Service Contract Modeling in Enterprise Architecture: An Ontology-based Approach

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Abstract— **Service contracts bind parties legally, regulating their behavior in the scope of a (business) service relationship. Given that there are legal consequences attached to service contracts, understanding the elements of a contract is key to managing services in an enterprise. After all, provisions in a service contract and in legislation establish obligations and rights for service providers and customers that must be respected in service delivery. The importance of service contracts to service provisioning in an enterprise has motivated us to investigate their representation in enterprise models. We have observed that approaches fall into two extremes of a spectrum. Some approaches, such as ArchiMate, offer an opaque "contract" construct, not revealing the rights and obligations in the scope of the governed service relationship. Other approaches, under the umbrella term "contract languages", are devoted exactly to the formal representation of the contents of contracts. Despite the applications of contract languages, they operate at a level of detail that does not match that of enterprise architecture models. In this paper, we explore and bridge the gap between these two extremes. We address the representation of service contract elements with a systematic approach: we first propose a well-founded service contract ontology, and then extend the ArchiMate language to reflect the elements of the service contract ontology. The applicability of the proposed extension is assessed in the representation of a real-world cloud service contract.**

Keywords: Legal contracts; service modeling; enterprise architecture; service contract ontology; ArchiMate.

1. Introduction

For almost a decade now, service phenomena have been accounted for from the perspective of the social relations established and maintained by service participants [1]. In the view put forward by Ferrario and Guarino in [1] and further developed in [2], services are provided and consumed in a network of social relationships in which commitments and corresponding claims play a pivotal role. While this social perspective is central to account for service phenomena, it does not explicitly recognize the legal dimension of services. In all service economies, services are subject to regulation, with service relationships transcending a purely social realm into a legal one. Because of this, service agreements are in their vast majority formalized into (written) contracts, which describe and stipulate how service relations are to be governed. Legal parties (such as enterprises) use contracts in order to guide their (mutual) actions in the scope of service relationships as well as to enact their legal consequences. Loosely speaking, we can say that a contract establishes legal commitments, duties, obligations, claims, rights, entitlements, prohibitions, exemptions, etc.

In addition to being formalized, services are subject to regulation. For example, in some legal systems, it is unlawful for an organization that has offered a service to refuse arbitrarily to provide the service to a particular customer in case no legitimate business reason is provided (in order to rule out arbitrary discrimination) [2]. Further, interactions throughout the service lifecycle have legal consequences. For example, legal execution of a debt may occur if a service customer fails to fulfill its payment commitments; a service provider may be required to offer compensation in case service delivery does not honor service agreements.

Given the potential impact of service contracts and their legal aspects, enterprises cannot afford to overlook them in service provisioning. This has motivated us to investigate their representation in enterprise models [3]. From the start, we have observed that approaches to the representation of contracts fall into two extremes of a spectrum. Some approaches, such as ArchiMate, offer an opaque "contract" construct [4]. This means that, while ArchiMate acknowledges the benefit of identifying contracts for service-oriented architectures, it does not reveal the various legal positions that parties assume in the scope of the governed service relationship. Other approaches, under the umbrella term "contract languages" and *e-contracting* [5] [6], are devoted exactly to the formal representation of the contents of contracts. This means that they are able to reveal the ways in which parties ought to act in the scope of (service) contracts, which can be fruitful, e.g., in the analysis of business process compliance, in

dynamic service discovery and matching, and in the verification of formal properties of contracts [7] [8].

Despite the applications of contract languages and e-contracts, they operate at a level of detail that does not match that of Enterprise Architecture (EA) models. This is because EA discipline adopts a "holistic" perspective on the enterprise [9], addressing enterprise-wide instead of detailed descriptions. In EA, it is essential to bridge the gap between various architectural domains [10]. In contrast, contract languages and e-contracts focus exactly on detailed descriptions of contracts.

Bearing in mind the demands of the representation of the legal aspects of service contracts in EA, we have been exploring the gap between the two extreme ends of the spectrum. Our approach has been to incorporate the representation of service contract elements into EA models. This results in a representation that, while not overly detailed, reveals important legal positions in the scope of a contract [3]. In line with advances in ontology-based language engineering, we have employed a systematic approach.

The first step was the design a well-founded service contract ontology, rooted in both a legal core ontology (called UFO-L) [11] [12] and a core ontology of services (called UFO-S) [2] [13] [14] [15]. The semantic foundations employed in our service contract ontology are aimed to ensure adequacy with respect to the underlying legal phenomena and a comprehensive coverage of the service lifecycle. The relational nature of the account is particularly suited for the conceptualization of contracts, as opposed to the monadic and non-related nature of standard deontic logics that underlie many of the current approaches to the representation of contracts.

The second step consisted in using the service contract ontology as a basis to propose an extension of the ArchiMate Enterprise Architecture language and framework. ArchiMate was chosen given the central role of the "service" construct in its design and the support for a "contract" construct since its inception [10]. It is a widely employed EA framework, with supporting tools and an active user community. The proposed extension was integrated into the ArchiMate "contract" construct. A notion of "contract element" was introduced to reveal the various legal positions of parties in the scope of the contract.

In this paper, we set that research agenda forward, extending the work described in [3]. We address here explicitly parts of the service lifecycle that had not been addressed previously in [3]. We address the provisions for services that, while not explicitly mentioned in contract texts, are part of legislation and, hence, must be observed in legal service settings. This broader coverage of the service lifecycle leads to extensions of the original service contract ontology as well as the extension of the ArchiMate representation to cover service modeling patterns that had not been covered in the previous paper. Furthermore, the case study that shows the applicability of the extension has been revisited also to take into account the extended coverage of the lifecycle. Overall, a more thorough treatment of requirements, ontological foundations, validation and related work is also offered in this paper.

This paper is organized as follows: Section 2 presents some methodological considerations, justifying our use of an ontology-based approach to EA representation; Section 3 presents the conceptual foundation for services that we adopt here (UFO-S). Section 4 presents conceptual foundations for legal relations stemming from UFO-L. UFO-L accounts for a comprehensive set of related legal notions, including *rights* and *duties*, *no-rights* and *permissions*, *powers* and *liabilities*, *disabilities* and *immunities*, as well as *liberties*. Section 5 presents the proposed service contract ontology founded on both UFO-L and UFO-S. Section 6 presents an overview of ArchiMate service modeling and discusses how we extend ArchiMate to incorporate service contract elements according to the service contract ontology. Section 7 shows the application of the extension to represent a real-world cloud service contract applying the extension introduced in Section 6. Section 8 provides some empirical support for the concepts underlying the extension. Section 9 discusses related work and Section 10 presents final considerations.

2. Methodological considerations and requirements

This research has been conducted in the tradition of ontology-based language engineering and, in particular, on the ontology-based definition of real-world semantics of modeling languages. As explained in depth in [16], in the case of *referential semantics*, the meaning of constructs in language is defined by relating syntactic constructs of the language to elements in a *semantic domain*. Since the main goal of conceptual modeling languages is to support its users in tasks such as communication, domain problem-solving and meaning negotiation, this semantic domain should be exactly the conceptualization of that domain shared by a community of those users. Understanding and characterizing that shared conceptualization is thus a pre-requisite to the design of a language to describe phenomena in that given domain. For this reason, the investigation of a language's real-world semantics takes precedence over that language's formal semantics and syntax definition. Uncovering and precisely characterizing the nature of these conceptualizations is the very business of the area of *Formal Ontology*.

