts may – even though they all are represented by one computing model – be of very different kinds. We, therefore, classify them to refer to their discriminating characteristics.

**Classification of Actionable Artifacts**

Starting with the physical realm of computing all computing devices may be considered as Actionable Artifacts. They perform an Action in accordance with an algorithm that defines the Action and the execution of the Action.

On the software level of computing we may think of a software system as an Actionable Artifact provided the software is installed on a computing device and the computing device will execute the software system.
On an even more abstract level we may think of “Services” as Actionable Artifacts provided the services will be delivered by a software system and installed and executed on a computing device.

This list of possible types of Actionable Artifacts above is by no means exhaustive: One may add to this list concepts like “Task”, “Activity”, “Process” and ultimately “Infrastructures”.

We may even extend the notation of an “Actionable Artifact” to the non-technical world and look at “Teams”, “Organizations”, “Business Units” etc.:

- man-made, societal set-ups with people, organizations in which people act and react and, hence, “interrelate” with each other;
- man-made, organizational units set up, for instance, as business units as a collection of people that are brought together to conduct one or a collection of Actions for a particular economic purpose and, hence, “interwork”;
- man-made, technical objects that are set up of a collection of component objects like, for instance, different machines to conduct one or a collection of “Automatic Actions”.

The above differentiation between Actionable Artifacts does – as for infrastructures – not intend to suggest that they may be independent of each other. In fact, Societal Actionable Artifacts may be needed to enable the existence of Economic Actionable Artifacts and vice versa, and Societal and Economic Actionable Artifacts may be needed to enable Technical Actionable Artifacts and vice versa. This may then be depicted as the following simple graphic model:
For the analysis and evaluation of Information and Communication Service Infrastructures we will also need to understand the relationships between different Actionable Artifacts.

**Structure of Actionable Artifacts**

Actionable Artifacts for our purposes will have the following fundamental characteristic:

- Actionable Artifacts may encompass Actionable Artifacts of different kinds as their building blocks

We may develop a first understanding of the great variety of Actionable Artifacts that an Information and Communication Service Infrastructure may comprise by looking at the following sample Actionable Artifacts of an “Enterprise Management Infrastructure”.

---

**Diagram Description**

- **S-AA** (Source Artifact) is connected to **E-AA** (Enterprise Artifact) and **T-AA** (Target Artifact) by enabling relationships.
- **E-AA** enables both **S-AA** and **T-AA**.
- **S-AA** and **T-AA** are connected by an enabling relationship.

---

*Fig. 1: Relationship between Actionable Artifacts*
A systematical classification for Actionable Artifacts will be provided later on in this monograph and in an accompanying PowerPoint presentation with the title “Information and Communication Service Infrastructures: A Conceptual Reference Framework”.
3 A Reference Schema for the Characterization of Information and Communication Service Infrastructures and Actionable Artifacts

The previous section introduced different classes of infrastructures depending on the different constituents of the infrastructure. A societal infrastructure may comprise “people”, “public organizations”, “business organizations”, etc. An economic infrastructure may be constituted of “management bodies”, “production lines”, “supplies”, and demands”. A technical infrastructure may encompass “machines”, “transport equipment”, “ICT equipment”, etc. A uniform characterization for all kinds of infrastructures that still enables the differentiation between the different classes of infrastructures must provide for common and specific information within the same reference framework.

Even though the previous introduction provided for a base understanding of Information and Communication Service Infrastructures, it was not elaborate enough to capture all the dimensions that characterize them: This leads, therefore, to the demand for a more complete capture and classification of the diversity of their characteristics.

Understanding of the characteristics of an Information and Communication Service Infrastructure and of Actionable Artifacts that constitute it is not necessarily the only subject of concern. In the future developments of Information and Communication Service Infrastructures will take place based on constituents offered in open markets. This is already obvious for apps offered as tradable Artifacts or for Services offered on service marketplaces. The future will most likely see many more offers in open markets that may be integrated into Information and Communication Service Infrastructures of very different kinds for very different purposes. They will be developed by businesses, other private and public organizations.

As a consequence, Information and Communication Service Infrastructures and tradable Actionable Artifacts must be precisely characterized to enable decisions about the suitability for a particular use environment. This, in turn, requires the solicitation and collection of information that characterizes them.

Information about the characteristics of infrastructures must be organized in a way to best support the

- understanding of existing infrastructures and Actionable Artifacts to enable decisions about their use/reuse
- selecting of infrastructures for their (re)use

This suggests that it is very important to properly define the information items and the relationships between them that will later on enable the use of this information in the decision making.
Information about the characteristics of infrastructures may also be used for their categorization and classification that may, in turn, support the selection of infrastructures for their proper purpose and for the selection of their constituent Actionable Artifacts for their incorporation into new or already existing infrastructures and – if necessary – for their removal from and replacement in an existing infrastructure.

The different characterizations of infrastructures subsequently introduced are meant to offer a first step for coping with societal, organizational and technical issues related to the development and use of Information and Communication Service Infrastructures.

3.1 Characterization of Infrastructures along the Virtualization Dimension

Different stakeholders may want to take different looks at Information and Communication Service Infrastructures by highlighting those characteristics that are of concern to the respective stakeholders and to suppress others. This separation of concern leads to the definition of characterizations along a “Virtualization Dimension” in the characterization of infrastructures.

The picture above is meant to explain the fact that infrastructures are made available at different levels of virtualization of the kind “applications as virtualizations”, “services as virtualizations”, “hardware/software units as virtualizations”. Applications may be seen without any reference to the services
that may be constituents of the application and services may be seen without any reference to the hardware and software units that will be able to compute them.

The characterization along the “Virtualization Dimension” may in fact be considered as constituting an “is-enabled-by” relationship as depicted below:

The collection of all infrastructures will hence – in accordance with the chosen schema – be subdivided into three different classes:
The picture expresses the fact that a superior infrastructure may be using a subordinate infrastructure: An infrastructure of the Application Infrastructure Class may be using services of the Service Infrastructure Class and the latter one may be using HW/SW units of the HW/SW Infrastructure Class.

3.2 Characterization of Infrastructures along the Granularity Dimension

Different stakeholders may want to take different looks at Information and Communication Service Infrastructures by looking at different levels of building blocks that constitute them. This corresponds to the application of the *divide and conquer* principle that leads to the characterization along a “granularity dimension” in the characterization of infrastructures.
The picture above is meant to explain the fact that infrastructures are built up of systems that in turn are built up of components. The characterization along the “Granularity Dimension” may in fact be considered as an “is-constructed-of” relationship.

The collection of all infrastructures will hence – in accordance with the chosen schema – be subdivided into three different classes.
The picture expresses the fact that an infrastructure of any infrastructure class may be constructed of systems of any system class which may, in turn, be constructed of any component class.

3.3 Characterization of Infrastructures Along the Virtualization and Granularity Dimension

The characterization of infrastructures along the two dimensions “Granularity” and “Virtualization” then leads to the following two-dimensional reference schema:
It enables the “horizontal” differentiation between
- HW/SW Infrastructures
- Service Infrastructures
- Application Infrastructures

but also between
- HW/SW Systems
- Service Systems
- Application Systems

as well as between
- HW/SW Components
- Service Components
- Application Components

and enables also the “vertical” differentiation between
- HW/SW Infrastructures
- HW/SW Systems
- HW/SW Components

but also between
- Service Infrastructures
- Service Systems
- Service Components
as well as between
• Application Infrastructures
• Application Systems
• Application Components

as depicted in the following table

3.4 Characterization of Infrastructures Along the Abstraction Dimension

Information and Communication Service Infrastructures exist as both, as Artifacts like Systems, Components, HW/SW Units, Services and Applications and as Engineering Artifacts that will be created prior to their creation as Artifacts to guide their development or after their creation for their analysis.

The characterization of an infrastructure along the abstraction dimension is an indication for a stepwise completion and for what engineering artifacts of the infrastructure exist: Implementations, designs or profiles. It is obvious that the characterizations of infrastructures along the abstraction dimension are related and may be distinguished as being a “mandatory” (solid lines) or “voluntary” (dotted lines) prerequisite.
This then leads to the following three-dimensional reference schema for Information and Communication Service Infrastructures as depicted below:
The diagram indicates that infrastructures will be characterized along the different dimensions:

- The “Abstraction Dimension” denotes the fact that artifacts may be seen to exist and be described at different abstraction levels: Artifacts may be implemented, they may be designed, and they may be “profiled”.
- The “Granularity Dimension” denotes the fact that artifacts may be seen as being decomposable/composable into building blocks like programs, systems, and infrastructures.
- The “Virtualization Dimension” denotes the fact that artifacts may be seen as consisting of HW/SW units, as services provided by these HW/SW units, or as applications that have been built by using services provided by the respective HW/SW units.

The picture shows the different classes of Artifacts as they may be introduced with the “Reference Schema for Infrastructures” and, in addition, the kinds of Engineering Artifacts that will usually be created to support the planning, development, maintenance and the use of infrastructures and Artifacts.

3.5 Sample Classes of Actionable Artifacts

The subsequently introduced profiling methodology will be capable of characterizing infrastructures and all of their constituent artifacts in a uniform way. The profiles developed may still be different in order to meet the different purposes the profiles are meant to serve for. Prior to the presentation of different profiles we, however, want to properly position Actionable Artifacts within the three-dimensional schema for the characterization of infrastructures with the
Actionable Artifacts are – as depicted above – first of all “Implementations” that can be executed. As implementations they may be implementations of “Infrastructures”, “Systems” or “Components” and they may be implementations of “Applications”, “Services” or “Hardware/Software Units”.

The next picture takes a look at a specific profile of an application infrastructure and of its “Implementation”, “Design” and “Profile” and neglects everything else that characterizes the infrastructure.
Yet another look at an infrastructure may focus at the Hardware/Software Artifacts that constitute the infrastructure.
To take another extreme look at infrastructures would mean to look at the “Profile” of “Hardware/Software Units” of the infrastructure and neglect anything else that might characterize it.
4 Profiling of Information and Communication Service Infrastructures and Actionable Artifacts

Profiles are descriptions of Infrastructures and Actionable Artifacts that are meant to capture all essential information about Infrastructures and Actionable Artifacts that are necessary to understand infrastructures, to communicate about them, and to evaluate them. Profiles are meant to be readable and understandable, also by interested stakeholders without expert knowledge. Profiling is a methodology for the description of Infrastructures and Actionable Artifacts. The methodology is aiming at a formalized description of infrastructures that enables their later analysis and evaluation.

As different as Infrastructures and Actionable Artifacts of concern may be and as different as their descriptions might be in the end, stakeholders interested in them will only take notice of them if their descriptions are simple and easy to read. Profiling is, therefore, intended to be a methodology to
• uniformly document societal, economic, and technical Infrastructures and Actionable Artifacts
• enable the communication about the different Infrastructures and Actionable Artifacts in a common language

Profiling has, therefore, been developed to enable a uniform description of all information about Information and Communication Service Infrastructures and Actionable Artifacts of concern. It is hence a notation that may be used across a set of different domains like information and communication technologies, applications of information and communication technologies, business settings in which applications of information and communication technologies exist, and even of societal settings that relate to the use of information and communication technologies.

Profiling is meant to be applied in both, the development of new infrastructures as a description for their expected functionality and for the description of existing infrastructures for their retrospective documentation.

In many instances information about existing Information and Communication Service Infrastructures and Actionable Artifacts is not available since it has not been systematically acquired and recorded or – if some information exists – it is not complete or outdated. Also, where this information exists it may be distributed across numerous documents that describe them in terms of different notations.

