Comparative Analysis of SOA and Cloud Computing Architectures Using Fact Based Modeling

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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 is occurring that enables ubiquitous and convenient computing on a pay-as-you-go basis. Access on demand is becoming available to networks of scalable, elastic, self-serviceable, configurable physical and virtual resources. On a more narrowly focused IT and business front, there is a parallel shift towards designing information systems in terms of the services available at an interface. The Service Oriented Architecture (SOA) development style is based on the design of services and processes and the realization of interoperability and location transparency in context-specific implementations. This paper analyzes the Cloud Computing and SOA Reference Architectures being developed by ISO ISO/IEC JTC1 SC38 (in collaboration with ITU-T SG13/WP6 for Cloud Computing), and offers a concept comparison using Fact Based Modeling (FBM) methodology. FBM has allowed us to distill the concepts, relationships and business rules - thereby exposing the strengths and weakness of each, and identifying the gaps between the two.

Keywords: Cloud Computing, SOA, Service Oriented Architecture, Reference Architecture, metamodel, ISO, Fact Based Modeling.

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 service-based model, users access services based on their requirements without regard to where the services are hosted or how they are delivered.

Several computing paradigms have promised to deliver this computing vision, of which the latest is known as 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 service, rather than to run

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on individual computers. Cloud computing represents a paradigm shift that will redefine 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. One influential organization has been the US NIST [9,10].

With multiple Cloud Computing initiatives on the horizon, ISO decided to initiate standardization work on a Cloud Computing vocabulary and a Cloud Computing reference architecture. On a parallel front, ITU-T was also in the process of developing Recommendations for Cloud Computing terminology and reference architecture. So now, the two groups have successfully initiated collaborative work on developing a common set of standards/recommendations for Cloud Computing vocabulary and reference architecture.

On a more narrowly focused IT and business front, there is also a shift occurring in the design of systems in terms of making services available at an interface and to provide well-specified outcomes. The Service Oriented Architecture (SOA) development style is based on services and processes that realize interoperability and location transparency for context-specific implementations. ISO SC38 is also addressing standardization in the area of SOA terminology and architecture.

Considering that both of these technologies address distributed platforms and services, it is important the Cloud Computing and SOA architectures be compatible, and that there exists a harmonious set of interfaces and common points of overlap. Without this harmonization we would be back at "square one" facing a plethora of incompatible standards.

Recognizing this trend, the ISO Joint Technical Committee (JTC1) formed a Sub-Committee, called SC38 and 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 examines the basic concepts that have been developed for both Cloud Computing and Service Oriented Architecture, and illustrates how Fact Based Modeling (FBM) provides a useful means to compare and contrast these initiatives, hopefully leading to a more cohesive and consistent direction for the next generation of ICT.

NOTE: The standards for Cloud Computing and SOA are still under 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 [8].

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 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", including 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 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 possible 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), and also a horizontal bar on top of a role of a fact type denoting a 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 Figure 2 is: A Party (in the cloud computing paradigm schema) shall be assigned to one or more Role(s). A Role 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 draft 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 services can be provided and shared by users.

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 [4] by utilizing the user view and functional view.

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

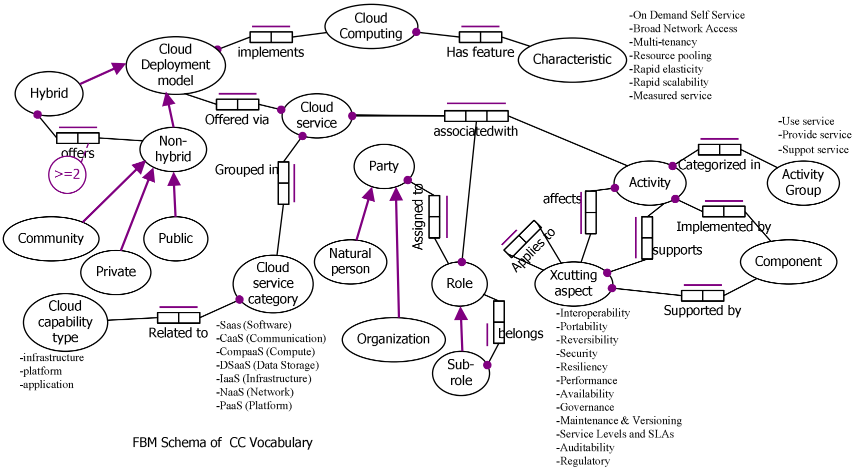

Fig. 1. Basic Cloud Computing Concepts from CD 17788.2

Tables 1 and 2 are the relevant definitions pertaining to the cloud computing models shown.