There is an established tradition of almost three decades of systematically analyzing and evaluating conceptual modeling languages by employing the results of formal ontological studies [17]. Since the pioneering work of [17], a number of languages have been evaluated and (re)designed using this approach, whose effectiveness has been empirically demonstrated by a myriad of empirical studies over the years [18] [19]. To cite one example, in [19], in an empirical study involving 528 practitioners, the authors demonstrate that the perception by practitioners of ontological deficiencies in conceptual modeling languages negatively affect their perception of both usefulness and usability of these languages.

The original method of [17] has been extended in [16] in several important ways[1]. We here emphasize that method strongly relies on the analysis of the level of correspondence between *the ontology underlying the language* [20] and an explicitly represented reference ontology. As demonstrated there, in the ideal case, the ontology underlying that language is isomorphic to the reference ontology in that domain. Whenever a language deviates from this ideal case, *domain appropriateness* and *comprehensibility appropriateness* of that language are affected [21] [16]. These possible deviations include: (i) *construct excess* – when there is a construct in the language that does not have an interpretation in terms of that reference ontology; (ii) *construct deficit* – when there is a notion in the ontology that cannot be expressed in the language; (iii) *construct overload* – when there is a construct in the language that admits more than one interpretation in terms of that reference ontology; (iv) *construct redundancy* – when there is more than one construct in the language that can be used to represent a particular notion in that ontology.

By using as a reference ontology the *Unified Foundational Ontology* (UFO) [22], this method has been successfully employed over the years to analyze, (re)design and integrate conceptual modeling languages and standards in different domains (e.g., UML, TOGAF, RM-ODP, TROPOS/i*, AORML, ARIS, BPMN). UFO was developed with the specific goals of providing foundations for conceptual modeling and by consistently integrating a number of theories originating from areas such as Formal Ontology in Philosophy, Cognitive Science, Linguistics and Philosophical Logic. Furthermore, a study published in 2016 [23], reveals that it is the second most used foundational ontology in conceptual modeling and the one with the fastest adoption rate. Over the years it has been used to provide conceptual clarification in complex enterprise domains such as Capabilities [24], Organizational Structures [25], Communities [26], Goals and Motivations [27] [28], Legal Relations [12], Business Processes [29], Discrete Event Simulation [30], Value [31] [32], Risk [33], etc. Of particular interest to the purposes of this article, UFO has been used to develop core ontologies in the domain of Services (termed UFO-S) [2], and Legal Relations (UFO-L) [11] [12]. Moreover, it has been used in several occasions to support ontological analyses and proposals for redesign of ArchiMate [24] [14] [33]. In this article, we employ the aforementioned method of language analysis and (re-)design to address the topic of Service Contract modeling in ArchiMate. In order to do that, we advance a reference ontology of *Service Contracts* built by properly integrating and extending UFO-S and UFO-L.

A suitable semantic foundation for services must characterize the multifaceted notion of service, covering its various perspectives, in particular addressing the social nature of service relations and the various aspects of the service lifecycle, i.e., the dynamic of service relations. In particular, as demonstrated by [2], the service phenomenon cannot be reduced to behavior. In fact, inherently relational notions such as service offering and service agreement are prior to and regulate the existence of service as behavior (i.e., service negotiation and delivery). With respect to contract phenomena, it is key to address the social nature of commitments and claims established by agents in their social context, but also the legal aspects that inevitably arise in highly developed (and formal) social contexts. The required account of legal aspects should include comprehensive treatment of the various *legal relations* that agents can enter into along with the legal positions they assume in the legal environment. Further, given that these legal relations are subject to change, the account should reveal their dynamic nature, i.e., their creation, destruction and change. As a consequence, a well-founded approach to the representation of service contract elements requires a clear and explicitly recognition of the *primacy of relations* in this domain. For this reason, our reference ontology must be based on a solid ontological theory of relations and on a legal theory organized around legal relational phenomena. As demonstrated in the remaining of the paper, through their grounding on UFO's *ontology of relations* [34] [35] and *Alexy's relational legal theory* (in case of UFO-L), UFO-S and UFO-L fit the bill as the foundation for our reference ontology of Service Contracts.

[1] [16] extends [17] by: (i) allowing for a more extensive analysis of the language considering it both at the level of a general representation system and at the level of individual diagrams; (ii) connecting the ontological theory also to the design of the language's concrete syntax; and, (iii) systematically evaluating the real-world semantics of the language in terms of the set of grammatically valid models of that language and the set of intended state of affairs accepted by the ontological theory. Moreover, [16], makes explicit that this method could in principle be employed by using any (domain-specific or domain-independent) ontology as a reference and that it is in no way restricted to the BWW ontology proposed by Weber & Wand [74]. For more details, one should refer to [75] [16].

3. Conceptual foundation for services

The complex and multifaceted notion of service has led to a number of service characterizations [36] [37]. One of these is the notion of "service as commitment" [2]. Existing works in Service Science [38] and Service Computing [39] explicitly mention commitments, promises and/or obligations for characterizing the *service relation* established between service participants. The benefits of a characterization based on commitments have been discussed from the perspective of business [38] as well as IT [40]. In the context of Service-Oriented Architectures (SOA), Singh et al. [40] remark that commitments can be used for raising the low-level abstraction of existing SOAs, allowing to reduce the gap between the business and the IT perspectives. In their view, commitments capture business meaning, which is not directly represented in process-oriented approaches [40], since process-oriented approaches focus on the sequence of tasks in which resources and capabilities are used and applied. Aiming to harmonize different perspectives, a reference ontology called UFO-S was developed [2].

As a *reference ontology* [20], UFO-S is intended to assist humans in meaning negotiation and shared understanding. It is grounded in UFO [21], from which it reuses foundational notions of objects, types, object properties, object relations, reified relational complexes (relators), events/processes, and further social concepts that specialize the more general notions and account for social reality. The social layer of UFO (UFO-C) includes important notions of social agents (e.g., enterprises), the objectives they pursue, the roles they play, the social relations they establish (composed of commitments and corresponding claims), etc. The author's choice for using UFO as a foundational for UFO-S is justified by successful application of UFO in previous works to evaluate, redesign, and ground ontologies, languages, and frameworks of several research areas, such as Software Engineering, Conceptual Modeling, and Enterprise Modeling (e.g., [41]). Moreover, a recent study [23] shows that UFO is perceived by modelers as particularly useful when analyzing notions pertaining to social and intentional aspects of reality.

In UFO-S, service relations are specializations of (UFO-C) *social relations*, which are, in turn, material relations. Like all material relations, service relations are grounded on a *relator* (a key notion in the UFO foundational ontology). A relator is an entity that is existentially dependent on at least two *individuals*, thus, mediating or binding them. A *relator* is composed of at least two (possibly complex) *moments.* The notion of *moment* in UFO refers to what is sometimes termed a trope, an objectified property, a feature or a quality in the ontology literature. The term bears no relation to the notion of time and derives from the German term *momente* to mean *momentary feature or property* as used by the philosopher E. Husserl. For our purposes here, we can understand a moment as an objectified (reified) property that inheres (and, hence, is existentially dependent of) another individual called its bearer. The moments that compose relators are called *externally dependent moments* as they inhere in one individual while being also existentially dependent on another individual. For example, understood as a relator, the service agreement between John and Amazon, Inc. is composed by a bundle of relational moments (commitments and claims of John towards Amazon) that inhere in John but that are still dependent on Amazon as well as another bundle of moments (commitments and claims of Amazon towards John) that inhere in Amazon but that are existentially dependent on John. For an extensive discussion on the notion of relators and of moments, please refer to [42] [35].