As demanded for the characterization of Information and Communication Service Infrastructures, profiling is also aiming at their uniform description along the previously introduced dimensions.
**Profiling Dimensions**

In order to enable the capture and representation of all essential information that would characterize Information and Communication Service Infrastructures we refer back to the three-dimensional characterization of Information and Communication Service Infrastructures and Actionable Artifacts as introduced above.

The following picture, representing the three dimensions for the characterization of infrastructures, also shows that each dimension represents a different kind of characterization of the Actionable Artifacts, expressed with the indication of the respective relationship between them along each of the dimensions:

The Actionable Artifacts along the Virtualization Dimension will be in a “is-enabled-by” relationship (or by its inverse relationship), and the Actionable Artifacts along the Granularity Dimension will be in a “is-constructed-of” relationship (or by its inverse relationship), and all Actionable Artifacts represented along the “Abstraction Dimension” are in a “is-abstracted-to” relationship.

![Diagram](image)

The completed picture of the three-dimensional reference schema for Information and Communication Service Infrastructures will then take the following form:
The picture again indicates that all Actionable Artifacts, independent of whether they are “Infrastructures”, “Systems” or “Components” and independent of whether they are “Hardware/Software Units”, “Services” or “Applications”, may all be characterized by their profiles, their designs and their implementations.

**Separation of Concerns in Profiling**

Even though profiling is intended to capture and represent all relevant information on Information and Communication Service Infrastructures and Actionable Artifacts that constitute them, not all information captured may necessarily be relevant for every stakeholder. It will, hence, be advisable to further classify profiling information along the “abstraction dimension” in accordance with their suitability for different stakeholders.

For that further characterization of Information and Communication Service Infrastructures by their profiles, we introduce three different profiling levels that represent three different profiling abstractions: “Specifications”, “Blueprints” and “Landscapes”, which will then lead to the following modified – and incomplete – version of the three-dimensional reference schema as depicted below:
Profiling Information and Communication Service Infrastructures is hence a matter of pragmatics driven by the purpose for which the characterization is meant to serve. It should constrain itself to the capture and provisioning of that part of information that is relevant for the respective purpose. Information considered to be relevant for that instance may later be reused and extended to a larger amount of information when necessary and abandoned when it becomes irrelevant. Profiles are hence meant to be an account for a current need.

4.1 Functional View at Information and Communication Service Infrastructures and Actionable Artifacts

The unifying functional view at Actionable Artifacts introduced above will now be applied to the description of the great variety of Building Blocks of Information and Communication Service Infrastructures. Since we expect infrastructures to be “large in size” and “complex” in the interrelationships between their Building Blocks, we also expect the functions delivered by Information and Communication Service Infrastructures as “large in size” and of “high complexity”. In order to cope with size and complexity we intend to represent them functionally at different levels of abstraction that will be called “Landscapes”, “Blueprints”, and “Specifications”
The Landscape of an Information and Communication Service Infrastructure

From a functional point of view an Information and Communication Service Infrastructure consists of three “gross functions”: 1) A function that is able to handle the demand for services provided by the infrastructure. 2) A function that is able to provide the supply of services to meet the respective demand. 3) A function that is able to “mediate” between the demand and the supply of services. The following graph is meant to depict the different gross functions and the relationships between them:

As shown all three gross functions do have relationships with one another: 1) The Demand function may request the service of the Mediation function to find an appropriate service that meets a user’s requirements provided by the Supply function. 2) The Supply function may request the service of the Mediation function to make its supplies available to the Demand function. 3) The Demand function may request the Supply function directly to provide a specific service.

If we translated the functional view of Information and Communication Service Infrastructures into an architecture, we would arrive at the following picture:
The picture suggests that the Demand Function for a service will be provided by a “Frontend” and the Supply Function will be provided by a “Backend” of the Information and Communication Service Infrastructure. The mapping between “Demand” and “Supply” will be provided by the Mediation Function. The rationale behind that architecture model suggests that any user of services offered by the Information and Communication Service Infrastructure acts out of a frontend in his/her possession and under his/her control. It also suggests that the services used will be available for their use in the backend that will be in the possession of the service provider and will be running under the provider’s control. The Mediation between “Demand” and “Supply” will either be located in the “Frontend”, in the “Backend” or may be administered by an independent “Service Provider”. The “Mediation Function” may – as we can easily conclude – be a very complex Function encompassing a number of complex SubFunctions:

1) Finding Supplies to a given Demand requests the Mediation Function to communicate with both, the Demand Function and the Supply Function of the Information and Communication Service Infrastructure.

2) For the selection of “Supplies” for a particular “Demand”, the Mediation Function must be able to analyze both, the “Demand” and the “Supply” based on their respective description. The proper description of them, hence, represents a prerequisite for their analysis.

3) For the mapping of “Demands” and “Supplies” the Mediation Function needs to be capable of deciding which of the selected Supplies to a given Demand fulfills the Demand perfectly well, sufficiently well or does not fulfill the Demand at all.
All these SubFunctions of the Mediation Function can best be supported if the available services are properly classified. For a first coarse classification of services we may extend the previously introduced architecture model with the following “Service Architecture” that suggests that services on a higher level in the service classification may be based on subordinate services in the service classification as depicted below:

The Blueprint of an Information and Communication Service Infrastructure

As indicated above the functional view at Information and Communication Service Infrastructures will also support the decomposition of gross functions into subordinate functions which, in turn, may again be decomposed into SubSubFunctions etc. The following graph is meant to schematically depict different SubSubFunctions of the three gross functions “Demand”, “Supply” and “Mediation”: 
The graph also represents next to the function decomposition the relationships between the gross functions “Demand”, “Supply” and “Mediation”. The red and green cycles depicted above represent the control flows in the execution of a “Demand” (the green cycle) and the control flows in the execution of a “Supply” (the red cycle). In that cyclic execution of a demand for a service the “knowledge base” of the “mediation function” will be consulted to find out as to whether a
“Demand” may be met by an existing service offer and subsequently the “Supply” enables the assignment of the respective service to its “Demand”. In that cyclic execution of a supply of a service to an Information and Communication Service Infrastructure the “knowledge base” of the “mediation function” will be consulted to find out as to whether the service intended to be supplied already exists and as to whether the service may be accepted as a new service of the Information and Communication Service Infrastructure. The “mediation function” may subsequently put that new service on offer. The picture has been produced in an experiment and shows only a few decomposition levels out of a total of nine function decompositions developed to capture the representation of the Information and Communication Service Infrastructure. A new elaborate description of the picture is beyond the scope of this report.

**Specifications of Information and Communication Service Infrastructures**

For a detailed description of a Function the functional view at Information and Communication Service Infrastructures provides for the association of a set of fixed sets of attributes with a Function.

The set of attributes associated with a function are:

- The “Objective Attribute” that represents the objective for the existence of the respective function.
- The “Stakeholder Attribute” that represents the possible stakes different people like users, developers, providers etc. may have in the respective function.
• The “Delivery Attribute” that represents the delivery the respective function may produce in the course of its execution.

• The “Enabler Attribute” that represents the support the function depends on for its execution.

• The “Process Attribute” that represents the execution path across the steps performed in the execution of the respective function.

As with functions attributes may, for this better and more detailed understanding, also be decomposed into SubAttributes that, in turn, may be decomposed into SubSubAttributes etc.

In addition to the set of five attributes another two may become of concern if the functions are either time- or location-dependent or both.

The graph indicates that four of the five other attributes “Objective”, “Stakeholder”, “Delivery”, “Enabler” may be time- and location-dependent.

A more elaborate discussion of the different ideas behind the functional view at Information and Communication Service Infrastructures will follow in the next sections.
4.2 Profiling Methodology

The methodology is based on formalized modelling techniques that enable the description and graphic visualization of infrastructure descriptions.

The methodology comprises a

- notation that is required to develop descriptions of Information and Communication Service Infrastructures and Actionable Artifacts

and

- rules of conduct for the development of descriptions of Information and Communication Service Infrastructures and Actionable Artifacts

With its notation the methodology introduces first “terms” and “concepts” as constituents of profiles across all the levels of descriptions of Information and Communication Service Infrastructures.

4.2.1 Terms and Concepts

Terms will be introduced to name (i.e., identify) abstract or concrete things. A term is a word or a collection of words or a combination of words of a spoken language with a common intuitive meaning. In a collection words may be enumerated without any delimiter or with a fixed set of delimiters like “,” / “:” / “;” / “_” etc. In a combination words may be combined in accordance with a fixed set of rules denoted by a fixed set of symbols like “and”, “or”, “if”, “then” etc. Both collection and combination of words represent term again.

The Profiling Methodology will strive for the use of most likely used terms in a particular setting that will be uniquely understood across a number of professional communities. The terms introduced in the Profiling Methodology otherwise bear the risk of being interpreted differently.

The concept of a term is its “intuitive meaning”. Concepts are perceptions that someone may develop of the meaning of terms. Concepts, therefore, do not have an explicit representation. It is, however, possible that different interpreters may develop different perceptions of the meaning of a term.

The notation introduced here for the profiling of Information and Communication Service Infrastructures and for Actionable Artifacts will have to be extended to avoid different perceptions of the meaning of terms to a maximum degree. This will be achieved with the “Refinement” of terms and concepts.
Concepts are not necessarily only developed as intuitive perceptions of the meaning (i.e., semantics) of individual terms. Their understanding may, in addition, be supported by associated terms that create a context in which the terms are used. The context in which terms are used may be explicitly represented again by terms that represent the context: Terms denoting a context will, therefore, be called Context Terms.

Context Terms and Terms are interchangeable since “Context Terms” represent a Context for a number of Terms, but Terms also represent a (part of the) Context for Context Terms. This leads to the situation that somebody’s Term is a Context Term for somebody else and vice versa.
A Term seen as being a Context Term may be in that role for a set of Terms.

This leads to the notion of term/concept hierarchies that will be used in the profiling at the initial stage of profiling Information and Communication Service Infrastructures. They may then be described in an architecture-driven fashion or in a service-driven fashion or in an infrastructure-driven fashion.
Term/concept hierarchies will be the conceptual basis for the introduction of a computing model for Information and Communication Service Infrastructures: The Functional View. The Functional View does not refer to Hardware/Software Building Blocks of Information and Communication Service Infrastructures as it would conventionally be done. The Functional View abstracts from Information and Communication Technology Artifacts and looks at the kind of thing they are able to perform or about Functions they are able to assume and what these Functions would be able to deliver.

The monograph later on introduces specific terms and concepts used in the description of Information and Communication Service Infrastructures: “Capabilities” provided by Information and Communication Technology Artifacts constituting Information and Communication Service Infrastructures and “Actions” capable of carrying out tasks in accordance with the Capability they are meant to “implement”. The profiling methodology is also based on a number of terms and concepts that denote “generic” Artifacts like “Platform” and “Service” and a number of “generic” terms and concepts that denote properties of Artifacts like “Attributes of Capabilities” or “Attributes of Actions”.

The “generic” terms and concepts are then the basic key words for the profiling language. Another set of “generic” terms and concepts will be incorporated in the profiling language to describe the permitted behavior of individual Artifacts and of Information and Communication Service Infrastructures as a whole. This extends the profiling language up to the point where it can be used to determine permitted behavior under concurrent demands for its use, for the concurrent demand for the services provided by the infrastructure and for the proper management of the infrastructure itself.

