# Ontology-based Modeling of Cloud Services: Challenges and Perspectives

Barbara Livieri[1], Nicola Guarino[2], Marco Salvatore Zappatore[1], Giancarlo Guizzardi[3], Antonella Longo[1], Mario Bochicchio[1], Julio C. Nardi[4], Monalessa P. Barcellos[3], Glaice K. Quirino[3], and Ricardo A. Falbo[3]

[1] University of Salento, Lecce, Italy
{name.surname}@unisalento.com
[2] ISTC-CNR Laboratory for Applied Ontology, Trento, Italy
{nicola.guarino}@loa.istc.cnr.it
[3] Federal University of Esprito Santo, Vitória, Brazil,
{gguizzardi,monalessa,gksquirino,falbo}@inf.ufes.br
[4] Federal Institute of Esprito Santo, Campus Colatina, Colatina, ES, Brazil,
{julionardi}@ifes.edu.br

**Abstract.** Cloud services (CCS) are a crucial element in the service sector, but there are still challenges left in their design, implementation, operation and dismissal, due to issues such as the integration of physical and technical components, interaction of social and technical aspects, dynamic and elastic reconfiguration. In modelling service systems, ontologies have been recognized as a useful instrument for reducing conceptual ambiguities and inconsistencies. However, none of the general approaches proposed in literature have addressed the specific aspects of CCS. In this perspective, we explore how the UFO-S core ontology can be used to describe IT services and, in particular, CCS. A case study and the challenges deriving by CCS are discussed.

**Key words:** Cloud services, Service ontology, Core ontology

## 1 Introduction and Motivations

For many years, services have been investigated from the economic, financial and juridical viewpoints due to their socio-economic relevance. More recently, IT services have become a very active field of study, due to the complex interplay among the above-mentioned aspects and the peculiar features of the digital milieu (e.g. ubiquity, mobility, context-awareness). Cloud computing services (CCSs) differ from traditional IT services for some characteristics, such as abstraction from the underlying hardware/software infrastructure, multi-platform accessibility, on-demand service provisioning, pay-per-use-based business models, dynamic quality of service (QoS) management, scalability and flexibility. These peculiarities, which are responsible for the rapid emergence of a large number of CCSs, motivate the importance of a specific analysis.

From the customer perspective, "the great amount of CCSs makes it hard to compare the offers and to find the right service" [11, p. 81]. The customer needs to evaluate service features and expected outcomes, their correspondence to his needs, the risks associated to the service (e.g., lock in, security) and the opportunities (e.g., integration with other services). Starting from these considerations, the customer can choose which service to buy. This information is also useful to the provider for strategic purposes; for instance in order to evaluate possible service compositions, service pricing, or the dynamic allocation of resources [23].

It seems clear that a proper analysis of CCS from the conceptual perspective requires a holistic approach, taking the whole *service system* into account. This means understanding target customers, relations among actors, and the specific ways of value co-creation. In turn, this demands understanding the way in which actors operate, interact and use resources to co-create value.

In modelling service systems, ontologies have been recognized as a useful instrument for reducing conceptual ambiguities and inconsistencies [5, 17, **?**, 16]. None of these general approaches, however, have addressed the peculiarities of CCS. In this paper we would like to explore how a general ontology of services – the core ontology of services developed in [16], named UFO-S – can be used to describe IT services, and in particular CCS. The choice of UFO-S for our analysis is due to some of its peculiarities with respect to other service ontologies [16]: (a) by communicating commitment-related aspects, it reinforces the importance of what "contract" and "policy" elements represent in service relations; (b) it clearly defines the roles of target customer, service customer, service provider, and so on, important for understanding the dynamics of service relations; (c) it incorporates the notion of commitments into dynamics of behavior in service provisioning; (d) taking a foundational ontology, UFO [8], as a basis, UFO-S incorporates a clear distinction between capabilities, their application, and resources; (e) it offers means for characterizing service specifications in terms of service commitments, often neglected in computational approaches.

