An FBM Model of ISO Cloud Computing Architecture

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Abstract. With the ever-changing dynamic Information and Communications Technology environment and the new shared deployment options for computing, a paradigm shift has occurred, which enables ubiquitous and convenient computing on a pay-as-you-go basis. Access on demand has become available to networks of scalable, elastic, self-serviceable, configurable physical and virtual resources. This paper updates the previous paper that addressed early ISO Committee Draft (CD) work on Cloud Computing by ISO ISO/IEC JTC1 SC38 (in collaboration with ITU-T SG13/WP6 for Cloud Computing), and models the full and expanded ISO Cloud Computing Reference Architecture and Service Level Agreement (SLA) using Fact Based Modeling (FBM) methodology. FBM has allowed us to distill the concepts, relationships and business rules - thereby capsulizing the Cloud Computing standards to enable understanding, and also exposing the strengths and weakness of the models, and thus allowing for identification of any gaps towards furthering the ISO standard.

Keywords: Cloud Computing · Cloud computing reference architecture
CCRA · SLA · Service level agreement · ISO · Fact Based Modeling
FBM · SLO · SQO · Cloud service
Cloud computing interoperability and portability · ODP

1 Introduction and Background

Information and Communications Technology (ICT) is being transformed to a model based on services that are commoditized and delivered in a standardized manner. In a cloud service-based model, users access cloud services based on their requirements without regard to where the cloud services are hosted or how they are delivered.

Several computing paradigms have promised to deliver this computing vision, of which the latest is Cloud Computing. The term "Cloud" denotes a computing infrastructure from which businesses and users are able to access applications from anywhere in the world, on-demand. Thus, the ICT world is rapidly evolving to develop software for millions to consume as a cloud service, rather than to run on individual computers. Cloud computing represents a paradigm shift that has redefined the relationship between buyers and sellers of IT-related products and services [1]. The ISO (International Organization for Standardization) SC38 Study Group on Cloud Computing in their 2011 report [1] identified at least 23 Cloud Computing industry initiatives that had published material, were developing standards or were doing at least some work in this area.

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With multiple and often confusing Cloud Computing approaches being offered to the IT community, ISO initiated standardization work on a Cloud Computing vocabulary and a Cloud Computing reference architecture in 2010. On a parallel front, ITU-T was also in the process of developing Recommendations for Cloud Computing terminology and reference architecture. The two groups successfully launched collaborative work on the development of a common set of standards/recommendations for Cloud Computing vocabulary and reference architecture.

The ISO Joint Technical Committee (JTC1) formed a Sub-Committee, called SC38 named Distributed Application Platform and Services, to harmonize the ISO work on standardization for: Web Services, Service Oriented Architecture and Cloud Computing. This initiative was largely driven by the IT marketplace having to face multiple incompatible choices of product sets, which essentially creates barriers to interoperability efforts.

This paper updates the previous work [10] of the basic Cloud Computing terminology and Reference Architecture that was based on the Committee Draft (CD) document. This update reflects removal of some overlapping items between the Vocabulary and Reference Architecture documents, along with minor clarifications of relationships. This paper illustrates how Fact Based Modeling (FBM) provides a useful means to capture and understand the Cloud Computing standards, hopefully leading to a more cohesive and consistent direction for the next generation of ICT.

NOTE: The standards for Cloud Computing are under continuing development and are subject to change. The contents of this paper are intended to be illustrative and should not be considered as an authoritative description of the emerging ISO standards.

In this paper, we have used the FBM notation and methodology as a description technique to define semantic models abstracted from the current Cloud Computing and SOA documents being progressed for standardization. FBM is a methodology for modeling the semantics of a subject area.

FBM is based on logic and controlled natural language, whereby the resulting fact based model captures the semantics of the domain of interest by means of fact types, together with the associated concept definitions and the integrity rules [9].

The roots of FBM go back to the 1970s. NIAM, a FBM notation style, was one of the candidate methodologies used for developing conceptual schemas as defined in ISO Technical Report TR9007:1987 Concepts and Terminology for the Conceptual Schema and the Information Base. Subsequently, several developments have taken place in parallel, resulting in several Fact Based Modeling "dialects", like NIAM, ORM2, CogNIAM, DOGMA and FCO-IM. The notation used in this paper is ORM2 notation.

