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# A METHOD TO CLASSIFY STANDARDS IN EMERGING TECHNOLOGIES: THE CASE OF CLOUD COMPUTING

*Complete Research*

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## Abstract

*Standards are an important part of any product or service as they impact many aspects such as interoperability, portability, and security. Hence, they constitute the cornerstone of any distributed, open, and flexible system – even more so for emerging technologies such as cloud computing as the rate of their adoption can heavily depend on it. Often there is a plethora of standards available and – despite their importance – accurate information that can be used to guide the selection of standards is missing. Selecting the wrong standards can increase cost, reduce uptake, profitability, or lead to a product or service being stuck in a niche. Selecting the right standards can result in as much as the exact opposite. Despite numerous efforts to create classifications of standards that should provide guidance for the selection of standards, there is a lack of conceptualization and methods on how to build standards classifications. In this paper, we provide a conceptualization of technology standards, which serves as the basis for our method to classify standards in emerging technologies (C-SET). The method provides a procedure to classify standards based on a conceptual data model and a stakeholder model. In doing so, C-SET provides the basis to structure the information that is required for an informed selection of standards in emerging technologies. In this paper, we illustrate C-SET referring to cloud computing as an example of an emerging technology.*

*Keywords: Technology Standard, Software Service Development, Standard Classification, Method Engineering, Cloud Computing*

## 1 Introduction

Standards provide rules, guidelines, or characteristics of products and services for common and repeated use (DIN, 2007). Standards appear in every aspect of life. They warrant product safety, build the basis for interoperability, or facilitate financial interactions. In software service development, standards regulate and ensure the quality of the development process and software services – in particular with respect to aspects such as interoperability, portability, and security. Standards often form the basis for technology development or capture best practices from successful technologies.

The research community has long neglected the economic and technical benefits that root from standards (Jakobs, 2000). In the past, the majority of research has been devoted to researching economic justification of spending on standardization, i.e. research on why standards are important and if so, how they can be developed to create maximum economic utility (de Vries, 1999, Tassey, 2000, Widjaja, 2010). Little research has been conducted, however, that focuses on the assessment of standards in the field of emerging technologies.

In established markets, the selection of standards can be comparably simple, as best practices are readily available and the market has matured so that the choice of standards is rather stable. In the context of emerging technologies, the selection of appropriate standards is more difficult as standards and the market are in constant flux and have not matured yet. Slow moving standards might be diminished or superseded by fast moving new standards, enabling or disabling access to certain customer groups. If laws or regulations do not dictate the choice of standards, the developers of products or services are required to choose from a plethora of technology standards. Selecting the wrong standards can entail additional cost for re-engineering products or services at a later stage or, ultimately, the selection might even decide over success or failure of the product or service. Cf. Figure 1 for a conceptual visualization of two exemplary competing standards. While standard ‘A’ was available earlier, it was maybe flawed or not supported by enough stakeholders. Hence, its uptake was very slow. Standard ‘B’ came only into play at a later stage. It was, however, more mature on arrival and had been supported by important stakeholders. Its uptake quickly surpassed standard ‘A’, making it obsolete so that it never entered a phase of post-dominance.

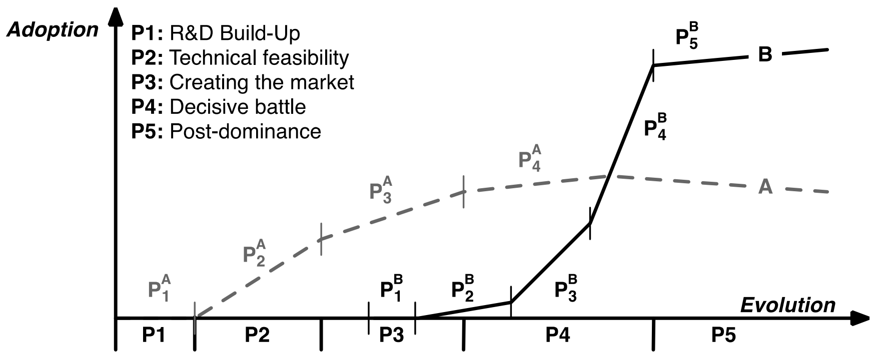


*Figure 1. Phases of Standards Competition*

Demanding for guidance on standards assessment is a typical behavior to counter inefficiencies in emerging technologies. Assessments include the determination of standardization needs, the evaluation of existing standards’ capability to fulfill a need, and also the identification of areas that need to be addressed by novel standards. While the future uptake of standards can hardly be predicted, this paper provides a method to prepare standards in emerging technologies such comparisons and evaluations.

Methodologies, frameworks, and tools that help standards developers, standards users, or policy makers to assess standards are few. Existing research works too specific for a particular technology (e.g., Pautasso et al., 2008) or technology field (for interoperability cf. Mykkänen & Tuomainen, 2008), provide historical backgrounds on technology evolution (e.g., Chen, 2003, Motahari-Nezhad et al., 2006), or research extension to existing standards (e.g., Nitzsche et al., 2008). Existing white papers describe procedures on how to select standards in development projects (de Vries & van der Zwan, 2008), but do not provide conceptualizations of the models and processes that are applied.

In this paper, we develop an approach to classify standards, technologies as well as their implementations. Our method is generic and can be used in different domains of emerging technologies. The method is intended to assist standardization stakeholders to better structure and assess the significance of relevant standards. This orientational knowledge builds the basis for standards developers, standards implementers, standards users, and policy makers to efficiently select a standard or a selection of standards based on their immediate needs. In order to demonstrate the relevance and usefulness of our approach, we have selected cloud computing as an emerging technology domain to exemplify and apply the general criteria we developed.