Table 1. Definitions of concepts used in Cloud Computing

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 services, providing services, and supporting 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

Table 2. Definitions of concepts used in Cloud Computing-continued

Concept	Definition	Examples
Cloud Service	one or more capabilities offered via cloud computing invoked using a declared interface	natural person, or an organization
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 Figure 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 SOA text [6] [7] and the CCRA text [3]. The purpose of the diagrams is being able to compare them using a formal methodology to represent the involved facts and relationships as opposed to comparing text paragraphs.

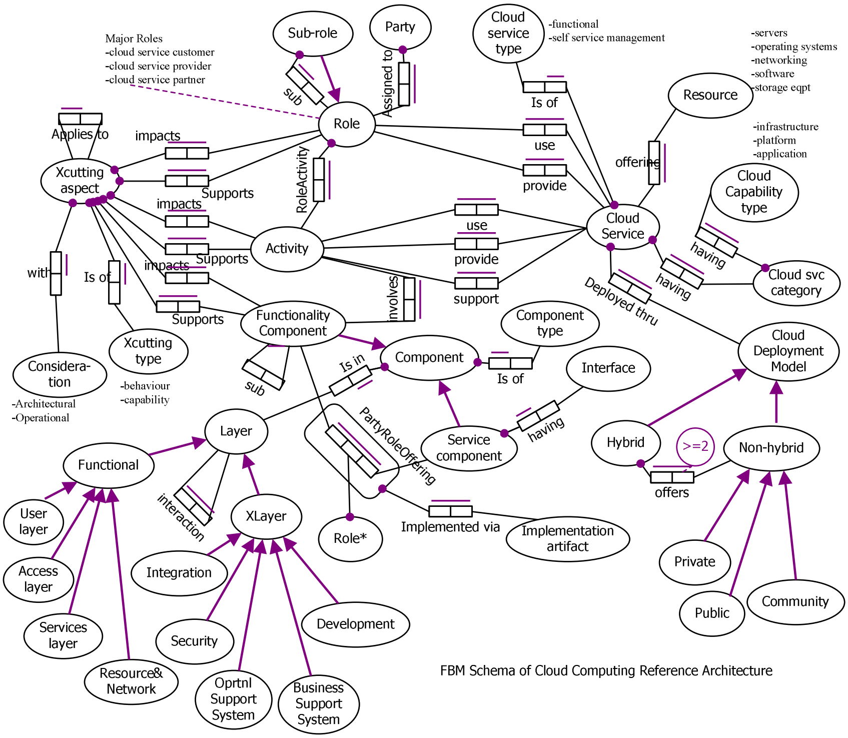

Fig. 2. Cloud Computing Reference Architecture Model from CD 17789.1

4 SOA Concepts

The basic SOA concepts [6] were derived from work already progressing in industry consortia and other standardization bodies. In a similar fashion to the Cloud Computing work, SOA terminology was first established in a Technical Report TR30102 [5]. Figure 3 includes the basic SOA concepts of entity, actors and their roles, and their relationship to a service. Figures 4 and 5 portray the SOA capability model as it relates to the service capability component. Figure 6 relates services with tasks, compositions, and processes.

The use of FBM has highlighted the overloading of the term ‘element’ in the SOA WD18384-1. The text defines element as ‘a unit that is indivisible at a given level of abstraction and has a clearly defined boundary’. It does appear that the document also uses element in a natural English language construct. However, the term "element" is specifically formally portrayed in the figures in order to include a service, human actor, task, system, and that the element orchestrates a composition. The authors can only conclude the term is being over-used. The use of FBM modeling in Figure 4 makes the overloading obvious by the depiction of subtype relationships in the FBM schema. Figure 5 provides a portrayal of the same relationships, but with the element concept removed.