A simplistic description of usage and reading the ORM2 notation follows. The subject area Universe of Discourse is seen as consisting of semantic objects (representing objects in the real world model) that can be described using natural language sentences—consisting of an object, predicate and possibly one or more objects, each

connected with a predicate-object pair. A real world object is represented by an object type denoted by a circle, also known as an entity type. Object types may have subtypes denoted by arrows from the subtype to supertype (e.g. object type Role has subtype Sub-role). Object types are involved in 'fact type' sentence descriptions that can be binary, or n-ary (ternary, quaternary etc.), as depicted by rectangle boxes, each box representing a 'role' that the object type plays in that sentence. Integrity rules are then associated with the fact types, like mandatory (shown as a dark dot on the object type connector). A horizontal bar on top of a role of a fact type denotes a uniqueness restriction on the occurrence of the set of role populations. The ORM2 notation contains several other rules that can be graphically depicted but are out of scope for our discussions. An example of a fact type reading from Fig. 1 is: A Party (in the cloud computing paradigm schema) *must* be assigned to one or more CCRole(s). A CCRole *may* be assigned to one or more Parties.

2 Cloud Computing Concepts

Figure 1 depicts the main Cloud Computing concepts using FBM, along with examples, as defined in the ISO Overview and vocabulary document [2]. The concepts are defined in terms of the cloud services that are available to cloud service customers and the cloud deployment models that describe how the computing infrastructure that delivers these cloud services can be provided and shared by users.

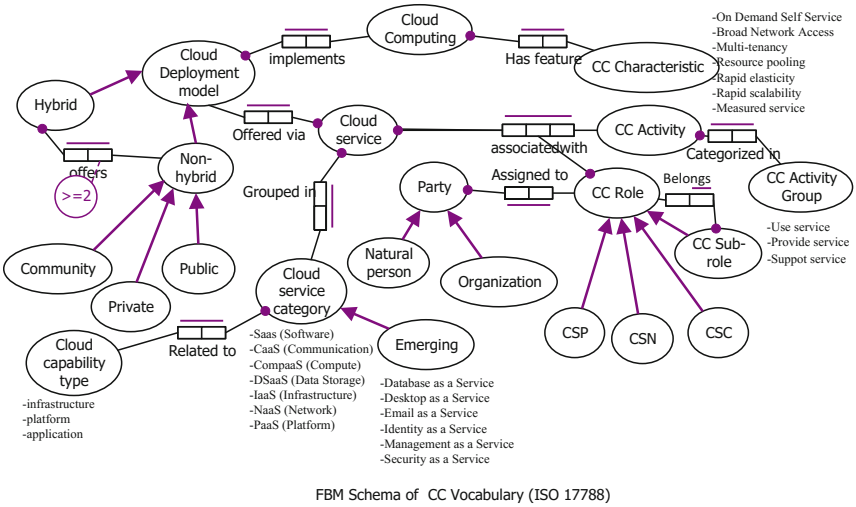

Fig. 1. Basic Cloud Computing concepts from ISO 17788

It is interesting to note that the Cloud Computing vocabulary and concepts were developed prior to an agreed upon architecture. The architecture itself takes its basis from the approach used in the ISO Open Distributed Reference Model (ODP) [4] by utilizing the user view and functional view.

The cloud paradigm is composed of key characteristics, roles and activities, cloud service capabilities and cloud service categories, deployment models, and cross cutting aspects as shown. The concept relationships generally appear in the cloud computing reference architecture.

Table 1 is the relevant definitions pertaining to the cloud computing models shown.

Table 1. Definitions of concepts used in Cloud Computing ISO 17788, ISO 17789

Concept	Definition	Examples
Party	Entities that play one or more roles (and sub-roles)	Natural person, or an organization
Role	Sets of activities	Cloud service customer Cloud service provider Cloud service partner
Subrole	A subset of the activities associated with a role	Sub-roles for a partner role are: service integrator, auditor, and cloud broker
Activity	A logical functional element of a cloud service	Using cloud services, providing cloud services, and supporting cloud services
Component	An implementation of an activity	
Cross-cutting aspect	Behaviors or capabilities that need to be implemented & coordinated across roles	Interoperability, portability, reversibility, security, privacy, governance, etc.
Cloud Computing	Paradigm for enabling network access to a scalable and elastic pool of shareable physical or virtual resources with on-demand self-service provisioning and administration	
Cloud characteristic	Basic user-oriented features of a Cloud Computing environment	On-demand self-service, Broad network access, Multi-tenancy, Resource pooling, Rapid elasticity & scalability, Measured service
Cloud service	One or more capabilities offered via cloud computing invoked using a declared interface	Natural person, or an organization