The rise of cloud computing over the past years is an example of such an emerging technology. Cloud computing enables on-demand provisioning of scalable, network-centric, abstracted IT infrastructures (IaaS), platforms (PaaS) and applications (SaaS) with a pay-per-use model, utilizing virtual processing and storage resources (Baun et al., 2011). On-demand network services have fundamentally changed the traditional model of self-hosted, self-owned IT solutions. In the big picture, cloud computing is, however, said to not leveraging its full market potential (European Commission, 2012), despite its appreciated benefits (European Network and Information Security Agency (ENISA), 2009), due to the lack of availability and guidance for standards to enable adoption of cloud services. Consequently, it is increasingly important to provide a method to classify standards and, thus, enable careful selection of standards in cloud computing.

The remainder of the paper is structured as follows. First, we present background information and related work on standards. Then, we conceptualize the problem of classifying standards in emerging technologies and develop our conceptual data model. We also introduce a stakeholder model to incorporate their varying perspectives on standards as well as the process of classification to coordinate classification activities. In the course, we illustrate the method for the domain of cloud computing taking into consideration related work on cloud standardization.

# 2 Methodology

The research conducted in this paper is governed by the fundamentals of Design Science research (Hevner & Chatterjee, 2010, Hevner et al., 2004). More precisely, the research approach follows the principles of Action Design Research (ADR) (Sein et al., 2011). Generally, ADR applies an iterative model to initially create research artifacts. In subsequent steps, each result undergoes a set of evaluations. The research process comprised cycles of building artifacts, intervention and learning, and enhancement, as described in Design Thinking (Meinel & Leifer, 2010) and as suggested by Sein et al. (2011). Figure 2 illustrates the applied sequence of research phases, instantiating the generic research cycle of ADR.

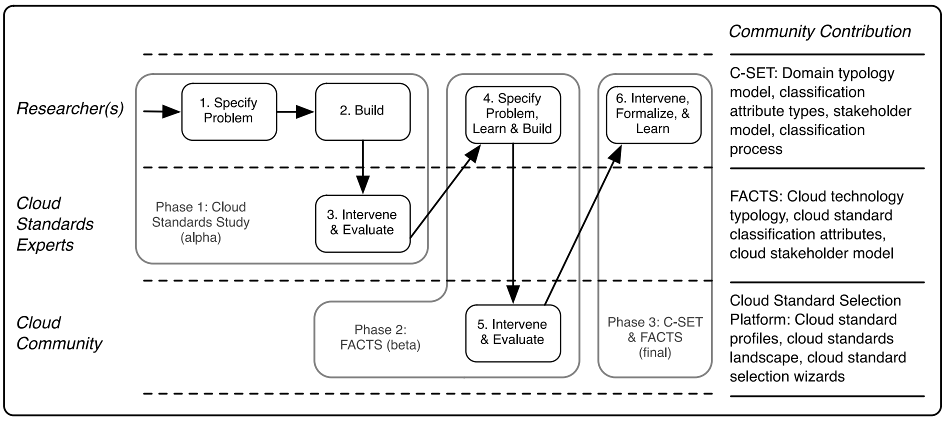


*Figure 2. Research Methodology based on (Sein et al., 2011)*

The research process consisted of six sequential steps, constituting the three cyclic phases: In Steps 1 to 3, the alpha versions of the research artifacts have been developed. We conducted a study of standards and standardization activities in cloud computing (Bernnat et al., 2012). In the course, we developed an initial classification scheme for cloud standards and an applied ad-hoc process to identify and classify 21 cloud standards (Fischer et al., 2013a). In the second ADR phase, comprising Steps 4 and 5, we reflected our lessons from the study and developed the beta versions of our research artifacts. The beta artifact, our Framework to Assess Cloud Technology Standards (FACTS) (Fischer et al., 2013b), comprised an initial conceptualization of the steps that are required for continuous standards assessment, the interplay of business, technology as well as legal and regulatory aspects in emerging technologies, and the stakeholders that are relevant for cloud standards assessment. Based on lessons learned from the alpha version, we derived a set of guiding questions that complement FACTS. Step 6, constitutes the final phase of our research process. It led to the creation of our method to classify standards in emerging technologies (C-SET) through formalization and learning. Thus, the generalizations of our previous research artifacts led to adaptations and enhancements and resulted in redesigns of the criteria, a common occurrence in Design Science research (Davison et al., 2004, Vaishnavi & Kuechler, 2008).

Applying ADR, all research artifacts were continuously evaluated. The domain typology for cloud computing was validated through questionnaires. We validated the research approach of the initial study and our Framework to Assess Cloud Technology Standards (FACTS) using expert interviews. The beta and final artifacts currently undergo an evaluation through a proof-of-concept implementation, which will result in a platform, offering actual guidance for cloud standards selection.[1]

# 3 Foundations and Related Work

## 3.1 Value of Standards in Emerging Technologies

As introduced in the motivation, standards provide rules, guidelines, or characteristics of products and services for common and repeated use (DIN, 2007). For example, they warrant product safety (e.g., CE marking), build the basis for interoperability (e.g., European Standard Gauge for railroads), or facilitate business interactions (e.g., IBAN, EDIFACT). Standards also provide a foundation of information and communication technology (ICT): They provide connectivity (e.g., HTTP, TCP/IP or WSDL), facilitate data exchange (e.g., XML, SOAP, JSON), or ensure security (e.g., SSL or ISO 27001) of services. Standardization is the process of creating or using standards. In standards creation, consensus is to be achieved over a common conceptualization of problems and best-practice solutions (Tassey, 2000). Standards use is the process of selecting and eventually employing standards into products and services or to widen or open a market.