Figure 6 portrays the SOA service capability model depicting how capabilities are related to services, components and architectural blocks.

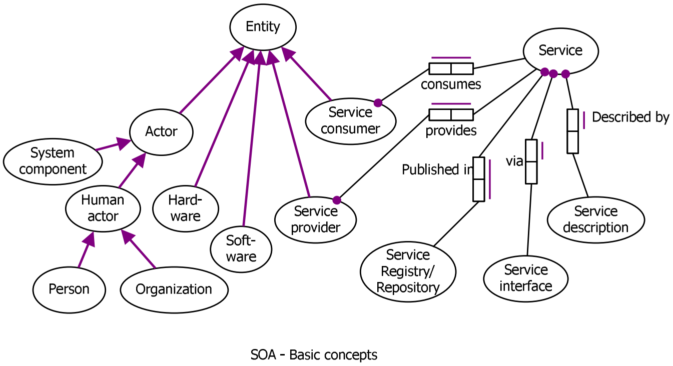

Fig. 3. SOA Basic Concepts Model from WD18384-1

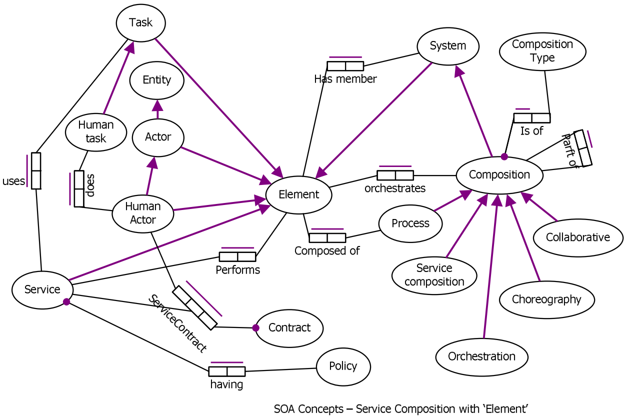

Fig. 4. SOA Task Composition Model – with 'Element' from WD18384-1

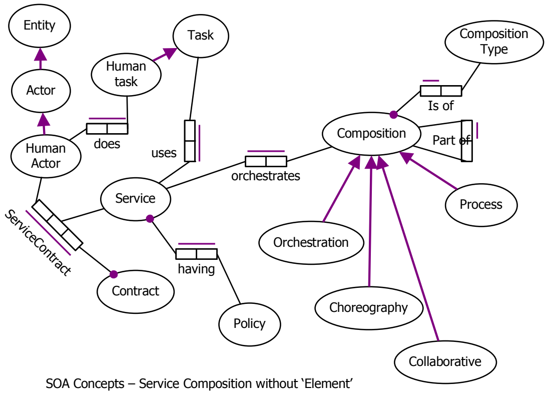

Fig. 5. SOA Task Composition Model – without 'Element' from WD18384-1

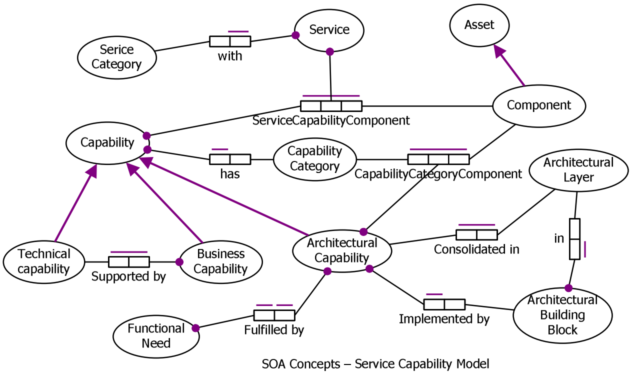

Fig. 6. SOA Service Capability Model from WD 18384-1

5 SOA Reference Architecture

The SOA reference architecture [7], illustrated in Figure 7, describes nine layers of considerations and responsibilities. For each layer, there are three aspects that should be supported by the SOA Reference Architecture:

- Requirements (exemplified by the capabilities for each layer). The requirements aspect reflects what the layer enables and includes all of its capabilities.
- Logical (exemplified by the architectural building blocks). The logical aspect includes all the architectural building blocks, design decisions, options, KPIs, etc.
- Physical (this aspect will be left to the implementation of the standard by an adaptor of the standard). The physical aspect of each layer includes the realization of each logical aspect using technology, standards and products that are determined by taking into consideration the different architectural decisions that are necessary to be made to realize and construct the architecture.