UFO-S focuses on the three basic phases of the service life-cycle, namely [2]: (i) service offer (when a service is presented and made available to a target customer community), (ii) service negotiation (when providers and customers negotiate in order to establish an agreement), and (iii) service delivery (when actions are performed to fulfill a service agreement).

Fig. 1 presents a UFO-S model fragment regarding service offer. In the models presented in this paper, the types reused from UFO are depicted in grey. A service offer is an event (e.g., the registration of a service provider organization in a chamber of commerce) that results in the establishment of a service offering, a relator which mediates the service provider and the target customer community. A service offering is composed of service offering commitments from the service provider towards the target customer community, and the corresponding service offering claims from the target community towards the service provider. Service offering commitments are meta-commitments (i.e., they are commitments to accept commitments), since they refer to commitments that can be established later in the negotiation phase, when a particular service agreement is instantiated from the service agreement type that is prescribed in the service offering. The content of the service offering commitments and claims may be described in service offering descriptions (e.g., folders, registration documents in a chamber of commerce, and artifacts in software service registries).

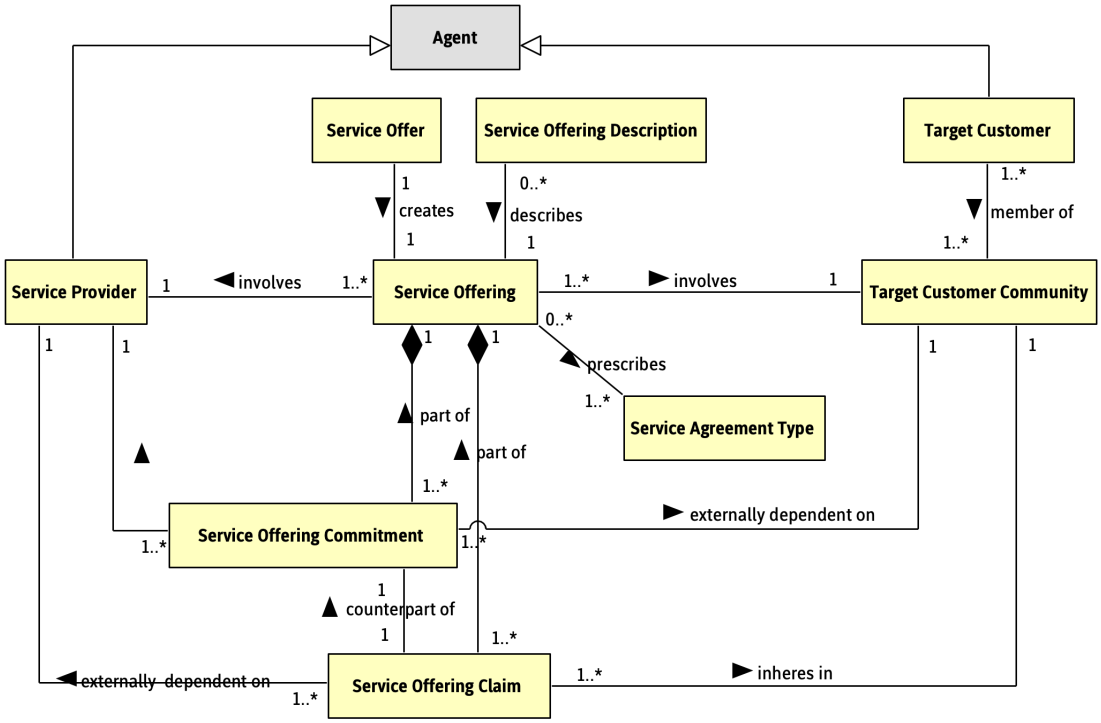

Fig. 1. UFO-S: Service Offering [2]

Service provider is the role played by agents (e.g., physical agents such as persons, and social agents such as organizations [41]) when these agents commit themselves to a target customer community by a set of offering commitments. Target customer community is a collective that refers to the group of agents that constitute the community to which the service is being offered. Target customer is the role played by agents when they become members of the target customer community, and, consequently, have claims for the fulfillment of the commitments established by the agent playing the role of service provider.

Once a service is offered, service negotiation may occur. Fig. 2 presents a UFO-S model fragment of this phase. If service negotiation succeeds, a service agreement is established, and the service provider starts to play the role of hired service provider, while the target customer starts to play the role of service customer. A service agreement then mediates the social relations between service customer and hired service provider, being composed of commitments and claims. Service agreements involve not only commitments from the hired service provider towards the service customer but may also involve commitments from the service customer towards the hired service provider (e.g., the commitment to pay). Hired provider commitments and claims are (objectified) properties that inhere in a hired service provider and are externally dependent on a service customer. Service customer commitments and claims are properties that inhere in a service customer and are externally dependent on a hired service provider. The content of commitments/claims of a service agreement may be described in a service agreement description (such as a written contract).

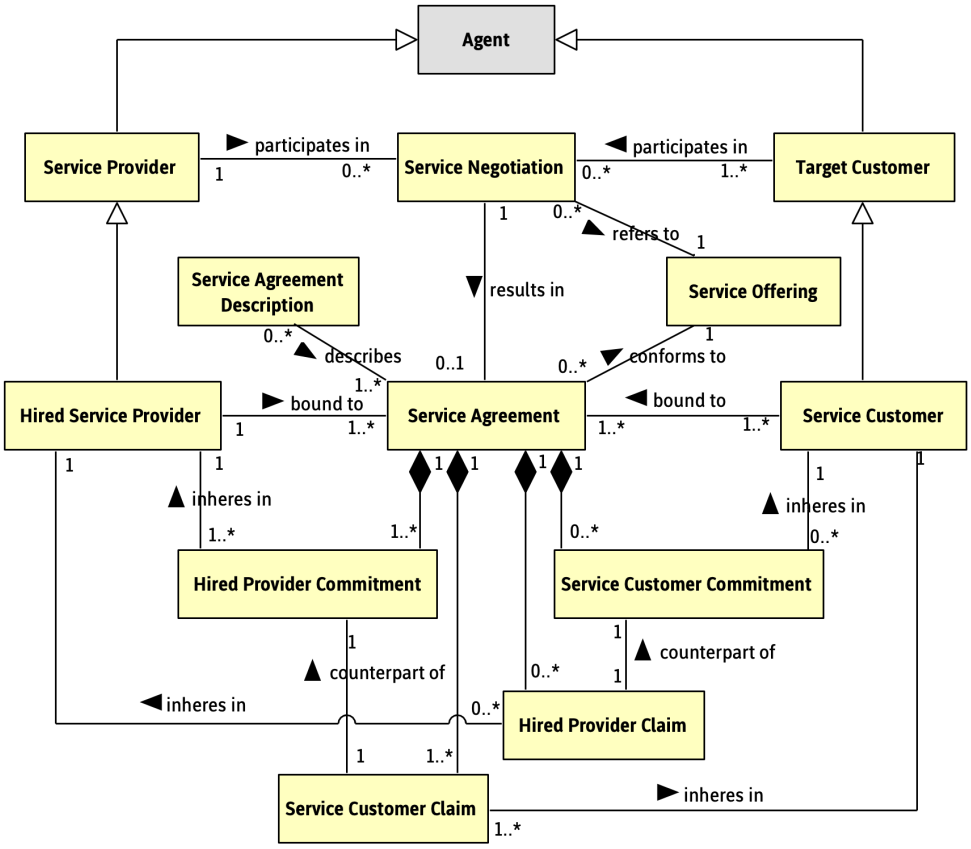

Fig. 2. UFO-S: Service Agreement [2]

An important aspect of this approach is that service relations are inevitably a social phenomenon between intentional agents [2]. Only intentional agents play the roles of service provider and service customer, since only this kind of agent can establish commitments to other agents. As a result, enterprise resources such as application components and infrastructure nodes do not themselves play the role of service providers and customers. Instead, service provider and service customers (agents) employ resources (such as application components and infrastructure nodes) as a means to fulfill their commitments [43].