Our aim is to identify which are the changes needed to UFO-S in order to account for CCS and which are the aspects that can be already modelled using the existing primitives. This will be based on the application of UFO-S to a specific case study, which – besides the immediate relevance to the cloud computing domain – represents a particularly complex domain.

The remainder of the paper is structured as follows. In Sec. 2, we outline the peculiarities of CCS, thus setting the groundwork on why these services pose more challenges than other IT services. In Sec. 3 we shortly recap UFO-S, which we use to model a case study (Sec. 4). Finally, based on the previous sections, we outline the main modeling challenges for IT services (Sec. 5).

## 2 Cloud Services

Cloud services are based on the cloud computing technology, which has been defined by the National Institute of Standards and Technology (NIST) as "*a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources [...]*" ([14], p. 3).

The heterogeneity in CCSs is so significant [11] that they can hardly be classified in a simple way. Among the most relevant classification factors proposed in the literature [14, 12, 11, 10, 18, 19] we can mention the service model, the underlying architecture, the license type, the pricing policy and other aspects. Based on these various aspects of CCS, a few taxonomies [10, 11, 19] and ontologies [22, 15] have been proposed. In the following, we address some of these aspects relevant for the ideas discussed in this pape

Service deployment is a complex process that undergoes several phases (collectively known as service lifecycle), such as service design, service implementation, service offering, service negotiation and agreement, service delivery, service support and service end-of-life management [13, 16].

On a first approximation, there are four main roles involved, namely service provider, service producer, service customer and service consumer [6] (or end-user [13]). A service provider is the agent who commits to have the service executed, while the service producer is the agent that actually performs the core service actions. These two roles may be played by the same actor, but this is not always the case. Furthermore, the service customer is the one that requests the service and then negotiates for its customized delivery, while the consumer is its direct beneficiary. Customer and consumer may or may not coincide. In the case of CCS, eight roles have been identified [2], as outlined in the following.

Providers can be either application providers, platform providers or infrastructure providers. The application provider provides applications to customers and is responsible for overall service monitoring and quality assurance. The platform provider offers "*an environment to develop, run and test applications*" ([2], p. 6). Finally, the infrastructure provider is concerned with the offering of virtual hardware and network connections.

Intermediate roles are played by consultants, aggregators and integrators. Consultants offer expertise on cloud computing and on the customer's business processes and requirements. Aggregators assemble CCS in order to provide more complex solutions. Integrators intervene when there is not a previous aggregation of CCS, but it is the customer that decide which services to integrate. Finally, consumers are the direct beneficiaries of the service.

Cloud services are characterised by high dynamicity from different points of view. We can distinguish the requirement layer (from the customer/consumer perspective), the resource layer, the value layer and the legal layer. From the customer perspective, requirements towards service functionalities – based on customers' goals, which can rapidly change – are the basis for choosing among services and differs based on the user community, which may have different needs. From the provider perspective, the dinamicity in the demand of the service brings to the dinamicity at the resource layer, in terms of capabilities required to design, develop and deploy the service. In accordance with with the resource-based view theory [21], resources and competences affects products value. Consequently the dinamicity at the resource layer creates value dinamicity, which affects both customers and providers. The resource dinamicity is also affected by the legal one, which concerns all the terms established in the SLA or the constraints set by law, which gains more importance due to the issue of service contracts that cross multiple jurisdictions. For what regards CCS, the resource dinamicity is the most critical factor, since cloud computing implies by definition a dynamic allocation of resources. This issue needs to be faced starting from service design, i.e. the service needs to be highly user-adjustableIndeed. More in general, the provider has to guarantee the contractually defined levels of service, allocating *"limited resources among competing users"* ([1], p. 16) in order to satisfy the agreed service levels while still minimizing the operational costs [23] and maximize potential revenues and perceived value. In this sense, the dynamism of user requirements, legal constraints and allocated resources, implies a dynamism of both the value proposition of the provider and the customer expected and perceived value. These considerations should also constitute the basis for adequate pricing policies and for setting QoS levels (e.g., the cost email loss is higher for managers than for other employees and it may change over time).