(*continued*)

Table 1. (*continued*)

Concept	Definition	Examples
Cloud service category	Group of cloud services that possess some qualities in common with each other	Infrastructure as a service, Platform as a service, Software as a service, Network as a service, Data Storage as a service, Compute as a service, Communication as a service
Capability	A quality of being able to perform a given activity	
Cloud capability type	Classification of the functionality, based on the type of resources used Cloud capability types follow the principle of separation of concerns, i.e. they have minimal functionality overlap between each other.	Infrastructure capabilities, Platform capabilities, Application capabilities
Cloud deployment model	The way in which cloud computing can be organized based on control of physical or virtual resources and how those resources are shared	Community cloud, Public cloud, or Private cloud
Hybrid cloud	A cloud deployment model that includes at least two different deployment models	Interoperability, portability, reversibility, security, privacy, governance, etc.

3 Cloud Computing Reference Architecture

A Fact Based Model for the Cloud Computing Reference Architecture (CCRA) is shown in Fig. 2. As noted earlier, the CCRA takes as its basis the ODP reference model but focuses only on the user and functional views. The CCRA does not address the implementation and deployment views. The user view is the ecosystem (or system context) including the parties, the roles, the sub-roles and the activities. The functional view is the distribution of functions necessary for the support of cloud activities.

The Fact Based Models in this paper represent the distillation and transforms as interpreted from the vocabulary text [2] and the CCRA text [3]. The purpose of these diagrams is being able to understand and analyze them using a formal modelling methodology to represent the involved facts and relationships as opposed to text paragraphs.

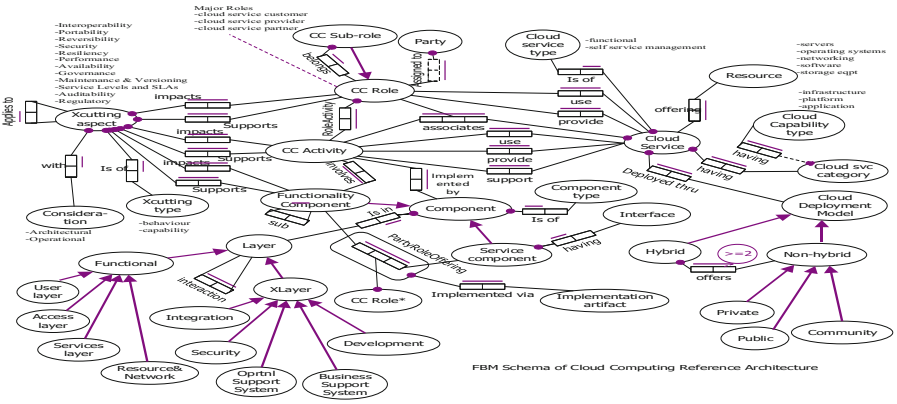

Fig. 2. Cloud computing reference architecture model from ISO 17789

4 Cloud Computing Service Level Agreement (Cloud SLA)

A service level agreement is part of a cloud service agreement that includes cloud service level objectives and cloud service qualitative objectives for the covered services. The cloud SLA accounts for the key characteristics of cloud computing that include: Self-service, resource pooling, multi-tenancy, rapid elasticity and scaling, tradeoff between cost and control, and more importantly, the ability to 'measure' cloud services.

Figure 3 relates cloud services with service level agreements, SLOs and SQOs.

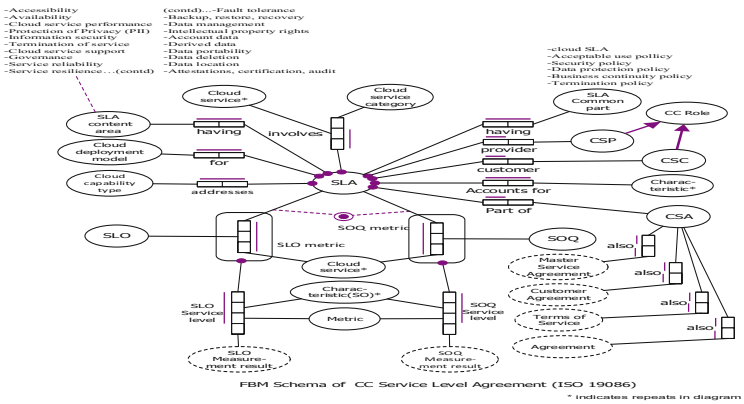

Fig. 3. FBM schema depicting ISO 19086-1 CC SLA

The use of FBM enables the capture of SLA standard semantics [5–7] in a succinct capsulated form in the FBM schema shown in Fig. 3 (Table 2).