**Term and Concept Refinements**

The Profiling Methodology will, therefore, provide for a notation that is based on refinements of terms and concepts that will be called a “Term and Concept Refinement”. In term and concept refinements terms will be explained by associating other subordinate terms with a term that is meant to explain the concept of the first term as depicted below:
This will be illustrated with the following example:

The refinement “explains” that a “vehicle registration” comprises the “turn-in of documents” and the “license plate delivery”.

With their refinement terms and concepts will play a dual role in the profiling of infrastructures and Actionable Artifacts: They will denote infrastructures,
Actionable Artifacts and any other artifacts and they will also denote “contexts” in which the terms are meant to be understood. As in the example above, the term “vehicle registration” may denote an activity. The terms “turn in documents” and “license plate delivery” denote subordinate activities. The term “vehicle registration” is meant to denote the context in which the terms “turn in documents” and “license plate delivery” are meant to be understood.

As the example shows the term “vehicle registration” as the denotation of the context for the terms “turn in documents” and “license plate delivery” narrows the meaning of the term “vehicle registration” down to its understanding as “turn in documents” and “license plate delivery” for a vehicle registration.

We are now able to conclude about term and concept refinements that superior terms denote the context for the subordinate terms and denote in part the concept of the subordinate terms and vice versa.

A full understanding of the concept behind a term will hence be based on the interpretation of the term and by the interpretation of the term that denotes the context of the term.
Term and Concept Refinement Hierarchies

Term and concept refinements will be used along all three dimensions for the characterization of infrastructures and Actionable Artifacts: Along the granularity, the virtualization and the abstraction dimension. Terms and concepts will be used to denote infrastructures, the constituents of infrastructures and their properties.

Since infrastructures are meant to be compositions of their constituents, terms denoting infrastructures and their constituents will also have to mirror these compositions. Term and concept refinements as introduced above are meant to reflect these compositions. In addition to the denotation of infrastructures and their constituents as term and concept refinements, the composition will explicitly be defined by a composition concept.

These term and concept refinements were also meant to define contexts and context hierarchies. One may assume that any term denoting a superior component in a composition hierarchy will be a context term to the terms denoting the subordinate components in the composition hierarchy.

Term and concept refinements may – in principle – also be based on different composition concepts:

- Specialization Compositions (is-a component)
- Aggregation Compositions (is-part of component)
- Construction Compositions (is-constructed of component)

Other types of refinements include:

- Ambiguous Terms and Disambiguations of Terms in Term Hierarchies

The use of natural language words and combinations of words as terms may lead to ambiguities in as much as the words of spoken languages may denote different concepts in different contexts and may, hence, cause ambiguities for their interpretation. Term and Concept Hierarchies are meant to remedy at least some of the possible ambiguities by providing a Context Term with every Term. Following this proposition we may – based on the Functional View at Information and
Communication Service Infrastructures – assume that superior Terms and Concepts in a Function Hierarchy always represent the Context Terms/Concepts for all subordinate functions’ Terms/Concepts. This may be demonstrated with the following example:

The picture indicates that the use of the Term “Window” denotes an opening in a building and not the collection of symbols appearing on a computer monitor screen. The two Terms “Building” and “Window” associated with each other in the term hierarchy with the superior Term “Building” denoting the context and with the subordinate Term “Window” for the “Term of Interest” provide means for the disambiguation of the Term “Window” since it will be unambiguously clear that the Term “Window” denotes the opening in a building.

If one extends the schema to allow Context Term/Term relationships in the hierarchy of arbitrary many levels the disambiguations may take place over arbitrary many refinements as follows:
The Term “Printing” will be, in accordance with the picture above, understood as an “Office Service” that will be provided electronically by an “Electronic Service” and printing will be provided as a “Service”.

The Functional View at Information and Communication Service Infrastructures denoted by Term/Concept Hierarchies not only allows tree-like Term/Concept Hierarchies but hierarchies that may be represented as directed acyclic graphs with subordinate “Common” Terms/Concepts to a set of superior Context Terms/Concepts.
as explained with the following example:

In the end, Term/Concept Hierarchies may take the format of multi-rooted, directed acyclic graphs.
At a later part of this monograph we will be able to explain how Context Term/Concept Hierarchies may be used to “navigate” in a functional description of an Information and Communication Service Infrastructure for the tracking of the impact of its changes.

4.2.2 Infrastructure-Driven Refinements of Terms and Concepts

Information and Communication Service Infrastructures have been or will be built for a multitude of purposes. As specific as they may be and as specific as the Actionable Artifacts that constitute them will be, infrastructures for different objectives may use similar or even identical Actionable Artifacts as their Building Blocks.

Term and concept refinements may, therefore, also be applied to classify infrastructures. This will be demonstrated with the following schema.
The Set of all Infrastructures

Class 1

SubClasses of Class 1

SubSubClasses of Class 1

and

SubClasses of SubClass 2

Class 2
This may be demonstrated with the following example:

This hierarchy may be interpreted as a data structure that represents a classification schema for a given sample of infrastructures.

In order to deal with classifications and classification schemas in a systematic way, we introduce a notation with which we will be able to uniquely identify a class in a classification schema as follows:
Hierarchical Refinement of a Sample Application Infrastructure Class

The following is a sample of possible hierarchical classifications along the Granularity Dimension. Since the hierarchical classification according to the “is-constructed-of” relationship corresponds to a refinement of the members of the class into members of SubClasses and since this corresponds to a “refinement” for the members of the class by members of its SubClasses, we also call the classification along the Granularity Dimension “Hierarchical Refinements” (the samples are described as linearized mind maps).

The set of all application infrastructures in the application infrastructure class may be subdivided into the following (arbitrarily chosen) SubClasses:

Application Infrastructure Class
▶ eBusiness Infrastructure Class
▶▶ eLogistics Infrastructure Class
▶▶ eManufacturing Infrastructure Class
▶▶ eFacility Management Infrastructure Class
▶ eGovernment Infrastructure Class
▶ eEnergy Infrastructure Class
▶ eHealth Care Infrastructure Class
▶ Smart City Infrastructure Class
etc.
Hierarchical Refinement of a Sample Service Infrastructure Class

The set of service infrastructures in the service infrastructure class may be divided into the following (arbitrarily chosen) SubClasses:

Service Infrastructure Class
- eGovernment Service Infrastructure Class
- eEnergy Service Infrastructure Class
- eHealth Care Service Infrastructure Class
- Smart City Service Infrastructure Class
etc.

Hierarchical Refinement of a Sample ICT Infrastructure Class

The set of ICT infrastructures in the ICT infrastructure class may be divided into the following (arbitrarily chosen) SubClasses:

ICT Infrastructure Class
- Terrestrial ICT Infrastructure Class
- Mobile ICT Infrastructure Class
- Satellite ICT Infrastructure Class
etc.

In a second refinement step we may divide, for instance, eHealth Care Infrastructures into the “eHealth Care Infrastructure SubClass” of the “Application Infrastructure Class” as follows in arbitrarily chosen SubSubClasses:

Application Infrastructure Class
- ...
- eHealth Care Infrastructure Class
- Medical Record Management Infrastructure Class
- Patient Management Infrastructure Class
- Medical Laboratory Management Infrastructure Class
etc.

As far as the sample classification above goes, it may then be represented as the following hierarchy (it is not drawn here as a graph but rather as a linear representation):
4.2.3 Architecture-Driven Refinements of Terms and Concepts

The model we propose for the architecture-driven refinement of terms and concepts is an architecture on a rather “high” granularity level that serves as a first breakdown on an Information and Communication Service Architecture as introduced above.

The Architecture is meant to deliver the gross picture of an infrastructure by identifying the first-level Actionable Artifacts that constitute the infrastructure. The Architecture represents first the structure of the Information and Communication Service Infrastructure with the following picture:
For its first characterization the architecture identifies a frontend and a backend of the infrastructure where the

- frontend of the Infrastructure is primarily set up to enable the “Delivery of Services”

- backend of the Infrastructure is primarily set up to enable the “Computing of Services” with particular hardware/software configurations.

The picture names the frontend of an Information and Communication Service Infrastructure as “Service Delivery Infrastructure” and the backend as “Service Computing Infrastructure”. Both are named “Infrastructure” as part of an Infrastructure for the reason that the two may not be permanently integrated in a “hardwired” fashion, but are infrastructures in their own right that interact on a case by case basis.

The services provided will be available for their use in the respective Service Repository that is meant to keep a collection of services ready for their use. Services will be used by service users by interacting with the Service Delivery Infrastructure for the selection and invocation of a service from the Service Repository.

The information that we expect to solicit about the Information and Communication Service Infrastructure on the Architecture is:
What kind of an infrastructure is it

For the purpose of defining the kind of the infrastructure we assume that it is built to deliver services to customers. It may comprise different Actionable Artifacts that offer different types of services. We, therefore, define the infrastructure in terms of its constituent Actionable Artifacts that deliver the different types of offered services:

- **Application Services**
  for different application domains like “Smart Cities”, “Smart Healthcare Management”

- **Process Management Services**
  for different types of processes like “Traffic Management Processes”, “Business Processes”

- **Information Management Services**
  for different types of information like “Geo Information”, “Human Resource Information”

- **Data Management Services**
  for different types of data like “Video Data”, “Audio Data”

The previous description of the architecture of an Information and Communication Service Infrastructure in terms of “Component Infrastructures” and Service delivered or computed by the respective infrastructure does not reflect the different types of interactions between them. Hence, in addition to the description of the architecture in terms of “Component Infrastructures” as the “Functional Building Blocks” of an Information and Communication Service Infrastructure, we need to introduce also terms and concepts to describe their interactions.

The Service Delivery Infrastructure will interact with the Service Computing Infrastructure. The Service Computing Infrastructure interacts with a (maybe external) Service Provider that ultimately computes the service and thereby delivers the result back to the Service Computing Infrastructure, to the Service Delivery Infrastructures and ultimately to the service user.

The following graphs represent these interactions in terms of “sequence diagrams”. For that purpose they list the interacting entities in the headline of the diagram: Service Users (SU), Service Delivery Infrastructure (SDI), Service Repository (SR), Service Computing Infrastructure (SCI) and Service Provider (SP). This indicates that the Information and Communication Service Infrastructures will have users and possibly also service providers that exist outside the infrastructure, but interact with the infrastructure.
Service Computing Infrastructures are also meant to enable the provisioning of unsolicited services for their later use. This may take place in accordance with the subsequently depicted Provide Cycle for the Service Computing Infrastructure.

A Service Provider may submit its offer for a service to the Service Computing Infrastructure which, in turn, attempts to register the offered service in the Service Repository. The Service Repository is responsible for analyzing the offered service
for its compatibility with the other services in the repository and accepts or rejects the registration of the offered service.

4.2.4 Service-driven Refinements of Terms and Concepts

The vocabulary introduced in the sequel is aiming at the establishment of a common terminology base for Information and Communication Service Infrastructures.

For that purpose we will introduce a first classification of the terms and concepts relevant for Information and Communication Service Infrastructures as follows, and by applying the classification concept, we will be differentiating between two essential types of constituents of infrastructures: Platforms and services. Platforms are meant to enable a uniform access to a number of services.

Platforms – next to providing access to services – do also provide for the scheduling of access to systems frequently called the “orchestration” of access to systems.