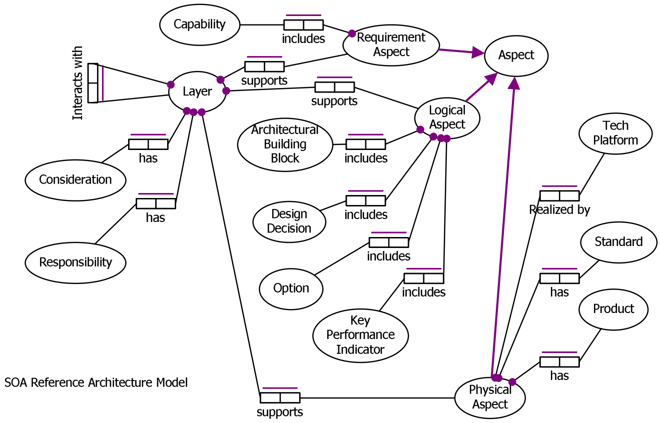

Fig. 7. SOA Reference Architecture from WD18384-2

Table 3. Definitions of concepts used in SOA

Concept	Definition	Examples
Entity	Individual in a service system with an identity which can act as a service provider or consumer.	organizations, enterprises and individuals, software and hardware
Actor	A person or system component who interacts with the system as a whole and who provides stimulus which invoke actions	Human actor
Task	Atomic action which accomplishes a defined result	Human task
Service	Logical representation of a set of repeatable activities that has specified outcomes, is self-contained, may be composed of other services, and is a "black box" to consumers of the service	Note: The word "activity" in the definition is used in the general English language sense of the word.
Composition	Result of assembling a collection of things for a particular purpose	Orchestration Choreography Collaborative
Process	Composition whose elements are composed into a sequence or flow of activities and interactions with the objective of carrying out certain work	
Service Component	Element that implements services	

6 Cloud Computing and SOA Analysis

By transforming each of the SOA and 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 two architectures.

It immediately becomes apparent that, cloud computing uses the term 'cloud service' so as to not be confused with a 'service' in SOA. The two architectures appear to skirt the issue of whether an SOA service is a cloud service or not.

Cloud Computing uses ODP views whereas SOA focuses on compositions and nine layers of considerations and capabilities.

The issue of entity and roles also appears to be not in sync between the two. Cloud Computing has distinctly identified the various roles of the various providers, brokers, auditors and users of the cloud services. SOA includes hardware and software as entities and appears to be using the roles of service consumer and service provider---and differentiating at times with actors and human actors.

Cloud Computing stays away from the physical implementation and deployment area, whereas SOA includes the physical aspect in each layer.

One question that arises is: Is there a true difference between an SOA service and a cloud service? SOA attempts to partly address the difference between a process and a service, whereas cloud computing distinctly isolates a 'process' as an operational process or business process.

These are only some of the examples of divergence between the cloud computing and SOA concepts and architectures.

It is clear that there needs to be an accord between the Cloud Computing standards group and the SOA standards group - especially since they are part of the same ISO committee.

7 Conclusions

In this paper we have demonstrated the use of Fact Based Modeling to facilitate a comparative analysis of the emerging ISO vocabulary and reference architecture standards for Cloud Computing and Service Oriented Architecture. As a result, we have identified a number of areas where the concepts in the vocabulary and architecture documents are misaligned. We have also identified a number of areas where Cloud Computing and SOA are using similar concepts, typically in ways that are not 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 between Cloud Computing and SOA.

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