Table 2. Definitions of concepts used in CC SLA ISO 19086

Concept	Definition	Examples
CSA	Cloud service agreement	Contract vehicle for organizations, enterprises and individuals, software and hardware
CSC	Cloud service customer	
CSP	Cloud service provider	
Cloud service	One or more capabilities offered via cloud computing invoked using a defined interface	
Metric	Standard of measurement that defines the conditions and the rules for performing the measurement and for understanding the results of a measurement	
SLO	Cloud service level objective - commitment a cloud service provider makes for a specific, quantitative characteristic of a cloud service, where the value follows the interval or ratio scale	
SQO	Cloud service qualitative objective: commitment a cloud service provider makes for a specific, qualitative characteristic of a cloud service, where the value follows the nominal or ordinal scale	

5 Cloud Computing Interoperability and Portability

The cloud computing interoperability standard [8] is aimed at all parties involved in cloud computing—cloud service customers (CSCs), cloud service providers (CSPs), and cloud service partners (CSNs) acting as cloud service developers. ISO DIS 19941 provides a common understanding of interoperability and portability as it applies to cloud computing. This common understanding helps to achieve interoperability and portability in cloud computing by establishing common terminology and concepts that are involved.

Figure 4, describes cloud computing portability and depicts the terminology used. Figures 5, 6, 7 and Table 3 describe cloud computing interoperability the terminology used.

It is important to note that using FBM and strongly typed subtypes, it was possible to abstract and condense much of the formal descriptions in the standard [8].