As presented in Fig. 3 service agreements conform to a service offering in the sense that the service agreement instantiates the service agreement type prescribed by the service offering. From that, UFO-S addresses some aspects of conformity between what is offered from a service provider towards a target customer community and what is agreed between a hired service provider and a specific service customer.

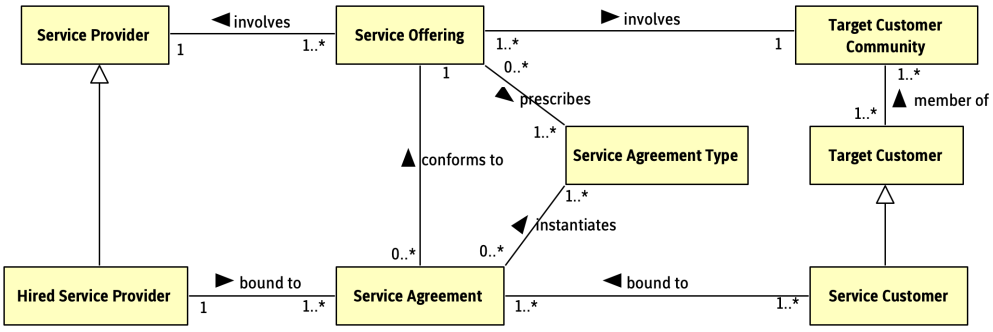

Fig. 3. UFO-S: Conformity of a Service Agreement to a Service Offering

When a service agreement is established, the service customer delegates a goal/plan achievement/execution to the hired service provider. Thus, the mutual service commitments/claims established in the service agreement will drive the service delivery. In other words, service delivery concerns the execution of actions aiming at fulfilling the commitments established in

service agreements. Thus, a service is successfully delivered if the actions are performed in such a way that their results (and also the way they are performed) fulfill the service agreement. Fig. 4 shows a UFO-S model fragment presenting the main concepts and relations involved in service delivery phase. Service delivery is a complex action, which is composed by several actions, including actions performed only by the hired service provider (hired provider actions), actions performed only by the service customer (service customer actions), and actions performed by both in interaction (hired provider-customer interaction). All of these actions are motivated by the commitments established in the service agreement, between the hired provider and the service customer. Depending on the business service model, other agents can also perform actions. For instance, the service provider can delegate some actions to a third-party. These actions are also part of the service delivery process, although they are not explicitly represented in Fig. 4.

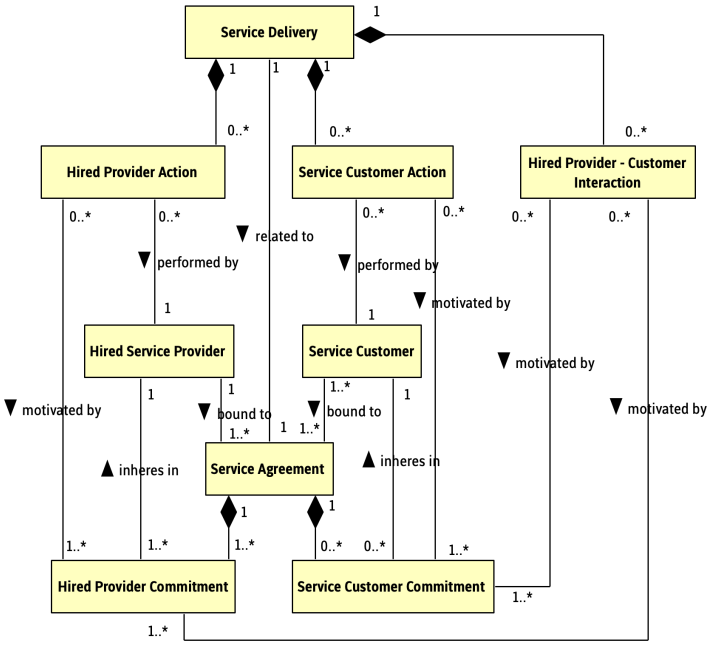

Fig. 4. UFO-S: Service Delivery

A consequence of social relations is that some of them extrapolate the social realm and reach the legal dimension, becoming legally relevant. This is particularly true for service relations. This means that there are important aspects of service phenomena – the legal aspects – that are currently not addressed in UFO-S. We address these aspects here, reviewing the conceptual foundations for legal relations that underlie UFO-L in section 4 and applying these to UFO-S, which results in a service contract ontology presented in section 5.

4. Conceptual foundations for legal relations

In a seminal work in the legal ontology literature, Hohfeld defined legal relation as a relation between subjects who are in certain legal positions [44]. He observed that key legal terms such as "right" were often misunderstood because of semantic overload. For instance, in the expression "you have the right to remain in silence" it takes on the meaning of *liberty;* in the expression "right to charge taxes" it takes on the meaning of *power*; in the expression "right to receives salary at the end of the month" it takes on the meaning of an *entitlement*. After an analysis of legal concepts, he identified eight fundamental legal concepts (*right*, *duty*, *no-right*, *privilege*, *power*, *liability*, *disability*, and *immunity*), and established relations between them. Table I shows these concepts, grouping them in pairs of correlative legal positions. Correlative positions are those with a counterpart in the same legal relation. For instance, the correlative of John's *duty* to pay his debt to Mary is Mary's *right* that John pay his debt. A right in this precise or 'narrow' sense is a legal position in which one may demand from another the performance of a certain conduct. Likewise, John's permission to use Mary's car correlates to Mary's no-right that John refrain from using her car.

TABLE I. FUNDAMENTAL LEGAL CONCEPTS ACCORDING TO HOHFELD

Correlative Pairs of Legal Concepts			
Right	*Privilege (Permission)*	*Power*	*Disability*
Duty	*No-Right*	*Liability*	*Immunity*

The legal positions are also classified into two kinds: (i) those that arise from *norms of conduct*, namely: *right, duty, permission,* and *no-right*; and (ii) those that arise from *norms of power*, namely: *power, liability, disability,* and *immunity.* While norms of conduct have mainly a coordinative nature, norms of power presuppose a clear subordinate nature [45], and concern the creation, change and alteration of other legal positions.