Based on CCS characteristics and their dynamism, it is necessary to account for: (a) the different roles that actors can assume (e.g., an organization is a customer of a company and provider of another one); (b) the characteristics of the actors involved, the external environment (e.g., competitors) and the internal structure and dynamics of the organizations, also in terms of resources used.

## 3 Unified Foundational Ontology for Services

UFO-S, a core reference ontology for services, is able to explain a number of perspectives on services, including those that emphasize services as value co-creation, as capabilities and as application of competences [16]. UFO-S establishes the basis for the service phenomena along the service lifecycle considering the notion of commitment as foundationally necessary, in agreement with [5].

As a core ontology [20], UFO-S refines concepts of a foundational ontology – the Unified Foundational Ontology (UFO) [8, 9] – by providing a conceptualization for services that is independent of a particular application domain. From a modelling point of view, UFO-S is based upon the usage of OntoUML language [8], an ontological extension of UML that incorporates the foundational directions in UFO. We now list the stereotypes that we will adopt for the case study, while forwarding the interested readers to [8, 16] for a thorough description.

First of all, each object is considered as an instance of a *kind*, which is a substantial sortal universal. Each entity can assume a *role* depending on the context. An entity capable of covering many other concepts with different principles of identity is considered as a *mixin*. Other kinds of types can be highlighted: *phases* represent possible stages in the history of a substance sortal (e.g., for a living thing, alive and deceased). In the same way, *modes* are individuals existentially dependent on other individuals.Other basic concepts include: *agents* (e.g., person, organization); physical or social *objects*, i.e., non-agentive substantial particulars; *actions*, which stand for intentional events whose existence depends on their own participants; *resources*, i.e., objects participating in an action. In addition, a crucial role in UFO-S is played by *relators*, which can be seen as reified relationship. More exactly, relators, whose ontological nature and significance for the practice of conceptual modelling has been recently revisited in [7] can be seen as aggregations of qualities (*modes*, in UFO) inhering in related entities, accounting for the way the related entities are involved in the relationship.

The UFO stereotypes sketched so far allow us to understand how service lifecycle phases have been modelled in [16]. For explanatory purposes, let us consider here only the service negotiation phase. This phase is an *event* involving a service provider – a *physical agent* (i.e., a person) or *social agent* (e.g., enterprise) – and a target customer community, i.e., a collective referring to the group of agents to whom the service is being offered and whose *role* is target customer. The successful outcome of a service negotiation is a service agreement, which mediates the social relations between provider and customer. Similarly, the agents involved in service lifecycle phases perform specific *actions* depending on the phase they are involved into. We forward the interested reader to [16] for a thorough description of those aspects.

In this paper, we focus on two phases of the service life-cycle according to the formalization proposed in [16]. More specifically: (i) service negotiation, when provider and customer(s) negotiate in order to establish an agreement about specific aspects that drive the service delivery, and (ii) service delivery, when actions are performed in order to fulfil a service agreement.

## 4 Applying UFO-S: a Case Study

Let us see now how a reference ontology of services, UFO-S, can be applied to develop a service ontology concerning a concrete example of a cloud service, coming from a real case study. The case study pertains an email service internally delivered to an Italian company with more than 5000 employees spread out into more than 100 offices all over the country. The IT Department of such company was responsible for procuring this service. After a public call, two service providers were selected for the mailbox service and the networking service.