Platforms may also permit for the concurrent access to the platform by a number of services and are hence capable of coordinating between different accesses.
This simple classification schema gives raise to a hierarchical classification as follows:

Both platforms and services will be called “generic enablers” if they play the role of multitenant building blocks. If we use this hierarchic classification schema for instance to classify “generic enablers” for services and platforms that enable access to services, we would be able to draw a picture as the one above.
The classification concept may be extended by defining services and platforms for a multitude of purposes. If we use this extension to characterize an infrastructure by means of the platforms and services it is capable of providing, we would be able to introduce for their classification the following schemata:

The classes of services that are meant to be represented in the schema are (from bottom to top):
- Base Services
- Generic Application Services
- Custom Services

The platforms that permit and coordinate the access to services (from bottom to top) are:
- ICT Infrastructure Access Platform
- Base Service Access Platform
- Generic Application Service Access Platform
- Custom Service Access Platform

The hierarchic classification schema does not necessarily conform to a tree like access structures but allows access as they may be represented by an acyclic directed graph.

A sample hierarchic service/platform classification schema may
- see generic enablers that provide for instance for computing and storage services at the “base service” level
- see generic enablers that provide for instance information management services at the “generic application service” level
- see generic enablers that provide for instance for ERP services at the “custom service” level

as depicted in the three pictures below.

The class of base services – as indicated in the picture above – may comprise services of the kind
- Storage as a Service (StaaS)
- Computations as a Service (CaaS)
- Communication as a Service (COaaS)
- Software as a Service (SaaS)
- Transactions as a Service (TaaS)
The generic application service class – as indicated in the picture above – may comprise services of the kind

- Information Management Services (IMaaS)
- Business Communication Management Services (BCaaS)
- Information Flow Management Services (IFaaS)
- Collaboration Management Services (CMaaS)
The custom service class – as indicated in the picture above – may comprise services that pertain to particularly entitled users of the services like

- Community Services
- Sub-Community Services
- Role Services
- Member Services

The previously introduced schema may not only serve as a vocabulary for terms and concepts of concern in Information and Communication Service Infrastructures. It also introduces a hierarchical classification of services and platforms as the building blocks of Information and Communication Service Infrastructures in accordance with their semantics. The top level in the hierarchy denotes the services and platforms closest to the users of the infrastructure. The bottom level denotes the services and platforms closest to the HW/SW Unit that executes the services and to the platforms that provide access to the respective services.

The hierarchy of platforms and services may in fact be seen as a composition schema for services and platforms in the architecture of an Information and Communication Service Infrastructure in which higher level services and platforms may invoke lower level platforms in services in their execution during the use of the Information and Communication Service Infrastructure.

It is important to note that services of different classes may be invoked by services of a higher level class in the class hierarchy.
• Custom Services may invoke Generic Application Services and
• Generic Application Services may invoke Base Services

It is also important to note that any of the services of any of the classes may also be directly invoked by users over the custom service access platform.

Services within the same class may also be invoked by other services of that class if the service invocation structure permits this. The pictures above indicate that the invocation structure permits hierarchical invocations and their respective returns, and all services within a class may invoke the respective subordinate platform.

4.2.5 Rules of Conduct

Information and Communication Service Infrastructures may be of a considerable size and complexity. Acquiring information about them may be a very cumbersome and tedious job. It is, therefore, of utmost importance to clearly define beforehand the purpose for which a profiling will be conducted to minimize the effort and to restrict the profiling to the appropriate level of detail.

Profiling as a task may be so complex that it will have to be conducted in a very disciplined way that enables its stepwise refinement and completion. This stepwise completion is proposed here to take place over three different stages. In order to enable the profiling for different purposes the different stages will be defined to gradually increase the expressiveness of the notation that is needed to describe profiles: It starts out with a very limited set of terms and concepts that will suffice in the profiling for some more administrative and less technical characteristics of Information and Communication Service Infrastructures.

It continues by adding new terms and concepts to the notation that will be needed to describe Information and Communication Service Infrastructures on some advanced technical level and it will end with the introduction of terms and concepts that allow a detailed technical description. It should be noted, however, that information gathered during earlier stages should carry over to their successive stages as depicted below:
5 Elements of the Extendable Profile Description Language

The Profile Description Language is meant to enable the description of Information and Communication Service Infrastructures and of Actionable Artifacts of any kind. At the same time it is meant to enable their description – as indicated in the previous chapter on term and concept refinements – on infrastructure level, on architecture level and on service level.

For the sake of simplicity we now assume that all kinds of infrastructures and all Actionable Artifacts are “constructed” of Services and Platforms. This corresponds very much to the current thinking about virtual cloud-centric Information and Communication Service Infrastructures and their provisioning.

The language elements we introduce now for the description of services and platforms will syntactically be the same for both, services and platforms. The differences in their semantics will be explained in the sequel.

The language element introduced will be chosen to enable a staged description of profiles of Information and Communication Service Infrastructures in terms of services and platforms as already indicated above. The staged profiling is introduced to serve different stakeholders in the development and use of Information and Communication Service Infrastructures by leading to differently detailed profiles.

The first stage, called the landscaping stage, of a profile description is meant to be used primarily by users and market-oriented presentations. The second stage, called the blueprinting stage, is meant to be used by technical experts responsible for the design of Information and Communication Service Infrastructures and for the integration of services and platforms. The third stage, called the specification stage, is meant to be used by technical experts responsible for the implementation of Information and Communication Service Infrastructures in terms of services and platforms.

The language elements in the profile description language suitable in stage one will describe services and platforms in terms of their “Capabilities”. The language elements in the profile description language suitable in stage two will describe services and platforms in terms of “Actions”. The language elements in the profile description language suitable in stage three will describe a set of “Attributes” associated with an “Action”.

The profile description language will, for its use in the staged approach for the development of profiles of Information and Communication Service Infrastructures, be an extensible language: The elements provided for stage one will remain valid in stage two and three, and the elements provided in stage two will remain valid in
stage three. Descriptions of profiles produced in stage one will be extended in stage two, and descriptions of profiles produced in stage two will be extended in stage three.

The language elements introduced below for the description of profiles of Information and Communication Service Architectures in terms of services and platforms are equally usable for any other Actionable Artifact. We will hence in the following paragraph introduce the language as being suitable for Actionable Artifacts of any kind.

5.1 Description of Profiles of Information and Communication Service Infrastructures and of Actionable Artifacts in Terms of Capabilities

Understanding and describing infrastructures in a commonly understandable way means – in our view – to understand and describe first their capabilities. Capabilities are, therefore, introduced as a concept that enables a very first and very abstract characterization of Infrastructures and Actionable Artifacts. The description of Infrastructures and Actionable Artifact in terms of capabilities represents a look at them from outside.

A capability will, hence, be a denotation for what the infrastructure of the Actionable Artifact is able to do, what job it can perform by giving it a name (represented as a term). Capabilities are not programs or software but an abstract representation of them.

It is, furthermore, assumed that one Actionable Artifact may offer one or a number of different capabilities.

Capabilities are, hence, a “black-box” characterization of Infrastructures and Actionable Artifacts by telling “what” they do and by hiding “how” they do whatever they do. Capabilities will hence be associated with interfaces of Infrastructures and Actionable Artifacts like user interfaces, application programming interfaces (APIs) or platform interfaces. This will be depicted as follows:
Capabilities are represented pictorially by arrows emanating the Actionable Artifact at its interface and pointing into its “environment”.

We furthermore assume that Actionable Artifacts may not necessarily provide for a “complete job”, they may need the “help” of capabilities provided by other Actionable Artifacts.
Capabilities required to enable an Actionable Artifact to do its job will be pictorially represented by arrows pointing towards an Actionable Artifact emanating from another Actionable Artifact.

Actionable Artifacts are consequently offering two different types of interfaces: the first interface that represents the “delivered” capabilities and the second interface that represents the “supplied” capabilities of an Actionable Artifact.
Cascaded Capabilities

With the capability model introduced above we may construct cascaded capabilities as orders of capabilities of “ordered” Actionable Artifacts. For the representation of cascaded capabilities pictorially we introduce the somewhat simplified graphical depiction:
Actionable Artifacts are now represented by horizontal lines and they may now represent both, the demand and the supply interface of the respective Actionable Artifact.

A profile defined in terms of capabilities will in the end look like a “Capability Hierarchy” that represents the composition of capabilities of different Actionable Artifacts without referring to the respective Actionable Artifact itself. A Capability Hierarchy may, therefore, be seen as a “more abstract” representation of Information and Communication Service Infrastructures as the one obtained with their description in terms of Actionable Artifacts.

Next to this “vertical” capability composition we may also introduce “horizontal” capability compositions. For their vertical composition of capabilities we assume the composition to be governed by a “Construction Semantics”, whereas the horizontal composition is meant to be governed by an “Ordering Semantics”. Both of these compositions will later on be explained together with the introduction of Actions and Action Compositions.

Capabilities of Tradable Actionable Artifacts

Tradable Actionable Artifacts are meant to be used in different use environments and they are meant to use other, different – maybe tradable – Actionable Artifacts. This may pictorially be represented with the following graph:
 Tradable Actionable Artifacts will be chosen for their use in (new) use environments because of the set of capabilities they provide for this (new) use environment and for the set of capabilities they need to use of other Actionable Artifacts.

Whereas the one interface of an Actionable Artifact represents the capabilities that may be used by other Actionable Artifacts that we have called “Supplied...”
Capabilities”, the second interface represents the capabilities that the respective Actionable Artifact needs to employ in order to deliver the expected result. The second interface, hence, does not represent a capability but the requirement a capability is meant to fulfill. We, hence, have called them Demanded Capabilities.

For their composition Actionable Artifacts will then be required to match with respect to their “Demand Interface” and their “Supply Interface”.

In a simplified pictorial presentation “Demands”, “Supplies” and “Matches” will be drawn as follow:

The picture suggests that the composition of two Actionable Artifacts leads to an “amalgamation” of the Demand Interface of the one Actionable Artifact with the Supply Interface of the other one.
Finally it can be concluded that across interfaces between composed Actionable Artifacts may take place both, the cascading of capabilities as well as their matching.

Capabilities may be said to point “to” or “from” an interface of an Infrastructure or an Actionable Artifact: They may be directed outside-in to indicate that the Infrastructure or the Actionable Artifact is able to accept supply from outside. They may be directed inside-out to indicate that the Infrastructure or the Actionable Artifact is able to provide for a delivery to its outside use-environment.

5.1.1 Architectural Classification of Capabilities

Classification of Actionable Artifacts is to enable interested stakeholders to develop an understanding about what the respective Actionable Artifact is capable of doing, and interested stakeholders may be able to more easily find a desired Actionable Artifact if it has been assigned to a class. This may even be of greater importance if classified Actionable Artifacts are made generally available on a marketplace. This might be especially beneficial if a class-based structured repository would support the navigational access and search in the repository.

Following the classification of Information and Communication Service Infrastructures one may, on a first level classify capabilities as

- Capabilities of Societal Actionable Artifacts
- Capabilities of Economic Actionable Artifacts
- Capabilities of Technical Actionable Artifacts
They may also be classified as capabilities for particular applications like
- Business Capabilities
- eHealth Care Capabilities
- eEnergy Management Capabilities
- eLogistics Capabilities
- etc.

Business Capabilities may subsequently be classified as
- Business Management Capabilities
- Business Operations Capabilities
- Business Process Management Capabilities
- Business Information Management Capabilities
- etc.

Capabilities may be classified in accordance with the “jobs” they represent as, for instance
- capabilities that represent user support functions
- capabilities that represent service support functions
- capabilities that represent ICT functions

Based on this classification one might be able to structure capabilities in analogy to the architectures of Information and Communication Service Infrastructures.