In a legal perspective, a *service contract* is an arrangement between two or more parties whose purpose is to produce juridical effects, i.e., to create, extinguish, modify, transfer or maintain legal positions. For instance, if a *service provider* A has a service contract to provide a service for *y* dollars to a *service customer* B, then *service provider* A has the *duty* to provide the service for *customer provider* B (who has the *right* to receive the service from A). Also, *service customer* B has the *duty* to pay *y* dollars to a *service provider* A (who has the *right* to receive *y dollars* for the service provided to B).

Alexy [45] proposed a system of legal positions embedding Hohfeldian legal positions in triadic legal relations and with the possibility to deny the legal relation's object (augmenting Hohfeld's theory). As a result, for each legal concept *right, duty, privilege,* and *no-right* to an action, there exists a concept of *right, duty, privilege,* and *no-right* to an *omission*. These legal positions are relevant in contracts because they define duties to negative actions (effectively prohibitions). For instance, in e-mail service contracts, the customer often has a duty to omit sending the same message indiscriminately to large numbers of recipients on the Internet (unsolicited e-mail or spam). The following categories are proposed by Alexy [45] combining the legal positions of Hohfeld's theory with the new legal positions.

Right to Positive Action. Subject *a* has the right *R*, against subject *s,* to an act ϕ: R*as*(ϕ).

In this case, the addressee (*s*) has the *duty to perform* action ϕ. For instance, in a service contract with warranty, the *service customer* has the right that the *service provider* fixes the service in case of defect or failure.

Right to Negative Action. Subject *a* has the *right R,* against subject *s,* to an omission ϕ: R*as*(¬ ϕ).

In this case, the addressee (*s*) has the *duty to omit* to perform action ϕ. For instance, a *service provider* shall not disclose a customer's private information.

Permission to Act. Subject *a* has permission *P* towards subject *s* to perform action ϕ: P*as*(ϕ).

In this case, the addressee (*s*) has *no-right* to demand that the permission holder (*a*) omit action ϕ. For instance, in a messaging service, a *service customer* has the permission to send messages using the provider's infrastructure.

Permission to Omit. Subject *a* has permission *P* to refrain from acting (abstain to perform ϕ) towards subject *s:* P*as*(¬ ϕ).

In a relational sense, the addressee (*s*) has *no-right* to demand that the permission holder (*a*) perform action ϕ. For instance, a *service customer* has the permission to abstain from paying contractual interest established by a *service provider* if it exceeds permitted by law in delayed payments.

In addition to combining Hohfeld's legal positions with positive and negative actions, Alexy also identifies the notion of *liberty*. The idea of liberty is related with an *alternative of action* as well with the fundamental legal concept of *permission.* It means that subject *a* is permitted to perform or to abstain from performing action ϕ. Conversely, subject *s* has no-right to demand that the liberty holder *a* perform or abstain from performing action ϕ. For instance, airline customers usually have the liberty to use in-seat entertainment. Alexy distinguishes between the so-called *unprotected* liberty, which is defined solely in terms of permissions, from the so-called *protected* liberty, which additionally provides rights to the liberty holder:

Unprotected liberty. It is a conjunction of *permission to act* and *permission to omit*. Thus, subject *a* has liberty *L* in face of subject *s* to perform action ϕ or abstain from performing it: L*as*(ϕ) = P*as*(ϕ) ∧ P*as*(¬ϕ).

Protected liberty. It is a combination of an *unprotected liberty* and a *right to negative acts*. Subject *a* has liberty to action ϕ in relation to subject *s*, and subject *a* has against the subject *s* a right that subject *s* not hinder his choice to perform or not perform ϕ: L*as*(ϕ) ∧ R*as*(¬ hinder *sa* (ϕ | ¬ ϕ)).

Alexy also discusses the legal positions that have a key constitute nature, making legal acts possible and creating the ability to change legal positions:

Power. Subject *a* has the power *K* in face of subject *b* to create, change or extinguish a legal position X for subject *b* by means of institutional actions: K*ab*(*Xb*).

The exercise of a power is an institutional action, which gives liberty and ability to act to a power holder. *Power* has a

converse position*;* if *a* has power against subject *b*, *b* is in a *subjection* position towards *a* (*subjection* is also called *liability*). For instance, often a *service provider* has the power to cancel the service agreement unilaterally in the case of contract violations. In this case, the service customer is *subject* to unilateral cancellation by the service provider. When power is negated explicitly, the subject holds a disability:

Disability. A subject *a* has, in face of subject *b,* no power to create, change or extinguish a legal position X for subject *b* by means of institutional actions: ¬K*ab*(*Xb*).

The converse position of a disability is *immunity,* and the subject *b* is immune to changes in its legal position. For instance, often a *service provider* is immune to unilateral cancellation of a service agreement in cases of *force majeure*.

Most legal core ontologies, such as: LKIF-Core [46], LRI-core [47], CLO [48], are based on Hohfeld's legal theory [44], which presents four pairs of correlate legal positions and formalizes the legal relations in dyadic terms (holder of the position, holder of the correlative position). On the other hand, UFO-L is based on the extension of Hohfeld's theory as proposed by Alexy [45], with ten sets of correlate legal positions (see Table II and Table III), and formalizes the legal relations in triadic terms (holder of the position, holder of the correlative position and object-action). Since contract is an inherently relational notion, Alexy's relational theory of legal positions is particularly suitable foundational theory for an ontological analysis of contracts.

TABLE II. LEGAL CONCEPTS ACCORDING TO ALEXY (BEHAVIORAL NORMS)

Correlative Legal Concepts			
Right to a positive action	*Permission* to act	*Unprotected Liberty*	*Protected Liberty*
Duty to a positive action	*No-Right* to an abstention	*No-Right* to an abstention and *No-Right* to an action	*No-Right* to an abstention, *No-Right* to an action, and *Duty* not to hinder
Right to a negative action	*Permission* to abstain from acting		
Duty to a negative action	*No-Right* to an action		

TABLE III. PAIRS OF LEGAL CONCEPTS ACCORDING TO ALEXY (POWER NORMS)

Correlative Legal Concepts	
Power to create, extinguish or modify a legal position	*Disability* to create, extinguish or modify a legal position
Subjection to the power to create, extinguish or modify a legal position	*Immunity* to creation, extinction or modification of a legal position

Based on these legal concepts, we have built a legal core ontology called UFO-L [49]. This core ontology uses UFO [21] as ontological basis specializing ontological categories from UFO (both its UFO-A upper fragment and its UFO-C social fragment). A central element of UFO-L is the notion of *legal relator*, which is a relator that is composed of externally dependent legal moments, each of which represents a legal position following Alexy (see Fig. 5). A Legal Relator specializes *Social Relator* (UFO-C), which in turn specializes the basic notion of *Relator* (UFO-A).

There are two kinds of legal relators: Simple Legal Relator and Complex Legal Relator. A Simple Legal Relator is composed of a pair of legal positions (categorized in UFO-L as legal moments), such as: Right/Duty, NoRight/Permission, Power/Subjection, and Disability/Immunity. In contrast, a Complex Legal Relator is composed of other legal relators in general. For instance, an Unprotected Liberty Relator is composed of two Permission-NoRight Relators.