The model we developed resulting from the application of UFO-S to our case study is reported in Fig. 1. To better understand the scenario, we have divided our model in two parts, representing what happens at the *contractual level* (upper yellow layer) and at the *delivery level* (bottom green layer). The central entities in these two parts are respectively the *IT Service Contractual Relationship* and the *IT Service Factual Relationship*. This structure reflects a peculiarity of our domain, and in particular of CCS: during the service delivery phase the actual resources allocated by the provider are dynamically adjusted, and contractual aspects keep being dynamically re-negotiated while the service delivery evolve. So we have two relationships that evolve more or less at the same time: a *contractual* relationship and a *factual* relationship. Thanks to the relator construct we can account for both. In particular, as we have shown in the model, we can account for different *phases* of the contractual relationship, such as, for example, a test phase where the optimal resources to be allocated are estimated, a normal phase, and an emergency phase where for some reasons there is a scarcity of resources, and some priority policies need to be adopted on the basis of the customer's needs. Concerning the customer's needs, we can see that they are represented as a *mode* inhering in the customer, but which depends on a specific department inside the customer's organization, namely the IT department. Together with the customer's and the providers' commitments, customer's needs are part of the bundle that constitute the factual relationships, whilst only the first two are relevant for the contractual relationship.

Both relationships involve the *Hired ICT Provider*, specialized in the *network* and *mailbox* service provider, and the *Business Customer*. It is important to highlight that although it is the business customer who is bound to the contractual and factual relationships, it is the *IT Department* who participates in the *Initial Service Negotiation*. Thus, it establishes commitments and claims on behalf of the business customer. As a consequence, the commitments and claims established by the IT Department "belongs" to the business customer.

It is worth noticing that the core action in the service delivery, namely the *Single Mail Action*, is not performed by the providers but rather from the *User* (see Sec. 5). The user is, at the same time, the beneficiary of the service, though is not the one that can choose which providers to hire or under which conditions the service is delivered (i.e., the IT department), nor the one who actually pays for the service (business customer). Thus, the user is the consumer of the service. The *Hired Network Service Provider* performs the action of providing the Internet connection, by allocating the required *Internet Bandwidth*.

We must observe that, despite we have tried to use UFO-S as much as possible, the peculiarity of our case study has forced us to deviate from it in many respects. One aspect concerns the relation between the provider's commitment and the action that constitutes what the provider commits on, that is, in our case, a mail sending/receiving action, or a mailbox management action. This action is *guaranteed* by the provider, but it is actually executed by the user, which is in this case a customer's employee. In this particular case, the action on which the mailbox provider commits presupposes another action, namely some kind of internet transport (or internet connection), which is guaranteed by another provider: the network provider.

## 5 Lesson learned: modeling challenges and perspectives

As we have seen, conceptual modelling of CCS poses several challenges, parts of which can be addressed with the current version of UFO-S and parts of which require its extension. Let us recap them.

The analysis of the CCS characteristics and of the case study brings to light how the corresponding models need to reflect dynamism and flexibility of CCS, in terms of both service structure and governance choices based on a cost-benefit analysis. The relational dynamic aspects can be modeled by means of relators since they are bundles of qualities – in this case, commitments and claims – that account for the way in which the related entities are involved in the relationship.

Indeed, it is necessary to distinguish among what is defined contractually, i.e. the contractual relation, and what is actually done, i.e., the factual relation.