In ICT, using standards contributes to compatibility of services. Compatibility comprises interoperability and portability, including compatibility of constituting components and supporting systems (Tassey, 2000). Interoperability allows services, components, and systems to communicate (Bower & Christensen, 1995). Portability, in contrast, refers to the capability of moving assets such as data, processes, and applications between services. Standards allow for defining unambiguous quality of service, based on common characteristics and metrics. Similarly, comparability of services is facilitated (Borenstein & Blake, 2011). Standardization achieves variety reduction through technology convergence, i.e. consolidation of alternative solutions. Terminologies, measurement units, process definitions, interface and data descriptions or even comprehensive reference architectures are only some exemplary categories of standards that address a variety of application areas.

Emerging technologies can lead to disruptive innovation, where a novel dimension of performance is brought into the markets (Bower & Christensen, 1995). They can also create new markets, which are characterized by a novel interplay of technologies and business aspects as well as the legal and regulatory framework.

These emerging markets require standards to create trust, fasten market uptake, and guide technology evolution. The need for standards can be met by creating new standards or by adapting existing standards to the novel needs of emerging technologies. Assessing needs and capabilities for

[1] Cf. http://www.cloudstandards.de/ for more information.

standardization as well as assessing capabilities of existing standards to the new application field are prerequisites to supply the standards needed.

In emerging technologies, standardization has often not taken place yet. Some or most of the technologies used are proprietary and possibly underspecified as they are a competitor's assets. Cloud computing is such a field. Nevertheless, the blueprints of these technologies or the combined efforts of multiple parties can turn into international standards. Then, only later in the development of an emerging technology, products and services are built according to a standard. In other cases, such as telecommunications, standardization has taken place before implementations of technologies were built.

Successful standardization in emerging technologies is, however, challenged by uncertainty. Uncertainty embraces market structure (e.g., market participants), technology dominance, and consumer requirements (de Vries, 1999). The problem of classifying standards in such environments, thus, has to address uncertainty in order to provide guidance to standardization stakeholders (Day & Schoemaker, 2000).

## 3.2 Systematization of Technology Standards

Knowledge and understanding of the general environment in which a standard provides value is key to a standard's success (Sherif, 2001) and, thus, is key to its assessment. Existing studies try to capture the standard environment, applying varying conceptualization of emerging technologies. Use cases models (National Institute of Standards and Technology (NIST), 2011a), technology challenges (Schubert et al., 2010, Smart Cloud Study Group, 2010) or reference models (National Institute of Standards and Technology (NIST), 2011b, Sakai, 2011) are frequent examples. The results, thus, resemble isolated snapshots in time, whose perpetuation is often too costly, leading to limited applicability and transferability of the results. The longevity of standards assessment information is typically high for standards in mature markets. With emerging technologies, development cycles are shorter (European Commission, 2011), especially if industry introduces proprietary implementations of their own de facto standards. The success of any assessment depends on quality of the data set, i.e. the classification scheme or the actuality of the classification of standards.

Classification is the process of putting objects into categories which share common attributes (Han & Kamber, 2006). Reasoning about objects heavily relies on the notation of classes of objects as similarities and differences are drawn from concepts of an object (e.g., things that objects of a class have in common). In doing so, natural complexity is countered by abstraction. Categories, which are used to classify objects, maximize similarity of objects within a class of objects, while similarities between classes are minimized.

Classifications of standards can build the foundation for the subsequent reasoning over standards and their respective values. Such reasoning may include finding a standard that matches a project's goal best, evaluating a standard's particular value for a project, or selecting a particular product or service based on the type and amount of standards it supports. These efforts are core to any strategic, tactical, or operational decisions to adopt standards.

Existing standards classifications are typically based on a strict taxonomy of standardization areas. The ISO (2005) international classification scheme for standards (International Organization for Standardization, 2005), e.g., comprises the generic category *Software*, seven categories for interconnection layers (OSI layers), and 10 application areas of information technology, which can be related to software services. Such taxonomies are too broad for classifying and selecting technology standards and for subsequent reasoning such as selecting standards according to a project at hand or selecting a product or a service based on its standardized features. Existing software or even cloud standards taxonomies, on the other hand, are often too specific to a given domain. Teckelmann et al. (2011b) develop a taxonomy that addresses the challenge of interoperability in IaaS clouds. While such an approach allows for a fine-grained classification of technology and standards, the foundation to integrate the taxonomy with other aspects of IaaS is missing. Since they do not define classification attributes (Teckelmann et al., 2011a), they lack guidance on how to perform the classification of standards, using the proposed taxonomies. Thornton and Bytheway (1993) also propose a framework for the classification and selection of standards. Building on a hierarchy of systems and a classification of standards according to type, rationale, and scope of the standard four high-level steps are described that apply questionnaires to classify and evaluate standards. Guidance on how to build a typology for an application domain or the aspect of building a knowledge base that supports repeated and diverging standard selection scenarios are missing. Mykkänen and Tuomainen (2008) propose a framework for classifying and selecting interoperability standards in software engineering. The framework comprises a generic taxonomy of interoperability and a process model to classify and select standards for a given software development project. While the approach is promising for selecting a candidate interoperability standard for a given software development project, it requires intense manual efforts and does not reflect dynamics of emerging technologies.