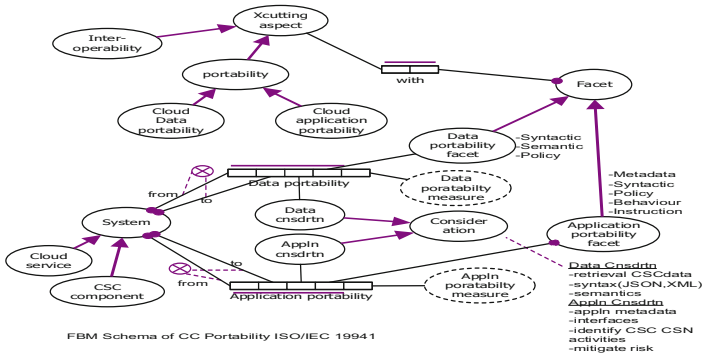

Fig. 4. FBM schema of CC portability ISO 19941

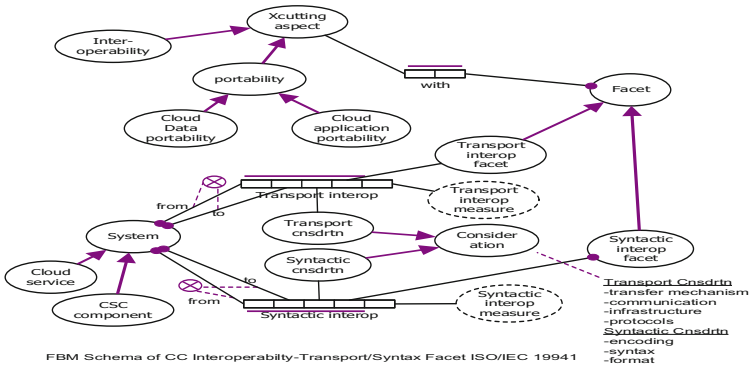

Fig. 5. FBM schema of CC interoperability – transport/syntax facet ISO 19941

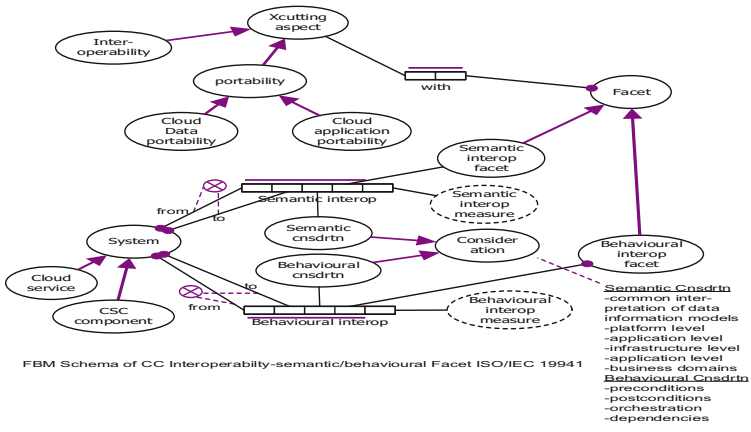

Fig. 6. FBM schema of CC interoperability – semantic/behavioural facet ISO 19941

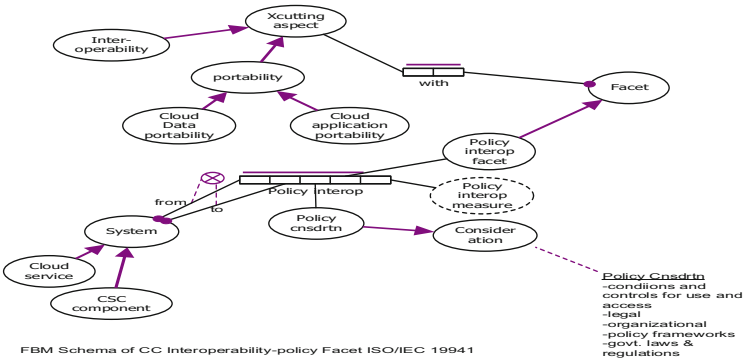

Fig. 7. FBM schema of CC interoperability – policy facet ISO 19941

Table 3. Definitions of concepts used in CC interoperability and portability ISO 19941

Concept	Definition	Examples
Interoperability	Ability of two or more systems or applications to exchange information and to mutually use the information that has been exchanged	
Cloud interoperability	Ability of a CSC's system to interact with a cloud service, or the ability for one cloud service to interact with other cloud services, by exchanging information according to a prescribed method to obtain predictable results	
Data portability	Ability to easily transfer data from one system to another without being required to re-enter data	
Cloud data portability	Data portability from one cloud service to another cloud service, or between a CSC's system and a cloud service	
Application portability	Ability to migrate an application from one cloud service to another cloud service or between a CSC's system and a cloud service	
Cloud application portability	Ability to migrate an application from one cloud service to another cloud service, or between a CSC's system and a cloud service	
Functional component	A functional building block needed to engage in an activity backed by an implementation	Cloud service client component

6 Cloud Computing Suite of Standards

By transforming each of the Cloud Computing concepts, terminology and architectures using Fact Based Modeling, we are able to distill the salient object types, relationships and some of the business rules to enable a comparative analysis of the involved

architectures—the Cloud computing reference architecture (CCRA), the cloud computing service level agreement suite of multi part standards (some are still in development), cloud computing interoperability and portability architecture, and cloud computing cloud service and devices: data flow, data categories and data use.

By using FBM any deviations from the established vocabulary immediately become apparent. Cloud computing reference architecture uses ODP views whereas the follow on standards do not. These are only some of the examples of divergence between the cloud computing and companion architectures.

It is clear that there needs to be an accord between the Cloud Computing standards group and other CC related standards groups like Security and Privacy, Metadata, Open-edi, Internet of Things (IoT RA), Blockchain and distributed ledger technologies, with other standards developing organizations (SDO), and industry consortia.

7 Conclusions

In this paper we have demonstrated the use of Fact Based Modeling to facilitate an analysis of the ISO vocabulary and reference architecture standards for Cloud Computing, cloud computing service level agreement framework, cloud service level agreement metrics, cloud computing interoperability and portability. As a result, we have identified a number of areas where the concepts in the vocabulary and architecture documents are generally aligned and provide a mechanism to explore any misalignments. We have also identified a number of areas where Cloud Computing and associated standards are using similar concepts, typically in ways that may be readily compared.

Fact Based Modeling appears to provide significant assistance both in the development of consistent architectures based on sound concepts and also in the analysis and comparison of different architectures.

Further effort to analyze the models in more detail would provide valuable insight into the complex relationships within Cloud Computing suite of standards.

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