It is assumed now that the services provided by an infrastructure will be enabled by Actionable Artifacts that do have the capabilities of delivering these services:
The characterization of an Actionable Artifact in terms of capabilities may be given for the various levels of an architecture for all interfaces in the architecture as depicted above.

For an architectural classification of Infrastructures and Actionable Artifacts one may primarily differentiate between
- Demand Capabilities
- Supply Capabilities
- Mediation Capabilities

The Demand Capabilities represent all that an Actionable Artifact can do to handle demands issued to it, the Supply Capabilities represent all that an Actionable Artifact supplies and, finally, Mediation Capabilities represent all that an Actionable Artifact can do to handle all the demands for the mapping of Demands and Supplies and from Supplies to Demands.

This classification may then be further refined, for instance, as follows:

- Demand Capabilities
  - Capabilities to accept new types of Demands (as introduced with the telephone network sample)
  - Capabilities to handle Requests for the availability of an accepted Demand
Supply Capabilities
- Capabilities to accept new types of Supplies (as introduced with the telephone network sample)
- Capabilities to enable the “uploading” of accepted Supplies
- Capabilities to handle the “uploading” of accepted Supplies

Mediation Capabilities
- Find Capabilities that are able to find an appropriate Supply to a requested use
- Matching Capabilities that are able to assign appropriate Supplies to match a requested use

Capabilities in a Capability Architecture may not be uniquely associated with one Actionable Artifact. A Capability named “Scheduling Support” may be a member of two Actionable Artifacts as defined below:

The Capability “Scheduling Support” may be a “component” in a “Railway Management Artifact” and a “member” in a “Process Management Artifact” at the same time. This indicates that classification may be based on different classification criteria, and it also indicates that classification may “overlay” in some of the Capabilities they comprise.
5.1.2 Capability Description

Capabilities are meant to be described as follows:

“Capability”:: = “Capability Name”;  
“Capability Name”:: = “Term”

Even though we will later introduce Capability Attributes that further characterize Capabilities, we assume that the concept behind Capabilities will be primarily understood intuitively by reading and interpreting its name in natural language. This, however, demands for the use of suggestive terms that will be commonly and correctly interpreted in the respective community of stakeholders.

**Capability Names**

Capabilities will be named by arbitrarily selected terms and concepts. The description of terms and concepts may be of different degrees of formality.

Just to identify capabilities is all one may want to represent in a first version of a profile.

Since capabilities are always associated with a particular Actionable Artifact, we will hence be able to describe them also by their identifiers and the identifier of the Actionable Artifact they are associated with:

The $i^{th}$ Capability $C^n_i$ of refinement level $n$ is associated with the $m^{th}$ Actionable Artifact $AA^n_m$ of refinement level $n$. It is obvious that the refinement level of Capabilities and the refinement level of the Associated Actionable Artifact must be the same. This will be shown in the following sample:
**Capability Attributes**

It will/may, however, not be sufficient to do just this but to also represent the profile in terms of “Capability Attributes” in which a term identifies the capability, and a collection of other terms represents attributes that may be associated with a capability. Attributes may then be abstract representations for some of the properties of the functions the capability represents. For example, attributes that represent the availability of a capability may be
- available at fixed points in time only
- available continuously
- available only at random
  etc.

Capabilities may be related with respect to their characterizing attributes. For instance, attributes that characterize the availability of a capability may be related to each other by constraining their availability with attributes like
- concurrently available
- sequentially available
- synchronized available
- scheduled available
  etc.
5.2 Actions of Information and Communication Service Infrastructures and of Actionable Artifacts

Actions are used to describe the “inside” of Capabilities. The description of the “inside” in terms of Actions is needed to understand the role that a Capability plays and to understand the relationships between Actionable Artifacts. Their full understanding is required to properly use or reuse an Actionable Artifact within another Actionable Artifact for which it has not been developed in the first place. The description of the Actions of a Capability documents the knowledge about “what” the Capability is able to do and how it does it.

Actions are, hence, “white-box” descriptions of infrastructures since they represent infrastructures by telling “what” they do and “how” they do whatever they do.

The picture indicates that a Capability provided by an Actionable Artifact is “implemented” by one Action provided “within” the Actionable Artifact. This simple 1:1 relationship between Capabilities and Actions is by no means mandatory. In fact, one Capability may be implemented by a set of Actions, and a number of Capabilities may be implemented with different subsets of the set of Actions provided inside the Actionable Artifact.

This corresponds to the notion of Cascaded Capabilities introduced above to represent the successive use of the capabilities of nested Actionable Artifacts.
In order to “implement” a Capability of an Actionable Artifact it may need to employ different Subordinate Actions in accordance with a certain order as represented above with the arrows between Actions.

Based on the computing model introduced for Actionable Artifacts above we assume that one Actionable Artifact may at any point in time during its execution stimulate the execution of another Subordinate Actionable Artifact and deliver a response to the first Actionable Artifact. In software engineering terms we call the relationship of that kind between Actionable Artifacts a “Use Relationship”. The term is meant to indicate that a “superior” Actionable Artifact is entitled to invoke a “subordinate” Actionable Artifact to receive a “return” from the invoked Actionable Artifact and that invocations and returns may be accompanied by data flows.
5.2.1 Actions of Actionable Artifacts

The generic term “Action” is introduced to enable a uniform description of a variety of “Executables”. We may, for instance, classify Actions as:

- Applications as Actions: They represent a level where end users of infrastructures will be interested in understanding Actions;
- Services as Actions: They are of interest at a level where application developers intend to use/reuse services across a number of applications;
- ICT Functions as Actions: They are of interest at the implementation level for infrastructures to identify software and hardware functions of concern in an infrastructure.

The description of Actions is expected to reveal insights about what a Capability and, hence, an Actionable Artifact can do, what it is expected to do. It must also reveals insights into what adjustments and adaptations must be made to enable the “replacement” of one Capability of an Actionable Artifact by another Capability of an Actionable Artifact.

5.2.2 Composition and Decomposition of Actions

Actionable Artifacts were introduced as being composed of building blocks that, themselves, are Actionable Artifacts again. This Composition/Decomposition of Actionable Artifacts was said to be implemented in terms of Compositions and Decompositions of Actions that the nested Actionable Artifacts comprise.
Compositions/Decompositions may be of different nature. The first differentiation will be between flat and nested Compositions/Decompositions.

Flat Compositions are of the kind where Actions are related with each other in a flat precedence relationship.

The precedence relationship depicted above is one where two Actions are related through their output and input: The output of the one Action is the input of the other Action and defines, hence, a precedence between the two Actions.

Nested Compositions/Decompositions are of the kind where one Action comprises other Actions as SubActions and, hence, the superior and the subordinate Actions are in nesting relationships.
The nesting relationship depicted above is one where a superior Action comprises two subordinate Actions.

A sample composition/decomposition of Actionable Artifacts and their constituent Actions may be drawn as follow:
If R is the nesting relationship between AA^0 on one hand and both, AA^{-1}_1 and AA^{-1}_2 on the other hand, and if R is the Composition Relationship, this Composition of Actionable Artifacts determines the respective Composition/Decomposition of Actions as follows:

A^0 of AA^0 is composed of
A^{-1}_1 of AA^{-1}_2 and of
A^{-1}_{21} of AA^{-1}_2 and A^{-1}_{22} of AA^{-1}_2

This indicates also, for instance, that the two Actions A^{-1}_{21} and A^{-1}_{22} are meant to be executed in sequence.

5.2.3 Common Actionable Artifacts, Common Capabilities and Common Actions

Infrastructures are usually built to enable the use of subordinate Actionable Artifacts in not just one but in a set of superior Actionable Artifacts.

We will call the Actionable Artifacts that will be used in more than one superior Actionable Artifact “Common Actionable Artifacts”.

The Composition/Decomposition Relationship will then not be presentable as a tree anymore but will be a directed acyclic graph. This extension of the Composition/Decomposition concept will then also carry over to the Composition and Decomposition of Actions. The extension has – as we will see later on when we discuss Action Attributes and especially the Action Attribute “Process” – far reaching consequences.
5.3 Action Attributes

Actions are characterized by a set of Attributes. In addition to a representation of its identity by a name, an Action will be characterized by five attributes that are meant to reflect five different questions one may want to ask about Actions.

![Diagram of Action Attributes]

The questions posed are:

The “Why” Question
With the “why” question we ask for the reasons and rationale for the existence of an Action or – if the Action does not exist yet – for the desire to have it.

The “Who” Question:
With the “who” question we ask for who – humans or other Actions – has an interest in the Action and what the respective interest is: for instance, as a user, developer, operator, etc.

The “What” Question:
With the “what” question we ask for what the Action will produce as a result whenever it is conducted.

The “With” Question:
With the “with” question we ask for the Enablers (e.g., resources, support) required to conduct the Action.
The “How” Question:
With the “how” question we ask how the Action is being conducted, what steps constitute the Action and in what order will the steps be applied to conduct the Action.

The Attributes that we will introduce to reflect the different questions will be:

Objective / Purpose
as the answer to the “why” question

Stakeholder
as the answer to the “who” question

Delivery
as the answer to the “what” question

Enabler
as the answer to the “with” question

Process
as the answer to the “how” question

The Attributes have been chosen to reflect the questions that (re)users may pose to the owners to find out as to whether an Actionable Artifact or its Capabilities and Functions meet the expected characteristics of the Actionable Artifact.

5.3.1 Attribute Relationships

This will then lead to the following model for the characterization of Actions that will be representing the respective Attributes and Relationships between Attributes:
The model indicates that the Attributes do not exist in isolation but are related in particular ways.

The “Objective / Purpose” Attribute is related to the “Stakeholder”, “Delivery”, and “Process” Attributes to indicate that the “Objective / Purpose” of an Action determines in one way or another the “Stakeholder”, “Delivery”, and “Process”.
The Relationship “determines” – as depicted – a binary relationship since it is quite possible and reasonable that “Stakeholder”, “Delivery”, and “Process” determine the “Objective / Purpose”.

The “Enabler” Attribute is related to the “Stakeholder”, “Delivery”, and “Process” Attributes to indicate that the “Enabler” for an Action provides in one way or another the “help” from outside of the Action that is required by “Stakeholder”, “Delivery”, and “Process” for conducting the Action.
The Relationship “provides” is depicted as a binary relationship since it is quite possible and reasonable that “Stakeholder”, “Delivery”, and “Process” also provide “help” to the outside Enablers in their use for conducting the Action.

The “Stakeholder”, “Delivery”, and “Process” Attributes are related to indicate that “Stakeholder” may have a role in conducting the “Process” and that “Process” is meant to “produce” the “Delivery” as expected.
The Relationship “conducts” is depicted as a unary relationship to indicate that “Stakeholder” invokes “Process” and that “Process” produces the “Delivery”.

5.3.2 Attribute Instances

Attributes will be represented in terms of Attribute Instances (i.e., “Attribute Values”). The Attribute “Stakeholder” may be represented by the Instances “Paul”, “Company X”, “Component X”, etc. The example already indicates that every Attribute may carry one or a set of Instances from a “Domain” of the Attribute. This then leads to the following Attribute Instance Model:
The picture represents the fact that an Action may be characterized by
- Multiple Objectives / Purposes
- Multiple Stakeholders
- Multiple Deliveries
- Multiple Enablers
- Multiple Processes

The picture does not explicitly represent which one of the Instances out of the sets of Instances of one Attribute is related to which other Instance of another Attribute. To define this will be left to the tabular representation of Attributes and Attribute Instances.