# 4 C-SET: Classification of Standards in Emerging Technologies

## 4.1 Problem Conceptualization

As argued, in this paper we do not cover standard selection processes, but the groundwork for them: the creation of a typology and the classification of standards. Figure 3 a) depicts our conceptualization of the problem to classify standards in emerging technologies. Both, technologies and business aspects can be defined through standards. Standards themselves found a basis for any legal and regulatory framework to constrain the markets of emerging technologies. We apply the concept of a domain typology to describe the various dependencies of technology, business aspects, and standards. A typology classifies concepts according to their structural and functional features. In contrast to taxonomies, our concept of a typology is more flexible towards changes and may comprise categories that do not (yet) find implementations. A domain typology in turn, constitutes the classification scheme that allows for classifying standards coherently for a given domain. It comprises two (sub-)typologies, one for technology and one for business aspects. As both aspects may be interdependent, we favor a holistic approach to support the classification of standards in emerging technologies (cf. grayed dashed line in Figure 3a) which cover business and technology aspects).

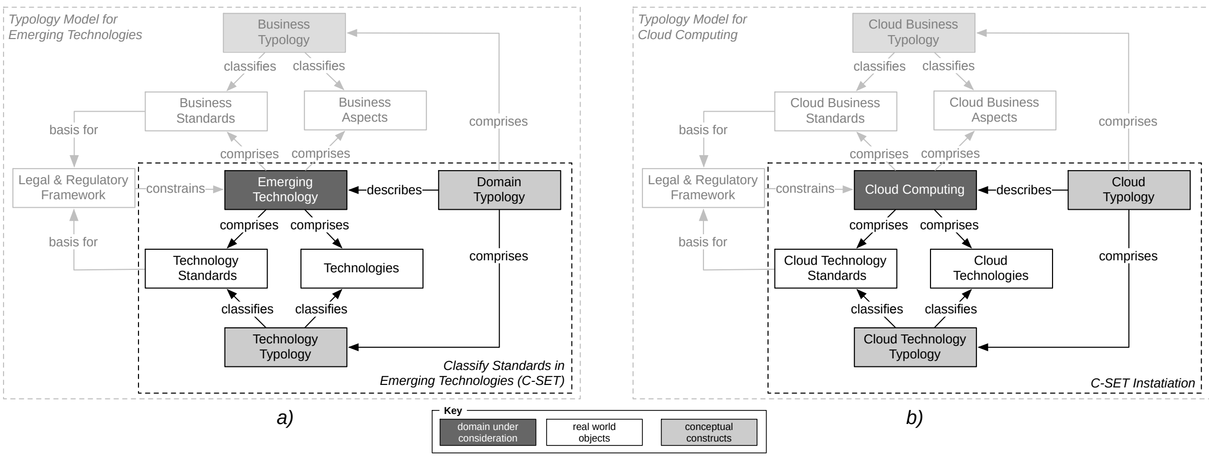


*Figure 3. Problem Conceptualization*

In this paper, however, we focus on a method to Classify Standards in Emerging Technologies (C-SET), which is tailored for the classification of technology standards. In doing so, we concentrate on the development of a technology typology to describe only technology and related standards (cf. C-

SET focus in Figure 3 a). Nevertheless, we have designed our models in a way that they can interface with a business typology.

In mature technology fields, the set of categories has stabilized over time, providing the conceptual order to the entire technology field and its stakeholders. In emerging technologies, however, discourse about constituting parts (e.g., enabling technology or implementations) and its categorization is still ongoing and stakeholders frequently change. As a result, any classification scheme against which objects are classified is in constant flux. Moreover, stakeholders, who decide on classifications, may change their alliances (Nickerson & zur Muehlen, 2007). Both arguments contribute to the need of frequent re-evaluations of the domain typology and its standard classifications.

The interplay of technology and technology standards differs depending on the emerging technology under observation. Consequently, a domain typology is required for every emerging technology, where standards should be classified. Figure 3 b) instantiates a domain typology for the example domain of cloud computing. We will further detail the components and the process of creating a technology typology in the next section.

## 4.2 Conceptual Data Model

The conceptual data model systematizes problem conceptualization and enables a structured classification of standards in emerging technologies. As introduced, we refer to the domain of cloud computing as an example to illustrate the peculiarities of the domain-specific information.

*Standards* and *technologies* are the core concepts in C-SET. A standard may define a best practice, a guideline, or a specification for any technology. Standards are classified into at least one, but potentially many different *standards fields*. A standard can be developed to guide an entire *technology field*. Both technology and standards fields provide a hierarchy to allows for grouping technologies and standards into more general technology and standards fields respectively. Every technology requires at least one implementation to be available. Standards, likewise, should relate to implementations. However, an implementation is not always required. An implementation, thus, is related to at least one technology, but may implement many technologies and standards.

For example, the Distributed Management Task Force (DMTF) developed the *Open Virtualization Format (OVF)* as a standard for the technology *virtual machines images* in cloud computing (Distributed Management Task Force, 2013). OVF falls into the standards field *data formats and exchange formats.* However, a technology may not only be governed by a single standard. The concepts, which are defined in OVF, could be already defined in another standard that provides a reference model or a common syntax for virtual machine images. Virtualization, for example, is a technology field that allows distinguishing technologies such as virtual machine images and hypervisors from data storage devices. *OpenStack Nova*, for example, defines not only a format for virtual machine images but also prescribe functions to application programming interfaces (API).[2]

Finally, standards constitute the *legal and regulatory framework* that may constrain the progression of an emerging technology. Laws or regulatory acts may cite or demand standards to do so. In summary, the technology and standards describe the *technology typology* of the emerging technology under consideration. Technology and standards fields may be reused in different technology typologies. Cf. the Figure 4 for an overview.