Legal Moments are specialized as follows: Right, and its specializations: Right to an Action, Right to an Omission; Duty and its specializations: Duty to Act, Duty to Omit; NoRight and its specializations: NoRight to an Action, NoRight to an Omission; Permission and its specializations: Permission to Act, and Permission to Omit; Power, Subjection, Disability, and Immunity. Legal moments are related each other by a correlation and are essential and inseparable parts of a legal relator [21]. For instance, the prohibition "Claire cannot send billing messages via Amazon Email Service", means that Claire's legal position of duty to abstain herself from sending billing messages by email is intrinsically related to her and it is externally dependent on Amazon as well. Furthermore, Amazon has the right that Claire abstain herself from sending billing messages by Amazon Email Service.

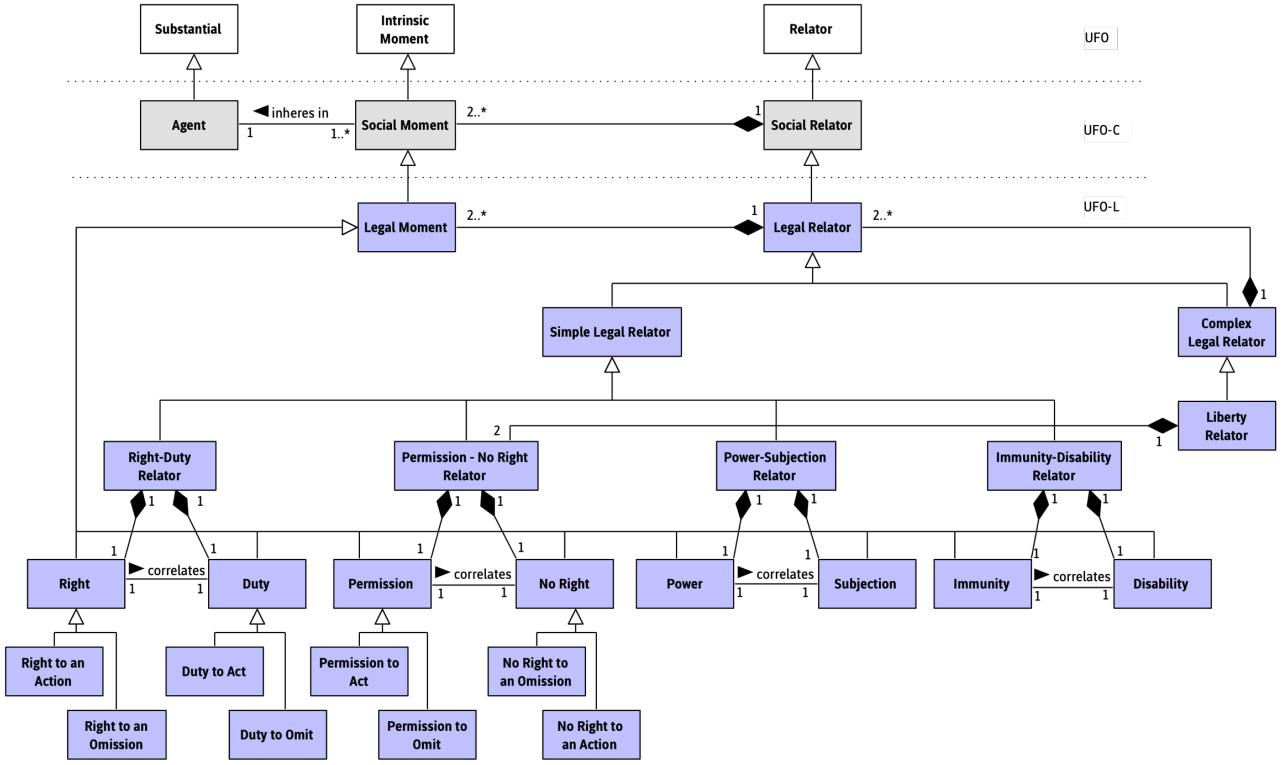

Fig. 5 UFO-L: Legal Relator Taxonomy

Fig. 6 focuses solely on the Legal Moment taxonomy, revealing how we group legal positions in two categories: 1) Legal Entitlements (Right, Permission, Power, and Immunity); and 2) Legal Burdens/Lack (Duty, NoRight, Subjection, and Disability). Legal positions that imply some advantage (or entitlement) are grouped in the first category: Right, Permission, Power, and Immunity; legal positions that imply some legal burden or lack of entitlement are grouped in the second category: Duty, NoRight, Subjection, and Disability.

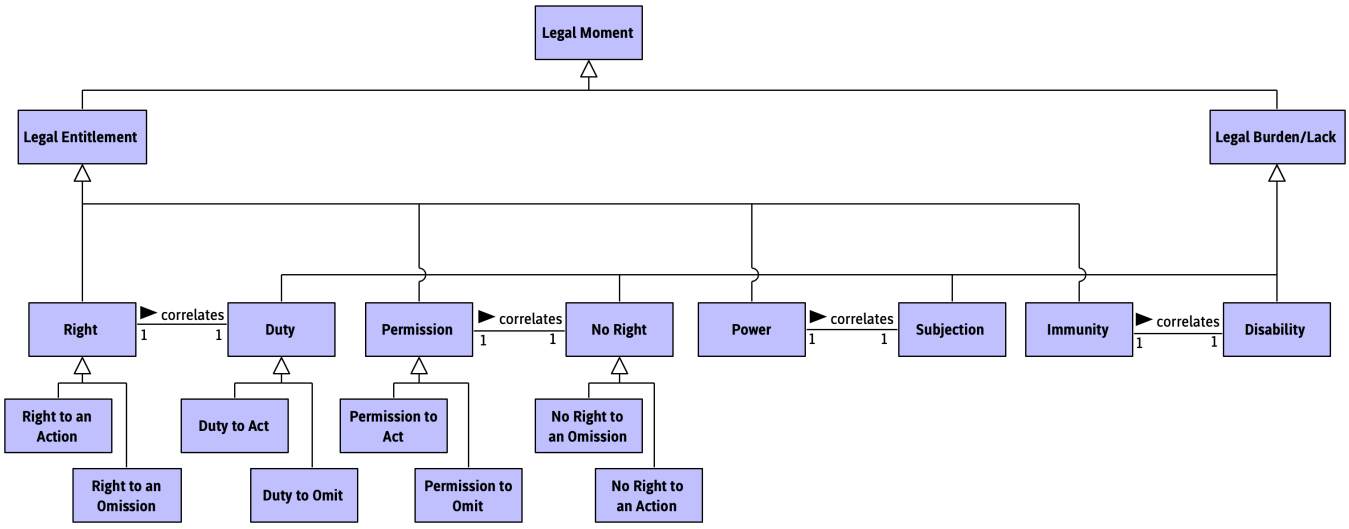

Fig. 6 UFO-L: Legal Moment Taxonomy

5. Service Contract Ontology

By analyzing service phenomena as considered in [2], we realized that service relations also are relevant in the legal

dimension. However, different dimensions suggest different requirements. From a legal perspective, by analyzing service contracts, for instance, it is relevant: 1) to understand and explain the "rules of the game" and therefore raise the awareness and compliance of these rules; 2) to explain the legal positions of each participant in a service relation and to clarify their roles, their actions and their responsibilities. The legal positions of UFO-L include not only those corresponding to commitments and claims from UFO-S (i.e., right and duty), but also other elements that had not been addressed earlier in UFO-S (no-right, permission, power, subjection, disability and immunity). Thus, in this section, we expand the reach of our service ontology by addressing a more comprehensive set of ways in which parties may participate in service relations, reflecting a comprehensive legal theory.