5.3.3 Attribute Refinements

In the same way as one composes and decomposes Actions one may as well want to compose/decompose Attributes. The Attribute “Stakeholder” may, for instance, be represented by the SubAttribute “User”, “Developer”, “Operator”. The SubAttributes may, in turn, be decomposed into SubSubAttributes, etc. which ultimately leads to the extension of the Attribute into an Attribute Refinement Tree:
The previous elaborations about Actions, Action Attributes, and Attribute Instances in the context of hierarchical breakdowns of Actions into SubActions lead now to an important conclusion: The set of Attribute Instances of a set of subordinate Attributes constitutes the Attribute Instance of the adjacent superior Attribute as shown in the following example:
One may conclude that the “User” Attribute carries the set of Attribute Instances (Paul, Company X), whereas the “End User” Attribute carries the Attribute Instance “Paul” and the “Sales Department” SubAttribute carries the Instance “Company X”.

5.3.4 Processes and Process Hierarchies

The previous section of this monograph introduced Action Attributes and especially also the Action Attribute “Process”. Processes were meant to describe how Actions may be executed after their enactment. Processes define the steps taken in the execution of an Action and the order in which these steps will be executed. Processes may hence be defined as a set of steps representing all the executions required to execute the Action and an Ordering Relationship defining execution orders.
The picture above suggests that Steps are executed in a linear order. We will later on show how processes may be executed following more elaborate orderings.

As Actions are meant to be composable/decomposable, we also assume that Processes must be composable/decomposable. We may think now of the Steps in a Process as Subordinate Processes.
The ordering of Steps, respectively SubProcesses in a Process, may now be defined by very different kinds of ordering relationships. The approach taken here is to specify all permitted orderings of Steps/Subordinate Processes. This will be achieved with “Path Expressions” that specify all permitted execution schedules for the set of Steps/Subordinate Processes of an Action.
Path expressions that are capable of expressing permitted execution schedules for two Steps/Subordinate Processes in an Action may be introduced with the following table:

A more detailed discussion of execution orders for Steps/Subordinate Processes of Actions are beyond the scope of this monograph.
6 Infrastructure Description Frameworks

The comprehensive description of Information and Communication (Service) Infrastructures in a schematic manner is the ultimate goal meant to be achieved with their profiling. The schematic description is meant to be represented as structured data that can be stored and managed with the aid of (relational) database management systems.

Actionable Artifacts were introduced as the unifying denotation for all kinds of Building Blocks of Information and Communication (Service) Infrastructures. Actionable Artifacts which, in turn, were defined as entities capable of providing and executing Actions and Action Compositions.

Action Attributes were introduced to also characterize Actions and Action Compositions to represent metadata about them: (I) What is the objective set forth for an Action; (II) who are the stakeholders related to an Action; (III) what is the delivery that results from an execution of an Action and (IV) what are the enablers needed to execute an Action; (V) how can Actions be executed as specified with a process that defines permitted schedules for their execution.

With these ingredients the schematic representation may be depicted as a table in which the one dimension represents the “Infrastructure Breakdown Structure” and the other dimension represents the Attributes associated with the respective Action. As indicated at the beginning of this report, profiling may differentiate between societal, economic and technical infrastructures that may all be described uniformly as profiles with their respective Action Compositions and their associated Attributes as depicted below.
<table>
<thead>
<tr>
<th>Sub-Sub-Objective</th>
<th>Sub-Objectives</th>
<th>Objectives</th>
<th>Mediation</th>
<th>Component</th>
<th>Component</th>
<th>Infrastructure</th>
<th>Demand</th>
<th>Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>
If the different types of Information and Communication (Service) Infrastructures, societal, economic and technical, are all meant to denote the same part of the reality, their schematic description will reveal the interdependencies between their characterizing Attributes and, hence, enable the checking of their compatibility.

The Action Compositions depicted in the schematic description above also indicate that Action Attributes may be decomposed as well to enable the refinement of the characterization of the respective Action or Action Composition. The following picture shows that schematic descriptions may also be extended to enable the representation of yet “unspecified” Action Attributes.
## Objectives

<table>
<thead>
<tr>
<th>A.1.1</th>
<th>A.1.2</th>
<th>A.1.3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>A.2.1</th>
<th>A.2.2</th>
<th>A.2.3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Stakeholders

<table>
<thead>
<tr>
<th>A.3.1</th>
<th>A.3.2</th>
<th>A.3.3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Deliverables

<table>
<thead>
<tr>
<th>A.4.1</th>
<th>A.4.2</th>
<th>A.4.3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Processes

<table>
<thead>
<tr>
<th>A.5.1</th>
<th>A.5.2</th>
<th>A.5.3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Enablers

<table>
<thead>
<tr>
<th>A.6.1</th>
<th>A.6.2</th>
<th>A.6.3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Actions

<table>
<thead>
<tr>
<th>AA.1</th>
<th>AA.2</th>
<th>AA.3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

© Copyright Prof. Dr. Herbert Weber
The schematic description as introduced above will be called “Infrastructure Description Framework”. An Instance of the Infrastructure Description Framework for a particular infrastructure or for a particular type of infrastructure will be developed by filling the schema with a particular Action breakdown structure, a particular breakdown structure for the associated Action Attributes and a filling of the schema with particular Action Attribute Instances in the respective elements of the schema denoting the characteristics of the respective Action. Action Attribute Instances will be any kind of term that would adequately characterize an Action by the respective Action Attribute.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Stakeholder</th>
<th>Delivery</th>
</tr>
</thead>
<tbody>
<tr>
<td>A^x_mn: Database Access</td>
<td>John</td>
<td>Data Selection x</td>
</tr>
<tr>
<td>A^x_mk: Database Access</td>
<td>Fritz</td>
<td>Data Selection y</td>
</tr>
</tbody>
</table>

It is obvious that the refinement of profiles will expand the schematic description of Actions and, hence, of Actionable Artifacts significantly. It is, therefore, a matter of pragmatics to decide what level of refinement is necessary to meet the respective purpose for the profile of an infrastructure.

For a very coarse grain representation of Infrastructures this monograph provides in Attachment 3 a proposal for Services and Service Compositions that constitute a Service Infrastructure.
Autonomous and Semi-Autonomous Systems as an Extended Computing Model for Information and Communication Service Infrastructures

The previous discussion of profiles and profiling suggested that Actionable Artifacts are the computing model for single Actions. In reality, Building Blocks of Information and Communication Service Infrastructures may “embrace” a set or – as we say – a Cluster of Actions in which each Action may be performed independently of all the other Actions in the Cluster or interrelated with some or all of the other Actions in the Cluster. The following pictures depict the different possible settings:

An Action in the Action Cluster may be enacted without any reference to another Action in the Action Cluster and may not produce any side effects on any other Action in the Action Cluster. Otherwise, an Action in the Action Cluster may be enacted without any reference to another Action in the Action Cluster, but produce side effects on other Actions in the Action Cluster by receiving or delivering data from/to other Actions in the Action Cluster or by changing data that are shared between all or some of the Actions in the Action Cluster.

Otherwise, an Action in the Action Cluster may be enacted without any reference to another Action in the Action Cluster, but produce side effects on other Actions in the Action Cluster by receiving or delivering data from/to other Actions in the
Action Cluster or by changing data that are shared between all or some of the Actions in the Action Cluster.

The side effect depicted above corresponds to the previously introduced compositions of Actions with the indication that stimuli and responses are associated with data receptions and deliveries.
The side effect depicted above is due to the change of Shared Data (SD) by both, Action 1 and Action 2.

For Action Clusters – as introduced so far – we assume that none of the Actions of the Action Cluster produces any side effects on Actions outside the Action Cluster. We, hence, call the Action Cluster an “Autonomous System (SA)”.

Many, if not most, Actions implemented in Building Blocks of Information and Communication Service Infrastructures will, however, produce side effects on Actions implemented in other Building Blocks not belonging to their own Cluster of Actions of their “own” Building Blocks. This requests for the extension of the Actionable Artifacts computing model that will be called “Semi-autonomous Systems”. Semi-autonomous Systems will comprise one or a set of independent or dependent Actions and refer to other Semi-autonomous Systems.
The kind of references $R$ that may exist between Actions of different Semi-autonomous Systems may be the same as the ones that may exist within an Autonomous System. They will be explained in more detail in the sequel.

7.1 Control Flow between Actions

A “Control Flow” between Actions will take place if one Action is capable of enacting another Action.
The picture indicates that execution control “moves” from one Action to the next Action. The mechanisms that provide that capability may be mechanisms like

- procedure call
- remote procedure call
- any protocol-governed passing of control etc.

Since Actionable Artifacts and, therefore, also Actions are structured horizontally and vertically, control flows may also differentiate between the two. A horizontal control flow between two Actions as depicted above may be extended to show both, horizontal and vertical control flows.
The picture indicates that Action $A_1$ is built of SubActions $SA_{11}$ and $SA_{12}$. The completion of $A_1$ depends – according to this picture – on the completion of both, SubActions $SA_{11}$ and $SA_{12}$. For their completion $A_1$ will have to pass control to $SA_{11}$ and to $SA_{12}$ and $SA_{11}$ and $SA_{12}$ will have to pass control back to $SA_1$ (this corresponds to a procedure call communication between $A_1$ and $SA_{11}$ and $SA_{12}$).

For the use/reuse of Actionable Artifacts one needs to identify and understand the Control Flow mechanisms since the use/reuse of Actionable Artifacts depends on the compatibility between the expected and the provided Control Flow mechanisms.

The subsequently shown table could be used to record control flow relationships between Actions.
7.2 Data Flow between Actions

The Interoperation mechanism may be abstractly characterized as one that is capable of establishing a “Data Flow” between Actions.
The picture indicates that data moves from one Action to the other Action. The picture also indicates that Data Flow can only take place in the presence of Control Flow. The mechanisms that provide the capability for Data Flow are mechanisms like

- message passing
- mail attachments
- file transfers
- etc.

For the use/reuse of Actionable Artifacts also Data Flow mechanisms existing between Actions have to be identified and understood.

The subsequently shown table could be used to record data flow relationships between Actions.
7.3 Data Dependencies between Actions

Interoperation may also take place in an indirect way if two Actions have access to and use the same data.

The one Action may place data into the common data store and the other action may use this data. This kind of Interoperation represents a side effect between the
two Actions. Acquiring knowledge about possible side effects is an essential task in the profiling of Actionable Architecture since they will create unexpected interferences between Actionable Artifacts if they are not fully discovered and understood.

Interconnections and Interoperation will have to be recorded in the profile repository. Their subsequent representation in tabular form will be a logical Data Model for their representation in a repository.

The subsequently shown table could be used to record data dependency relationships between Actions.

![Logical Data Model](image)

**Logical Data Model for the Representation of Information about Infrastructure Classes**

The information collected about Actions may be placed in the data repository for their later use and update. In order to store the information we propose to use the simple tabular schema above as the “logical data model” for the representation of the information that can be mapped into a spreadsheet structure or to a Relational Database Schema.
8 Profiling Procedures

It is very obvious from the explanations above that the development of a profile will be quite an effort and that it would be advisable to conduct the task in stages. For that purpose the profiling methodology will introduce a number of terms and concepts that support this staged approach to their development in the next section.

Profiling is expected to collect the essential characteristics of an infrastructure. We will have to cope with the fact that profiles can only be developed in an iterative fashion by starting with an initial profile that will get refined and completed as we look at more and more details. We will, therefore, have to differentiate between “deep drill” profilings and “long tail” profilings.