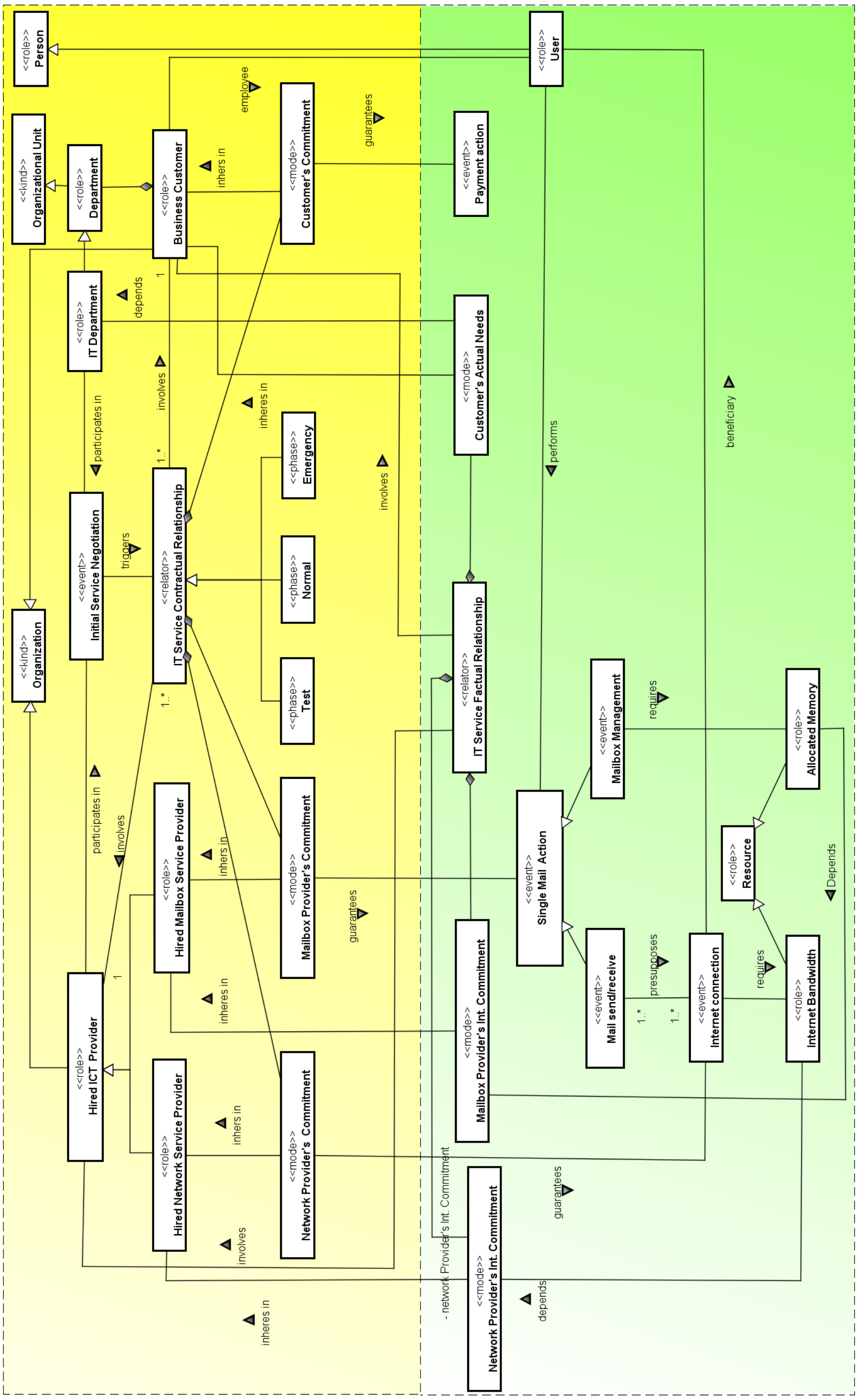


**Fig. 1.** Service Agreement Sub-Ontology and the Service Delivery Sub-Ontology

As previously stated, in the service delivery phase it may be necessary to dynamically re-negotiate contractual conditions and allocate resources. The former aspect concerns the redefinition of the contract based on the actual commitment of the providers and on the customer needs expressed by the IT department. The contractual relation is accounted for in UFO-S, while the factual relation is not yet factored in. The latter trait, together with the dynamic optimization of resources, is one of the key aspects of cloud services. This peculiarity requires to account for both the resources and the value of the service, in order to face the trade-off between costs, QoS, potential revenues and penalties. A change in the allocation of the resources, may bring to the payment of penalties or to revenue loss. The potential revenues can be analyzed by understanding how value is perceived by the target customers, thus more effectively tailoring the price to the context in which the service is sold and on the characteristics of the target customers. In this sense, it should be possible to model organizations, societal aspects, target customers, high-level preferences. Among the aspects that may affect customers' preferences , there are the lock-in risk, software license type, privacy and security concerns, which can be modeled with resources, besides the more common considerations of the actions needed to buy or use the service.