The C-SET conceptual data model, as described so far, does not allow for incorporating dependencies among standards. However, any assessment will be a judgment between alternative standards. It is,

[2] Cf. http://docs.openstack.org/developer/nova/.

therefore, necessary to conceptualize ways in which two or more standards can be related. This conceptualization of standards is not specific to a particular application domain such as cloud computing.

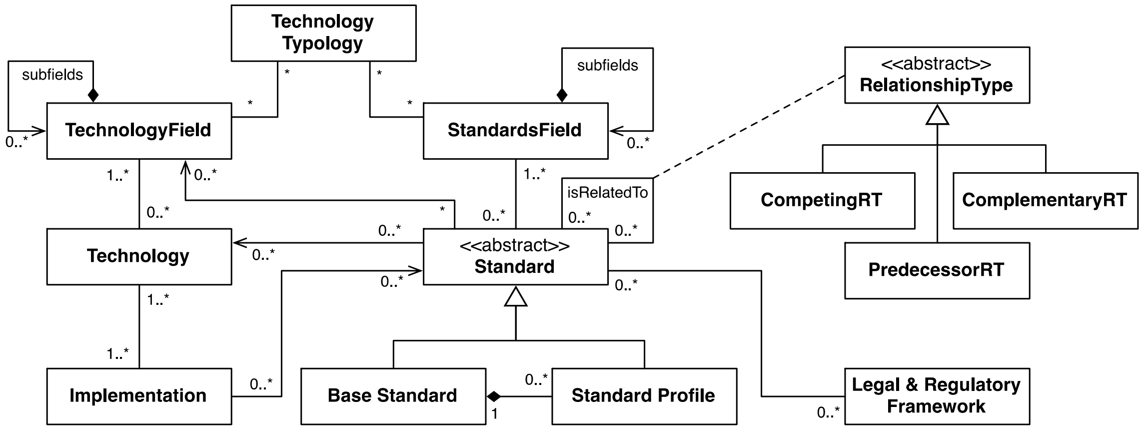


*Figure 4. Overview: Conceptual Data Model (Extract)*

A standard may be considered a *base standard* or a *standard profile*. Standards developers aim for broad applicability of their standards, while trying to create specifications that are as precise as possible. Using both base standards and standard profiles is a means to overcome this dilemma (Distributed Management Task Force, 2010). While a base standard is broad in its applicability (e.g., by defining a meta model), standard profiles allow for application specific extensions.

The series of standards published by the Distributed Management Task Force (DTMF) for the management of computing resources are a prime example for such approaches in the context of cloud computing. The CIM System Virtualization Profile (Distributed Management Task Force, 2010) is only one example of the profile family that tailors the CIM Infrastructure Specification standard (Distributed Management Task Force, 2005) to the technology field of resource virtualization. Each CIM profile "identifies the classes, properties, methods, and values that should be instantiated and manipulated to represent and manage a given domain" (Distributed Management Task Force, 2007). Profiles can be autonomous, defining a self-contained domain, or a component, describing a subset of a domain (cf. Distributed Management Task Force, 2011). Generalizing from the management focus of DMTF, we distinguish *base standards* from *standard profiles* in our conceptual data model. In DMTF's sense, base standards represent autonomous profiles, while standard profiles reflect component profiles.

Next to content-related modularization of standards, there are market-based and temporal dependencies between standards. These kinds of dependencies are incorporated in C-SET's conceptual data model using the three *relationship types*: CompetingRT, ComplementaryRT, and PredecessorRT.

The development of standards faces competition to establish dominance of concepts for a given technology: i.e., *CompetingRT* (cf. also Figure 1). Especially, in the early phases of technology development a variety of competing standard approaches exits. This is not only limited to formal standards, being developed by accredited standardization organization, but also by industry standards that lack formal consensus building processes. In cloud computing, signs of competition can for example be found in the field of management of virtualized resources. As of now, there exist at least two major proposals that define application programming interfaces for managing virtualized resources. Both, the Open Cloud Computing Interface (OCCI) and the Cloud Infrastructure Management Interfaces (CIMI) are developed as standards. As their scope targets the same subjects, both standards compete for market dominance. Both standards, furthermore, compete with industry standards such as the Amazon Elastic Compute Cloud (EC2) API.

Similar to the concept of base standards and standard profiles there can be a dependency between standards that add value when used together. C-SET incorporates these dependencies using complementary relationship type: i.e., *ComplementaryRT*. These standards do not share the subject of standardization nor have they been developed with to goal to complement one another. In cloud computing, the Open Grid Forum is the developer of the Cloud Data Management Interface (CDMI), while CDMI's sponsor is the Storage Network Industry Association (SNIA). Both, OCCI and CDMI provide a specification for an application programming interface. OCCI targets the management of virtualized computing resources and CDMI supports the management of data on virtualized data storage devices. As the standardization community has identified the potential of using OCCI and CDMI combined, they started to hold so called plug-fest events that promote both standards, while testing their interoperability.

Finally, there are temporal dependencies between standards. C-SET supports temporal dependencies between standards through predecessor association, i.e., *PredecessorRT*. In contrast to the evolvement of technology fields or standards fields, different versions of a standard coexist. A given implementation of a technology may perfectly implement one version of a standard, but not another version. Legal and regulatory frameworks, likewise, may refer to older versions of a standard, due to slower development lifecycles in jurisdiction. The C-SET conceptual data model therefore allows for the modeling of predecessor dependencies. In doing so, further analyses may, for example, examine drifts in the scope of a standard along its maturation.

In contrast to this versioning of standards, C-SET does not version the technology typology. A change to the technology typology is a response to adequately capture the evolvement of the state of the art in the emerging technology. Applying an older classification scheme puts the accuracy or even the meaningfulness of the classification at risk.