“Deep drilling” will always be based on clarification dialogues between infrastructure owners and profilers. “Long tail” will probably be possible with “tick box” multiple choice questionnaires.

Profiling of infrastructures and Actionable Artifacts is hence seen as a continuous completion and a continuous refinement process.

It has already been indicated that the development of Profiles will take place in stages:
- Identification of Infrastructures
- Identification of Artifacts that constitute the Infrastructure
- Identification of Capabilities of the Artifacts constituting the Infrastructure
- Specification of Actions implementing the Capabilities of Actionable Artifacts

Stage 1

Stage 1 captures information about infrastructures that are required to develop a first classification of infrastructures

Stage 1 differentiates, therefore, between infrastructures like
- Societal Infrastructures that are built to deliver value to the society at large or to communities in the society
- Economic Infrastructures that are built to deliver value to the economy at large or to particular institutions and enterprises
- Technical Infrastructures that are built to deliver value by supporting economic and societal activities

The description of Information and Communication Service Infrastructures in stage 1 will be based on a number of “Infrastructure Attributes”. The “Infrastructure
Attributes” will serve in the identification and basic characterization of the respective Information and Communication Service Infrastructure.

“Infrastucture Attribute”

- Stakeholder
  Who has an interest in the Information and Communication Service Infrastructure
  - Owner
  - Provider
  - Operator
  - User
  - Developer
  etc.

- Objective/Purpose
  What is the objective/purpose of the existence of the information and communication infrastructure in terms of its
  - Availability for its Users
  - Availability for the interfacing with other information and communication infrastructures
  - Availability for the interoperation with other information and communication infrastructures
  etc.

Stage 2

Stage 2 introduces “Actionable Artifacts” as the building blocks of Information and Communication Service Infrastructures. “Actionable Artifacts” are introduced as a common descriptive term and concept for the many different types of building blocks that constitute an Information and Communication Service Infrastructure. This common descriptive term and concept indicates that all “Actionable Artifacts” will be described uniformly. This enables the description of all types of infrastructures introduced in stage 1 in exactly the same way.

It then enables the uniform description of different types of Computing Artifacts like data management systems, ERP systems, computer communication systems etc.

The description of Information and Communication Service Infrastructures in stage 2 will be based on the term and concept of “Capabilities”. Capabilities are denotations for what an Actionable Artifact is capable of doing – what actions it is capable of conducting.

Capabilities are an “outside” view at an Actionable Artifact. They do not reveal information on how the Actionable Artifact conducts Actions.
Capabilities represent the “potential value” of Actionable Artifacts to their stakeholders, they also serve in the mapping of stakeholder requirements and offers provided.

In order to support the search for appropriate Actionable Artifacts, the Profiling Methodology provides for a “Capability-based Classification” of Actionable Artifacts.

The classification of Capabilities may, however, also relate to the Infrastructure Attribute “Objective/Purpose” or “Availability” introduced in stage 1. Insofar stage 2 does not introduce any new terms and concepts but is based on the same Attributes that were introduced to characterize infrastructures. It is, however, left to the profiler to decide on other “Capability Attributes” that might be necessary to classify Capabilities in other ways.

Stage 3

Stage 3 introduces “Actions” as “Abstract Implementations” of Capabilities. They represent the “inside” view at Actionable Artifacts. In order to serve as abstract implementations for Capabilities, Actions will be characterized with a set of five different “Action Attributes”:

- Objectives/Purposes of the Actions
- Stakeholders of the Actions
- Deliveries of the Actions
- Enablers of the Actions
- Processes that govern the conduct of the Actions

These five Attributes are meant to answer the following questions about Actions:

- Why is the Action being defined (Objective/Purpose)?
- Who has an interest in that Action (Stakeholder)?
- What is the Action providing as a response (Delivery)?
- With what support can the Action be conducted (Enabler)?
- How is the Action being conducted in steps (Process)?

The description of Information and Communication Service Infrastructures in stage 3 is – as one can easily conclude – meant to be used for a very detailed description of their Actionable Artifacts.

Since both, the Actions and Action Attributes may be hierarchically composed, the tabular description of Actionable Artifacts and infrastructures ends up with a “nonnormalized” table.

The first three will most likely be essential for any Profiling of Infrastructures, the fourth one will be required whenever detailed information is required in order to enable the use/reuse of Actionable Artifacts in different Infrastructures.
We hence propose to distinguish between “Quick-checks” that will encompass the first three stages.

The picture is meant to indicate that infrastructures will be identified in quick-checks, and the identification of Actionable Artifacts, of their Capabilities, and of Actions will be conducted in full range profilings.

This staged approach to the profiling of Information and Communication Service Infrastructures may then be depicted with the following diagram:
9 Conclusion

The previous sections introduced quite a number of terms and concepts for the characterization of infrastructures that are not necessarily common sense for all stakeholders of the one or other kind of infrastructure. That does not come as a surprise since infrastructures require for their characterization the intellectual capabilities and technical competencies of different disciplines. For information and communication infrastructures for instance information technology and communication technology experts often use the same terms but associate a complete different semantics with these terms. Nonetheless, their communication and mutual understanding is essential to jointly develop technical solutions that depend on competencies of both domains. Many attempts are being made and many more are demanded to get to a better understanding and an easier communication by equipping them with vocabularies, taxonomies or ontologies. Some of these attempts have been successful, others have failed or have been forgotten. The attached appendices will hopefully help in that respect:

- Appendix 1 will introduce Profiles and the Profiling Methodology in general terms and will explain their expected use with a set of PowerPoint slides (“Profiling of Information and Communication Infrastructures and their Application Environment”).

- Appendix 2 will introduce the notation introduced for the description of profiles as a “picture book” in a more formalized form (“Methodology for the Profiling of Information and Communication Infrastructures”).

- Appendix 3 introduces a taxonomy of terms relevant to the Future Internet in its various facets (“Taxonomy of Concepts for the Future Internet of Services”).

- Appendix 4 introduces the taxonomy of terms as a “picture book” in a more formalized form (“Work in Progress: Conceptual Reference Framework for the Future Internet”).
Acknowledgement

The Profiling Methodology introduced in this monograph is for its large part based on previous software engineering research and good practices developed over many years. It especially benefits from very early research on functional descriptions of software. It would be impossible to compile a bibliography that would give reference to all that work. Readers may for themselves judge what part of the work deserves to be called original.
PROFILING

of

Information and Communication Service Infrastructures

and their

Application Environment

Part 1
The subsequently provided PowerPoint presentation is a corrected and extended version of Task T3.2, Deliverables, “Methodologies for Infrastructure Profiling” of the Project “INFINITY – INfrastructures for the Future Internet CommuNITY as part of the Future Internet Public-Private Partnership Contract Number 285192 of the European Community.
Methodologies for Infrastructure Profiling

Prof. Dr. Herbert Weber
March 2013
THE ICT TOWER OF BABEL

Nonprofessionals

Models

Algorithms Programs Designs Architectures Requirements

Specifications

Professionals

LOST IN TRANSLATION
THE ICT TOWER OF BABEL

PROFILING:
THE HUNT FOR THE
„GREATEST COMMON FACTOR“
IN THE
MULTITUDE OF LANGUAGES
PROFILING: WHY?

TO ENABLE THE PROPER UNDERSTANDING OF INFRASTRUCTURES AND THEIR RESPECTIVE APPLICATION ENVIRONMENT
PROFILING: WHY?

TO

UNAMBIGUOUSLY COMMUNICATE

ABOUT

ICT INFRASTRUCTURES AND THEIR RESPECTIVE APPLICATION ENVIRONMENT
PROFILING: WHY?

FOR

STANDARDIZED

DESCRIPTIONS

BENCHMARKS

EVALUATIONS

AUDITS

OF

INFORMATION AND COMMUNICATION

TECHNOLOGIES

AND THEIR RESPECTIVE

APPLICATION ENVIRONMENT
PROFILING: WHY?

FOR SUSTAINABLE DOCUMENTATION OF INFRASTRUCTURES AND THEIR APPLICATION ENVIRONMENT AS STRUCTURED INFORMATION IN COMPUTER-SUPPORTED DATA REPOSITORIES
PROFILING: WHAT?

HIGH-LEVEL
UNIFORM
UNAMBIGUOUS
DESCRIPTION OF INFORMATION AND COMMUNICATION INFRASTRUCTURES AND THEIR RESPECTIVE APPLICATION ENVIRONMENT
PROFILING: WHAT?

DESCRIPTION OF INFORMATION AND COMMUNICATION INFRASTRUCTURES AND THEIR APPLICATION ENVIRONMENT ALONG THREE DIFFERENT DIMENSIONS

© Copyright 2014 Prof. Dr. Herbert Weber
PROFILING: WHAT?

AN OUTSIDE-IN LOOK AT INFORMATION AND COMMUNICATION INFRASTRUCTURES AND THEIR RESPECTIVE APPLICATION ENVIRONMENT AS DEEP AS NEEDED AND AFFORDABLE
PROFILING METHODOLOGY: WHAT?

Profiling as a way to describe systems like

» Organizational Systems
» Technical Systems
on
» Different Levels of Granularity and Virtualization
in a
» Uniform Notation at Different Levels of Abstraction
PROFILING: HOW?

Granularity

Virtualization

Abstraction

Infrastructures

Systems

Components

Services

Applications

Specifications

Blueprints

Landscapes

Hardware and Software Units

innova

© Copyright 2014 Prof. Dr. Herbert Weber
PROFILING: HOW?

PROFILES OF INFRASTRUCTURES AND THEIR APPLICATION ENVIRONMENT ON DIFFERENT GRANULARITY LEVELS IN TERMS OF COMPONENTS, SYSTEMS, INFRASTRUCTURES
PROFILING: DELIVERIES

PROFILES OF INFRASTRUCTURES AND THEIR APPLICATION ENVIRONMENT ON DIFFERENT VIRTUALIZATION LEVELS AS HARDWARE / SOFTWARE SERVICES APPLICATIONS
PROFILING: DELIVERIES

PROFILES OF INFRASTRUCTURES AND THEIR APPLICATION ENVIRONMENT ON DIFFERENT ABSTRACTION LEVELS AS LANDSCAPES BLUEPRINTS SPECIFICATIONS
PROFILING: HOW?