The dynamic allocation of resources affects also the relevance of the notion of *commitment*, on which UFO-S is built. Indeed, the customer pays for having the provider committed to procure the amount of resources needed by the user in order to benefit from the service [16, 5]. UFO-S does not specifically tailor resources and value aspects, although the notions concerning resources and, more in general, organizations are considered in the Enterprise Ontology Pattern Language [3] and taking UFO as a basis, UFO-S incorporates a clear distinction between capabilities, application of capabilities, and resources. Such concepts are clarified, respectively, in terms of dispositions (as intrinsic moments), manifestation of dispositions, and individuals that bear such dispositions.

To consider also the aspects related to value propositions and contractual issues, the different phases of the service lifecycle have to be analyzed and extended, from the service design to the offering, the delivery and, finally, the termination phase. In the latter phase, data storage issues gain particular importance for CCS, since the provider is in charge of deleting all customer-related data after service termination. The concept of *commitment* is useful to model this traits, as well as all other obligations assumed by the provider towards the customer. These aspects affect value as well, as customers evaluate potential data breaches, penalties in case of cancellation of the contract and several other aspects to decide how valuable the service can be for itself or for its company.

Moreover, it is important to tackle role changes for a given actor, especially in service chain scenarios. If we refer to the proposed case study, we have that a given company buys two services from two different external providers in order to integrate them and offer them to its employees. Thus, the company offers the integrated IT service to its employees, without being responsible for the quality of these services (QoS) or being able to intervene on the delivered QoS. In this sense, the company is not only a customer but rather a service aggregator that, from the employees' point of view, behaves as a service provider, thus denoting the modelling need of role changes for actors.In addition, another issue related to roles has to be mentioned as well. As highlighted in Sections **??** and 4, besides the roles of service provider and customer, other ones should be accounted for, such as service consumer and service aggregator.

Finally, IT services – and in particular CCS – are seldom *instrumental services*. With instrumental service we mean that the offer of the provider does not consist of an action (e.g., cutting your hair), but rather of allowing the user to perform a given action, which constitute the *core action* of the service. In our case study, the providers offer the Internet connection and the mailbox application, with whom they guarantee to the users that they can send/receive or manage emails. In this frame, the provider performs *supporting actions* apt at enabling the core service consumption [4]. In other words, although the actions are guaranteed by the provider, they are executed by the user.

## 6 Conclusions

This work investigate whether cloud services can be represented by means of the core ontology for services, namely Unified Foundational Ontology for Services (UFO-S). In order to do so, we outline CCS peculiarities, e.g., dinamicity, and the roles of the actors involved in their deployment and usage. Thus, we apply UFO-S to a case study concerning the external provisioning and internal delivery of an email service in a big company.

Through the modeling of the case study, we outline the main benefits of UFO-S and the extension required to model CCS, focusing on the necessity of representing dynamism, value, roles and actions . Besides the previously described general advantages of the adoption of UFO-S, we analyze the relavance of relators for CCS modeling. Relators are a bundle of qualities, through which it is possible to represent dynamic relationships among providers and customers in the lifecycle phases e.g. contractual and factual relationships. In the current version of UFO-S only the initial agreement relationships is factored in, while there is no account, e.g. for the factual relationship. Thus, an extension is needed.

We also show that in order to account for value, value propositions and contractual aspects the phases of the service lifecycle need to be expanded, so to include the service design and termination phases. The complexity of CCS requires for an in-depth analysis of roles, which can be multiple for the same actor. At the moment, it is not possible to represent this with UFO-S. The complexity of CSS requires for an in-depth analysis of roles. Thus, the number of service participant roles should be extended in UFO-S in order to include also the ones defined in cloud computing literature. Finally, we highlight how the analysis of the notions of *core* and supporting actions is necessary in order caractherize instrumental services.