To respond to these demands, we built the *Service Contract Ontology (SCO)* based on concepts and relations from UFO-S and UFO-L. In the SCO, the UFO-S notion of Service Agreement is specialized into Legal Service Agreement. Since a legal service agreement has different kinds of service legal relations, with customers and service providers playing different roles, a legal service agreement can be understood as the composition of legal moments, which we call: Hired Service Provider Entitlement, Hired Service Provider Burden/Lack, Service Customer Entitlement, and Service Customer Burden/Lack). These specialize the 'social' notions of Hired Service Provider Claim, Hired Service Provider Commitment, Service Customer Claim and Service Customer Commitment of UFO-S (Fig. 7).

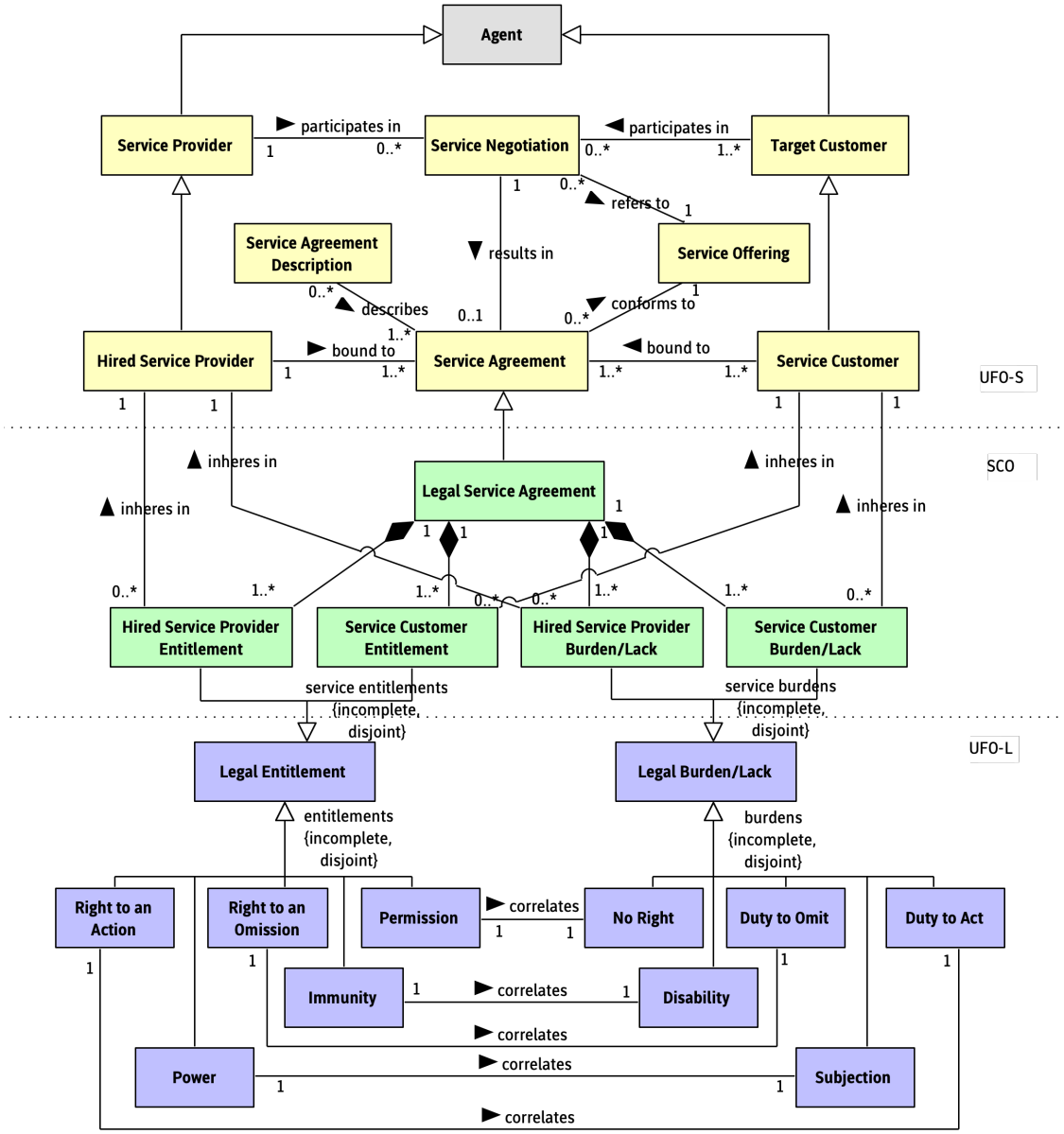

Fig. 7. SCO: Legal Service Agreement

A Legal Service Agreement is often drawn up formally, making explicit the legal positions of the parties to the agreement. Since the State[2] has interest to regulate agreements between individuals, the agreement established in a service contract when properly drafted, following the legal parameters, will have the force of law. Because of this, the agreements go beyond social rules and reach the legal dimension.

A similar specialization to introduce legal aspects is applicable to the Service Offering fragment of UFO-S, as shown in Fig. 8. A Legal Service Offering has as parts Service Offering Burdens/Lacks (inhering in the Service Provider) as well as Entitlements inhering in the Target Customer Community. In this setting, a Service Offering Description expresses the service offering not only in terms of Marketing – to attract buyers – but also in terms of Law. In this case, for instance, a clause determining the temporal interval for a service offering binds the Service Provider to a Target Customer Community in a legal sense. This is because of Legal Normative Descriptions (such as pieces of legislation) determine what constitutes a legal service offer.