In addition to defining dependencies between standards and technologies as well as their respective fields, the C-SET conceptual model allows for defining customizable *attributes*. C-SET distinguishes domain-specific attributes from standard-specific attributes. Reflecting this requirement, every attribute relates to one *attribute type* (AT). AT can be defined for a standards field or a technology field. While the model does not prevent an AT to be assigned to both a standards field and a technology field, C-SET assumes each AT to belong to either a standards field or a technology field. A standard may be described by at least one but potentially many attributes of the same AT. For this reason, the cardinality of an AT defines the amount of instances of an attribute, which can be created for describing a standard. The *attribute domain* defines the data type of an AT, i.e. a set of allowed values may be defined as well as their scale. The amount attribute instances of the same type that can be ascribed to a standard are defined using *attribute cardinality*. An *assessment rule* defines the function, how attributes of different values will be aggregated for a given attribute type. Attributes and their relationships have been included in Figure 5.

## 4.3 Stakeholder Model

Information that is required to classify standards is spread among a variety of stakeholders, who collaborate in standardization. A method to support the classification of standards in emerging technologies must, therefore, incorporate different perspectives in varying points in time.

C-SET defines its stakeholder model using four conceptual entities (cf. Figure 5): *stakeholder*, *role*, *standards role*, and *domain role*. Classification attributes can be marked as important for a set of stakeholder roles. In doing so, we ease standardization stakeholders' efforts by filtering unnecessary information. The C-SET stakeholder model unites the traditional standardization roles with domain-specific roles of stakeholders. Both types of stakeholder roles try to influence the development of standards and technologies within the emerging market for the emerging technology field. In the case of cloud computing, the DomainRole summarize the roles and responsibilities for developing cloud services.

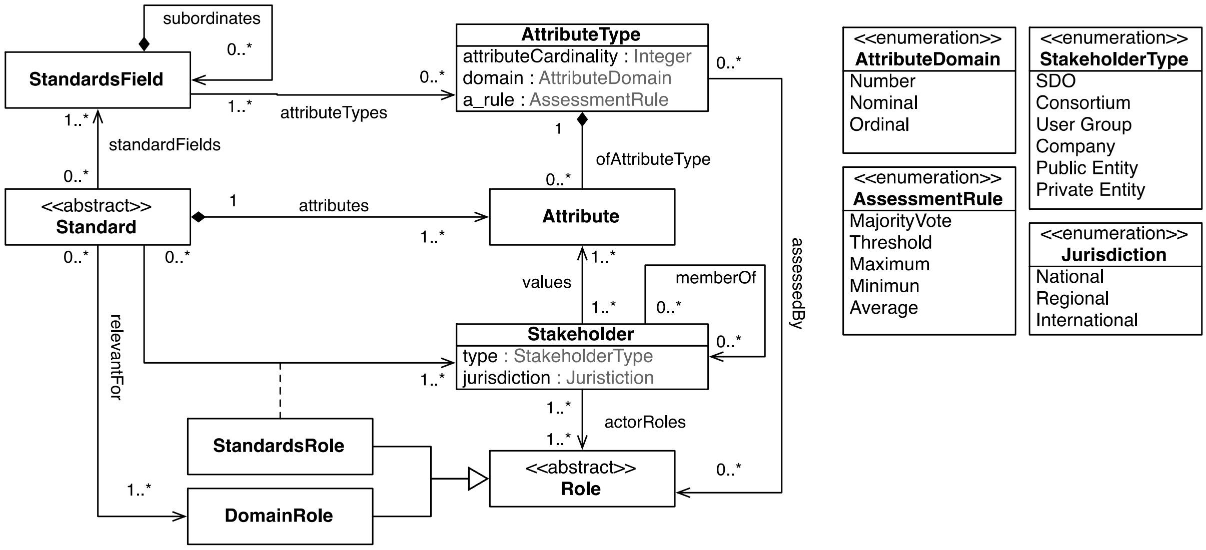


*Figure 5. Conceptual Data Model: Stakeholder Roles (Excerpt)*

The entity stakeholder corresponds to any actor who participates in the process of standardizing an emerging technology. All stakeholders have a type. They may fall into the categories of an accredited standards development organization (SDO), a consortium (i.e., a group of organizations working on standardization but lacking accreditation), a group (i.e., a collection of stakeholders for a purpose), a private organization (e.g., any companies), a public organization (e.g., ministry or government agency) or an individual (e.g., an end-user in case of customer facing services). Stakeholders are further bound to a particular jurisdiction. In doing so, stakeholders may develop, use, or generally influence standards on the national, regional, or international level. C-SET allows for modeling structural dependencies between stakeholders. In doing so, networks of stakeholders can be created using C-SET. A public organization, may for example, actively contribute to different standard development efforts, while at the same time joining a variety of user groups aiming to improve the usability of a standard.

C-SET distinguishes a standards role and a domain role, being specializations of the abstract roles class. Standards roles allow for expressing the standard-specific roles in which a stakeholder may act for a given standard. C-SET, therefore, comprises a typed association between standard and stakeholder based on standard roles. C-SET includes four standard-specific roles, which will be briefly summarized in the following. Cf. (e.g. Söderström, 2003) and (Fischer et al., 2013b) for more details.

- *Standards developers* create standards. Formal or accredited SDO, such as ISO, NIST, ETSI, and DIN, create standards by applying pre-defined consensus-based standardization procedures. Consortia lack standards setting accreditations, but create de-facto standards exploiting market dominance.

- *Standards implementers* provide implementations of standards by incorporating standards into products or services. Implementers may receive certificates testifying proper realization of a standard. Standard implementing organizations often also participate in standards creation and are, thus, key influencers of standards development.