Future work will be directed at the integration of these aspects in UFO-S, with the aim of providing a new version of the core ontology.

## References


1. Bayrak, E., Conley, J.P., Wilkie, S.: The economics of cloud computing. The Korean Economic Review 27(2), 203–230 (2011)
2. Böhm, M., et al.: Towards a generic value network for cloud computing. In: Economics of Grids, Clouds, Systems, and Services, pp. 129–140. Springer (2010)
3. Falbo, R.d.A., et al.: Towards an enterprise ontology pattern language. In: Proceedings of the 29th SAC. pp. 323–330. ACM (2014)
4. Ferrario, R., et al.: Towards an ontological foundation for services science: The legal perspective. In: Approaches to legal ontologies, pp. 235–258. Springer (2011)
5. Ferrario, R., Guarino, N.: Towards an ontological foundation for services science. Future Internet–FIS 2008 p. 152 (2009)
6. Guarino, N.: Services and service systems under a mesoscopic perspective. Service Dominant Logic, Network and Systems Theory, and Service Science: Integrating three Perspectives for a New Service Agenda (2013)
7. Guarino, N., Guizzardi, G.: "we need to discuss the relationship": Re-visiting relationships as modeling constructs. In: CAiSE2015. Springer (2015)
8. Guizzardi, G.: Ontological foundations for structural conceptual models. Ph.D. thesis, Universiteit Twente (2005)
9. Guizzardi, G., de Almeida Falbo, R., Guizzardi, R.S.: Grounding software domain ontologies in the unified foundational ontology (ufo): The case of the ode software process ontology. In: CIbSE. pp. 127–140 (2008)
10. Hoefer, C.N., Karagiannis, G.: Taxonomy of cloud computing services. In: GLOBECOM Workshops (GC Wkshps), 2010 IEEE. pp. 1345–1350. IEEE (2010)
11. Höfer, C., Karagiannis, G.: Cloud computing services: taxonomy and comparison. Journal of Internet Services and Applications 2(2), 81–94 (2011)
12. Katzan Jr, H., et al.: On an ontological view of cloud computing. Journal of Service Science (JSS) 3(1) (2011)
13. Kohlborn, T., et: Business and software service lifecycle management. In: EDOC'09. IEEE International. pp. 87–96. IEEE (2009)
14. Mell, P., Grance, T.: The nist definition of cloud computing (2011)
15. Moscato, F., et al.: An analysis of mosaic ontology for cloud resources annotation. In: FedCSIS 2011. pp. 973–980. IEEE (2011)
16. Nardi, J.C., et al.: A commitment-based reference ontology for services. Information Systems (2015)
17. Oberle, D., et al.: Countering service information challenges in the internet of services. Business & Information Systems Engineering 1(5), 370–390 (2009)
18. de Oliveira, D., Baião, F.A., Mattoso, M.: Towards a taxonomy for cloud computing from an e-science perspective. In: Cloud Computing, pp. 47–62. Springer (2010)
19. Rimal, B.P., et al.: A taxonomy and survey of cloud computing systems. In: NCM'09. pp. 44–51. IEEE (2009)
20. Scherp, A., et al.: Designing core ontologies. Applied Ontology 6(3), 177–221 (2011)
21. Wernerfelt, B.: A resource-based view of the firm. Strategic management journal 5(2), 171–180 (1984)
22. Youseff, L., et al.: Toward a unified ontology of cloud computing. In: Grid Computing Environments Workshop, 2008. GCE'08. pp. 1–10. IEEE (2008)
23. Zhang, Q., Cheng, L., Boutaba, R.: Cloud computing: state-of-the-art and research challenges. Journal of internet services and applications 1(1), 7–18 (2010)