RETROSPECTIVE PROFILING
FOR THE HIGH-LEVEL ANALYSIS OF INFRASTRUCTURES AND
THEIR RESPECTIVE APPLICATION ENVIRONMENT

PROSPECTIVE PROFILING
FOR THE HIGH-LEVEL PLANNING OF INFRASTRUCTURES
AND THEIR RESPECTIVE APPLICATION ENVIRONMENT

FOR THE EVALUATION OF INFRASTRUCTURES AND THEIR
RESPECTIVE APPLICATION ENVIRONMENT
PROFILING: DELIVERIES

PROFILES
AS
DURABLE ASSETS
IN AN
INFRASTRUCTURES AND APPLICATION ENVIRONMENT
KNOWLEDGE BASE
On the highest level of abstraction profiles will be described as

» **Landscapes**

of ICT artifacts delivering a

» **Capability View**

of the ICT artifacts
PROFILING METHODOLOGY: HOW

On a lower level of abstraction profiles will be described as

» Blueprints of ICT artifacts delivering a

» Functional View of the ICT artifacts
On the lowest level of abstraction profiles will be described as

» Specifications

of ICT artifacts delivering a

» Technical View

of the ICT artifacts
Behavior of ICT artifacts will be expressed in terms of

» Data Flows between Actions

that will be performed during the execution of the ICT artifacts
A „VENDOR“-INDEPENDENT STANDARDIZED DESCRIPTION OF INFORMATION AND COMMUNICATION INFRASTRUCTURES AND THEIR APPLICATION ENVIRONMENT
PROFILING

of

Information and Communication Service Infrastructures

and their

Application Environment

Part 2
The subsequently provided PowerPoint presentation is a corrected and extended version of Task T3.2, Deliverables, “Methodologies for Infrastructure Profiling” of the Project “INFINITY – INfrastructures for the Future Internet CommuNITY as part of the Future Internet Public-Private Partnership Contract Number 285192 of the European Community
Methodologies for Infrastructure Profiling

Prof. Dr. Herbert Weber
March 2013
Partners in INFINITY
Profiling of Information and Communication Infrastructures at a Glance
Profiling Methodology: Why

- Documenting
- Describing
- Modelling

- Understanding
- Evaluating
- Compatibility / Incompatibility
- Consistency / Inconsistency

- Comparing
- Similarities
- Differences
- Equivalence
Profiling Methodology: What

Profiling as a way to describe systems like

» Organizational Systems

» Technical Systems

on

» Different Levels of Granularity and Virtualization

in a

» Uniform Notation at Different Levels of Abstraction
Profiling Methodology: What is it?

Profiling is a notation and a method for the

» **High-level Description of Artifacts**
   that will take place in the course of an

» **Outside-in Analysis of their**
   **Structure and Behavior**
Profiling Methodology: What

Profiling is meant to be used

» Retrospectively

in the

» Understanding and Documentation of Artifacts

and for the

» Analysis and Positioning of Artifacts within a Reference Framework
Profiling Methodology: What

Profiling: What for?

Profiling is meant to be used

» Prospectively

in the

» Capture and Documentation of Requirements for Artifacts

and for the

» Analysis and Positioning within a „Requirements Architecture“
Profiling Methodology: How

Granularity

Infrastructures

Systems

Components

Hardware and Software Units

Specifications

Blueprints

Landsales

Virtualization

Applications

Services

Abstraction
Profiling Methodology: How

Landscape as a Profile

On the highest level of abstraction profiles will be described as

» Landscapes of ICT artifacts delivering a
  » Capability View of the ICT artifacts
Landscape as a Profile

Profiles on the highest level of Abstraction are

» **Structure Descriptions as Landscapes of Artifacts**

that represent the

» **Building Blocks of Artifacts**

and

» **Interoperation Relationships between Building Blocks**
On a lower level of abstraction profiles will be described as

» Blueprints of ICT artifacts delivering a

» Functional View of the ICT artifacts
Profiling Methodology: How

Profiles on the next lower level of Granularity are

» Structure Descriptions as Blueprints of Artifacts that represent the

» Functional Breakdowns of Artifacts and

» Interoperation Relationships between Functions
Profiling Methodology: How

On the lowest level of abstraction profiles will be described as

» Specifications
of ICT artifacts delivering a

» Technical View
of the ICT artifacts
Profiling Methodology: How

Profiles on the lowest level of Abstraction are

» Specifications of Functions of Artifacts

by means of

» A Fixed Set of Features
Profiles are also

- Behavior Descriptions across all Granularity and Virtualization Levels

in terms of

- Data Flow Relationships between Artifacts
Behavior will be represented as

» Tabular Data Flow Schemas
PROFILING
of
Information and Communication Service Infrastructures
and their
Application Environment
Part 3
The subsequently provided PowerPoint presentation is a corrected and extended version of Task T3.2, Deliverables, “Methodologies for Infrastructure Profiling” of the Project “INFINITY – INfrastructures for the Future Internet CommuUNITY as part of the Future Internet Public-Private Partnership Contract Number 285192 of the European Community
Methodologies for Infrastructure Profiling

Prof. Dr. Herbert Weber
March 2013
Partners in INFINITY
Contents

Actions as Entities
Process and Process Compositions
Composed Actions
Action Model Abstractions
Action Behavior
Side Effect and Impact Management
Actions as Entities
Entity-Relationship models have been introduced to describe

» Data Entities
and will now be used to describe

» Process Entities
» Action Entities
» Task Entities
» etc.
Action Model

An Action is an Executable of the kind

» Stimulus.Execution.Response

like

» Invocation.Execution.Result

» Start.Execution.Stop

» Start.Execution.Preemption ...

» etc.
Action Model

Action Entities represent Actions as
- Executable Units that will usually exist in
- Relationships with other Action Entities
Relationships represent Links from / to Actions to express

» Precedence Relationships like
» precedes, succeeds
» initiates, triggers, invokes
» interrupts, preempts, terminates
» etc.
Action Entities are

» Autonomous Actions if they are not related to other Action Entities

or

Action Entities are

» Semi-Autonomous Actions if they are related to other Action Entities in

» Action Relationship Networks
Semi-Autonomous Actions are Actions that exist in an environment constituted of the set of all Linked Actions and Semi-Autonomous Actions will always have to be conducted in compliance with all the Relationships with its environment.
Action Model

Attributes

Attributes characterize an Action to enable the

» Understanding of an Action

by explaining

» What are the Characteristics of an Action
An Action carries a fixed set of Attributes to represent the

» Characteristics of the Action
and

» Dependencies between Attributes

Attributes

Action Model
Profiling Methodology: What

Questions to be posed about an Infrastructure

- Why has it been developed, i.e., its purpose/objective?
- Who are its stakeholders?
- What will it deliver when it is used?
- Which enablers are required to use it?
- How is it conducting its jobs?
Profiling Methodology: What

Profiling

Questions to be posed about the

» Relationship between its characterizing Attributes
to understand the

» Dependencies between characterizing Attributes
Action Model

Attributes

O: Objective/Purpose  What is the objective/purpose of this Action?
S: Stakeholder      Who has a stake in this Action?
D: Deliverable      What is the Action expected to deliver as a result?
P: Process          How is the Action conducted and what processes will be executed?
E: Enabler          What Enablers are required to conduct an Action?
T: Time             What are possible time constraints for conducting the Action?
L: Location         What are location constraints for conducting the Action?
The Contour of an Action will be represented by the R, S, D, E, T, L Attributes that all represent requirements posed upon an Action.

- **O**: Objective / Purpose
- **S**: Stakeholder
- **D**: Deliverable
- **P**: Process
- **E**: Enabler
- **T**: Time
- **L**: Location
Contour Attributes characterize the

» Interfaces of an Action with its Environment

across the Links to other Actions in order to express the

» Constraints that Actions pose upon each other
Process
and
Process Decomposition
Action Model

Processes

One of the Attributes of an Action characterizes the

» Behavior of an Action

in terms of

» Processes

that will be performed in the conducting of the Action
“Process” is defined as an

» Ordered Set of Steps

that will be executed

» From the Stimulation of the
Execution of the Process until the
Delivery of a Response
Processes and Process Decompositions

"Process" is defining the

» Execution of an Action in terms of Execution Orders for Subordinate Actions of an Action
An Execution Order is defined as being a

» Schedule for the Execution of Subactions of an Action

or as being a

» Path Expression for the Description of all Permitted Schedules for the Execution of Subactions of an Action
Processes and Process Decompositions

Schedules

A Schedule defines an Execution Order in terms of

» Precedes / Succeeds Relationships between (Sub)Actions of an Action
Path Expressions

A Path Expression defines the

» Set of Permitted Execution Schedules

in terms of

» Actions and Scheduling Operators
Processes and Process Decompositions

A Schedule Operator is a(n)

- **Sequence Operator** \((x;y)\)
- **Mutual Exclusivity Operator** \((x|y)\)
- **Concurrency Operator** \((x+y)\)
- **Optionality Operator** \(*x*\)
- **Simultaneity Operator** \({x}\)
- **Repetition Operator** \([x]\)
Composed Actions
Composed Action Models encompass both

» Composed Action Entities

and

» Basic Action Entities
Composed Actions are

- Encapsuled Submodels representing
- Compositional Abstractions of related Action Entities
Composed Actions are defined as

» Composition Relationships

that may be represented as

» Hierarchies of Action Entities
Compositional Actions

Composed Actions will be represented as

» Compositions of Attributes of the respective Subordinate Actions

or as

» Decompositions of Attributes into the respective Subordinate Actions
Compositional Actions

Compatible Contour Compositions

Compositions and Decompositions of Attributes will have to take place in

» Compatible Compositions and Decompositions for all the Contour Attributes

characterizing a Composed Action
Compositional Actions

Compatible Contour Composition

Composed Actions will be composed if they are

» Compatibly Composed for all of the Attributes

that characterize the Action
Compositional Actions

Compatible Process Compositions

Compositions and Decompositions of Attributes will have to take place in

» Compatible Compositions and Decompositions for its Process Attribute

colorizing the Composed Action
Compositional Actions

Compatible Enabler Compositions

Compositions and Decompositions of Attributes will have to take place in

» Compatible Compositions and Decompositions of the Enabler Attribute

classifying the Composed Action
Action Model Abstractions
Action Model Abstractions

The Landscape of a Composed Action represents its

» Structure in terms of Geometric Figures

together with a

» Depiction of the Set of Relationships between the Subordinate Actions
Action Model Abstractions

The Blueprint of a Composed Action represents its

» Structure in terms of a Component / Function Graph
together with a

» Depiction of the Set of Relationships between First-level Subordinate Actions
The Specification of an Action represents

» All the Attributes of an Action
together with a

» Decomposition of the Attributes into Subordinate Attributes
The Behavior of an Action is characterized by its

» Data Flow in terms of its Inputs, Outputs, and Inputs / Outputs
Action Behavior

Data Flow of Composed Actions

The Behavior of a Composed Action is characterized by its

» **Data Flow between the Superior and all its Subordinate Actions**
The Behavior of Related Actions may be defined as

» Consistency Preserving Transactions

for

» Data shared between the different Actions
Action Behavior

The Behavior of Composed Actions may be represented as a

» Precedence Graph

that represents the

» Data Flow between all Subordinate Actions
Side Effect and Impact Management
Executions of Related Actions may cause

» **Side Effects**
whose nature will depend on the

» **Type of Relationship**
existing between the Actions
Side Effect and Impact Management

Relationships and Side Effects

Relationships that cause Side Effects in the Execution of Actions may be of type

» $P_1 2 P_2 2 P_1$
» $S_1 2 P_2 2 S_1$
» $P_1 2 E_2 2 P_1$
» $S_1 2 D_2 2 S_1$
» etc.
Side Effect and Impact Management

Dependencies and Impacts

Dependencies may cause
- Impacts of Changes of Attributes on other Attributes

as, for example for

\[ R \xrightarrow{\text{changes}} R \]
Side Effect and Impact Management

Action Modeling also enables Dependencies between Attributes for each Action

» R2S2R, R2P2R, R2D2R
» S2P2S, P2D2P
» E2S2E, E2P2E, E2D2E

and

» S2R2S, S2P2S, S2E2S
» R2P2R, P2E2P
» D2R2D, D2P2D, D2E2D
Side Effect and Impact Management

Action Modeling enables additional Dependencies between Attributes for Location and Time-dependent Actions

- **T2R2T** → **L2R2L**
- **T2S2T** → **L2S2L**
- **T2P2T** → **L2P2L**
- **T2D2T** → **L2D2L**
- **T2E2T** → **L2E2L**
Summary

Profiling
Actions as Entities
Links as Relationships
Composed Actions
Fixed Set of Attributes
Dependencies between Attributes
Data Flows as Behavior