- *Standards users* eventually decide on the success or failure of a standard, i.e. standard or more generally design dominance (Suarez, 2004). Imbalanced standards that lean towards developer benefits (e.g., creating market entry boundaries) are a consequence of missing user involvement (Jakobs, 2000).

- *Policy makers* subsume government or public representatives. Regulatory agencies enact "instruments which help to regulate a specific sector" (European Commission, 2002). These can be laws and regulations passed by the government. Regulatory agencies, however, do not create standards.

Domain roles, in contrast, allow scoping the applicability of standards for a given role. For cloud computing, we consider *service providers* to perform activities for *service consumers*. Service consumers compensate service providers through payments. Some authors identify additional roles like a service creator or a service broker (Borenstein & Blake, 2011). We concentrate on the two fundamental roles. Thus, we assume the provider to have also created the service and a service broker to be a particular kind of a service consumer. Both, service providers and consumers perform a set of activities to develop a software service. In brief, these activities fall into five types of activities of the service life-cycle model, namely *specification*, *design*, *implementation*, *deployment*, and *operation*. Depending on the current activity type, the assessment criteria of standards may differ (Wittern & Fischer, 2013).

## 4.4 Process Model for Classification Coordination Support

Classification of standards is a collaborative effort among participating stakeholders. In order to create a domain typology, derive and maintain suitable classification attributes, and to (re-)classify standards, coordination among the varying stakeholders is required. This includes requesting information only from participants that are generally capable of assessing a particular classification attribute. For example, cloud service consumers should assess the value of how well a standard contributes to ensuring interoperability. Only cloud service providers, however, can evaluate the efforts, which are required to implement a given standard to support interoperability.

Apart from guiding standardization stakeholders by filtering classification attributes, overall guidance is required to balance the requirements and efforts of classifying standards. Doing so is especially important in case of changes to the domain typology or standard specifications. On the basis of our conceptual and stakeholder model, we provide process models that show which attributes are to be re-evaluated in case of changes to the domain typology or standard specifications.

The C-SET process model aims at minimizing maintenance efforts, which are required after the technology typology has changed. The goal of the process of classifying standards, thus, is to provide a data set, which stakeholders of the emerging technology may use to evaluate the use of standards for their purpose. We, thus, model the overall process of standards classification in emerging technologies to comprise two steps: *Create Domain Typology* and *Classify Standard*. Figure 6 shows the *Top-level Classification Processes* as well as the two respective sub-processes.

*C-SET Top-level Classification Process* is triggered when an emerging technology appears. In line with our earlier conceptualization, we denote the appearance of an emerging technology to be the moment when a new novel interplay of technical and business aspects is first perceived in the market (cf. also Figure 1). Once the technology typology has been created, standards can be classified. A standard is classified as soon as its first standard specification is published. Subsequent publications trigger reclassifications of the standard. In consequence, multiple classify standard sub-processes can be executed concurrently. For formal standards, the events that trigger standard (re-)classification can be drawn from standardized lifecycle models (e.g. ISO standards life-cycle model). In case of industry standards, the release of a new version of the specification represents a publication event.

The recreation of the technology typology is triggered as soon as a technology or a technology field, which belongs to technology typology, changes. Also, any emerging technology may develop a technology that has previously not been considered in the technology typology. In such cases, the domain typology will also be updated to evaluate if the new technology should be included into the technology typology. Apparently, it is much harder to define the point in time when a technology typology update is required.

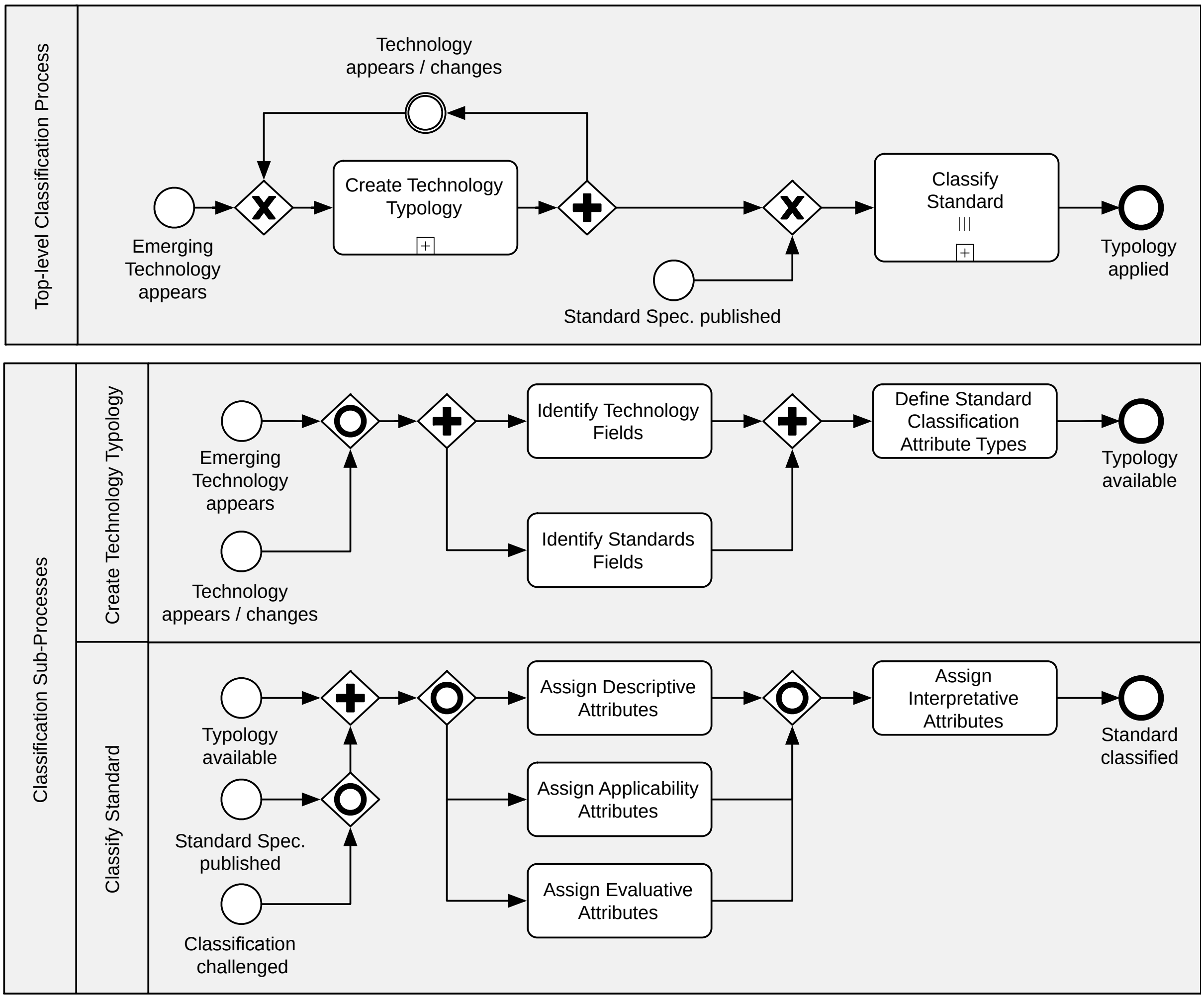


*Figure 6.* *Classification Process Model*

The goal of the *Create Technology Typology* sub-process is to create or update the technology typology. Based on the conceptual model, this sub-process identifies and structures technologies into technology fields. Stakeholders in the standards developer role or policy maker role typically engage most in this process. Glossaries, taxonomies, and reference models are typical artifacts that are used in this step. These artifacts help technology providers to structure their solution architecture or define functional scopes of their technology implementations. Use case models, are other frequent artifacts that are applied in this process. These models try to grasp the potential use cases of the emerging technology. However, use case models are more tailored towards using the new technology than are reference models. Thus, they reflect the perspective of a technology user more than the perspective of a technology provider. Existing taxonomies for technologies and technologies fields can be re-used from related or enabling technologies. However, the structure between technology fields may differ from emerging technology to emerging technology, i.e. the structure is domain-specific. Once the structure is agreed upon, the standards classification attribute types are defined.

The goal of the *Classify Standard* sub-process is to use the technology typology and the role model to classify standards, i.e. mapping standards to technologies, technology fields, and implementations as well as assessing the classification attributes, which are defined for the emerging technology under consideration. The classify standards sub-process is triggered once the technology typology is available and whenever a standard specification is published. Moreover, stakeholders may question the classification of a standard by questioning the value of an attribute or the set of attributes in C-SET issue a *classification challenged* event. Using C-SET, changes to the technology domain can be tracked down to technology and standards fields, which allows for reassigning the affected attributes.

# 5 Conclusion

Technology standards are an important part of any information system as they impact many different aspects such as interoperability, portability, and security. Hence, they constitute the cornerstone of any distributed, open, and flexible service-oriented software system – even more so for emerging technologies such as cloud computing. Despite the importance of the task, often there is a plethora of standards available and a lack of guidance on which ones to choose. Hence, the selection of the best standards for a given service development project is a challenging task.

Within this paper we have created a number of conceptual artifacts to support the structured and collaborative classification of emerging standards and technologies as a basis for this task. The artifacts consist of:

1. A modular conceptual model for standardization knowledge: Reusing information across standardization stakeholders is the key to efficient standards classification. We developed a conceptual data model, which is the basis for collaborative standards classification.
2. A stakeholder model: The stakeholder model enables the separation of different perspectives. In doing so, the complexity of assessing standards is reduced.
3. A method to classify standards: The constructs and models, which are defined by the domain typology, are used as input for C-SET. As motivated earlier, the field of emerging technologies is dynamic. We therefore devised a coordinated approach to classify standards and to keep the technology typology current.

The method cannot only be used by developers of products and services but also by governmental agencies or SDO to perform qualitative analysis of the state-of-affairs in standardization. Reports such as the Cloud Standards Coordination Final Report from the Cloud Standards Coordination workgroup by ETSI could have benefited from such a conceptual model and process model (European Telecommunications Standards Institute (ETSI), 2013). The evaluation of standards in this report is based on a selection of high level use cases but no relations (competing, predecessor, complementary) between standards have been defined. Also, the evaluation is a narrative based on experience rather than comparable attributes. Hence, while the report gives an overview of standards in cloud computing, it falls short of actually supporting decisions based on the available data set.

Also, any assessment of standards is already outdated, once it is published. Future research will concentrate on continuing the proof-of-concept implementation for a platform offering living standard profiles, which can be updated collaboratively as standards, technologies, and implementations evolve. Also, we will develop a method and tool to assess and select standards for development projects based on the classification method that we have introduced in this paper. The method will build on databases of standards, technologies, and implementations. Moreover, it requires defining steps, which are necessary to configure a sub-typology, in order to match project scope and requirements with the scope and goals of (cloud) standards stored in the databases. Next to selecting scopes and requirements, the method will help developers to prioritize their requirements. Using this additional input, the method would be able to calculate a ranking of standards relevant for a given product or service development project.

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