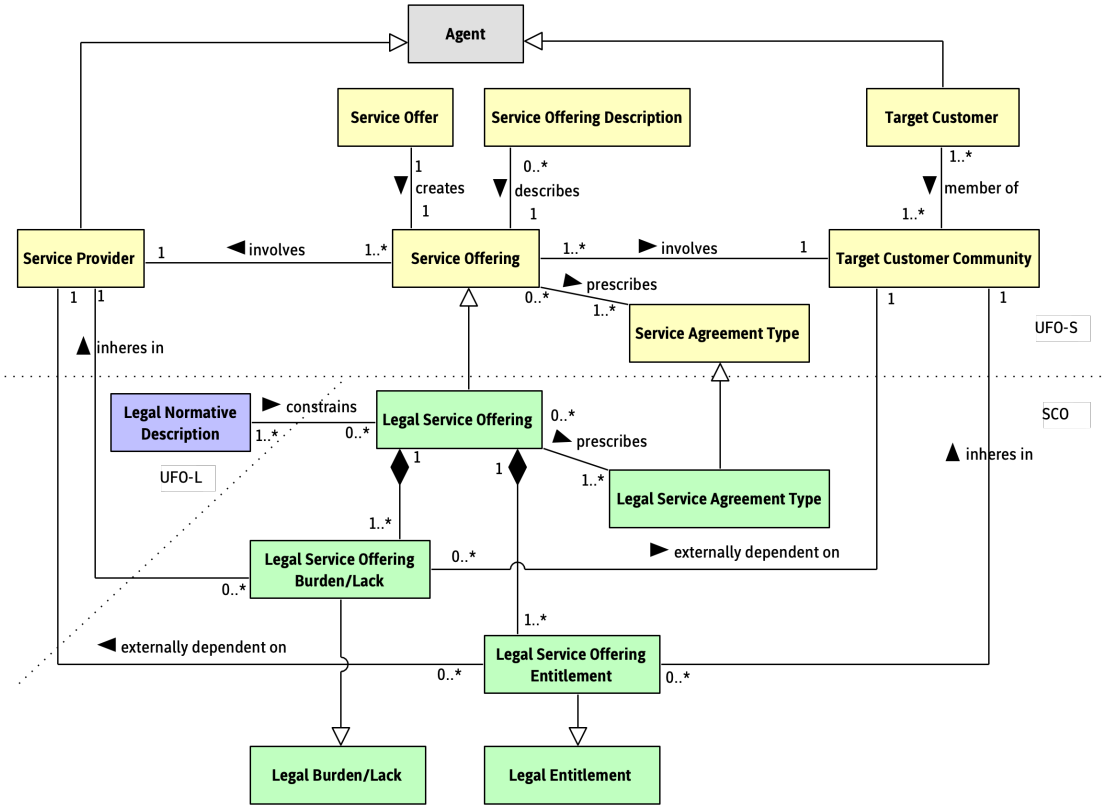

Fig. 8. SCO: Legal Service Offering

Further, in contextualizing the Service Offering from the legal point of view, we perceive some legal requirements, such as: the provision of licit services before a legal system, the delivery of the service to a legally capable buyer, and the procedure of offering the service *per se* observing legal rules. These legal requirements are based on some general rules or principles, for instance: prohibition of social discrimination, freedom of choice of services, prohibition of leonine clauses or observing the legal form to establish a contract. Such general provisions for services arise from applicable *metanorms* (*e.g.,* the UK Consumer Rights Act 2015 [50]). These provisions are also part of the legal service offering, establishing legal entitlements and burdens even when they are not explicitly enunciated in service offering descriptions.

Making explicit the legal environment supports the analysis of settings in which contractual clauses that violate public norms. For example, in the experiment performed by [51] to evaluate how many service users really read the End-User License Agreements (EULA), they created an Internet service called *NameDrop* with an EULA with two outrageous clauses: 1) the sharing of any and all collected and generated data with National Security Agency (NSA); and 2) the immediate assent of the

[2] In this paper, the term "State" refers to a politically recognized authority capable of creating legal norms (rules and principles) and subjecting natural or legal persons to those rules.

users in designating their first-born as payment for the service delivered. In case the user does not have children, the contract will be applicable until the year 2050. In cases like this (or not as extreme as this), contractual clauses that conflict with constitutional rules or principles (*e.g.* violation of the good faith principle), an action or omission that "violates" the conflicting clause could give rise to a review of the contractual clauses in court to rule whether the contractual clause should be observed.

Fig. 9 shows that the Legal Service Agreement must conform to what was offered by instantiating the Legal Service Agreement Type that was prescribed in the offering. In fact, it is common in e-contracts that End-User License Agreements (EULA), such as Amazon EULA, Google EULA, among others, be a kind of non-negotiation agreement. In this case, the service offering prescribes a fixed Legal Service Agreement Type independent of negotiation. Customers only submit themselves to clauses stipulated by the Service Provider (*adhesion contracts* or *standard form contract*). In this case, Service Negotiation is reduced to "agree" or "disagree" with the terms of the agreement. If a customer presses the "I agree" button, this action creates a service agreement that instantiates a Legal Service Agreement Type prescribed in the Legal Service Offering.

Conformity includes observance not only of those terms in a Service Offering Description (EULAs, terms and conditions) but also of legal precepts, since the applicable Legal Normative Descriptions (Consumer laws, contract laws) are reflected in the Legal Service Offering. Let us suppose that a service provider makes the following offer: Internet service with a bandwidth of 1 Gbps for 19.90 euros. The agreement must stipulate the consumer's right that the Internet provider delivers a 1 Gbps connection to the consumer (or the service provider's duty to provide 1 Gbps connection to the consumer). The contract cannot stipulate a speed rate different from this because the provider is bound by the service offer marketed. In other words, the entitlements and burdens in the Legal Service Agreement must instantiate corresponding types stipulated in the Legal Service Agreement Type that is prescribed by the Legal Service Offering.

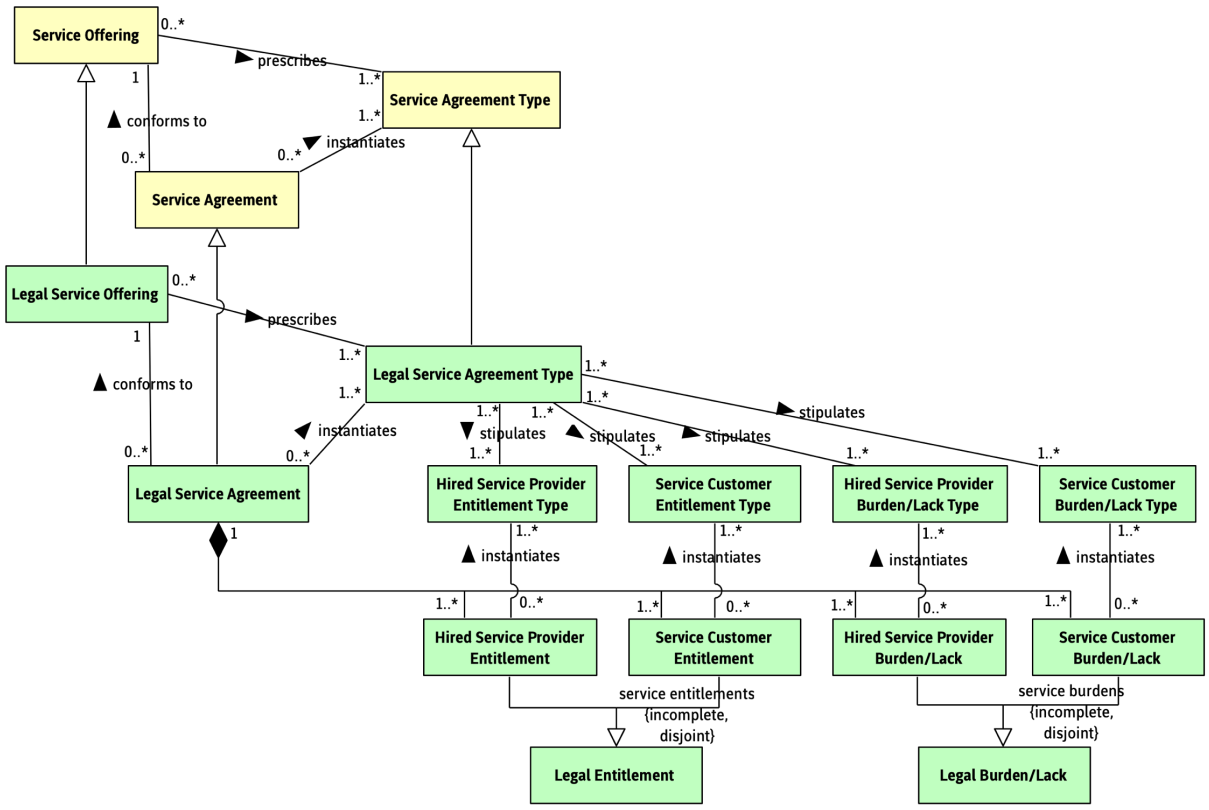

Fig. 9 SCO: Conformity to Legal Service Offering

An action taken during the lifecycle of the service by the parties can be an action in compliance with a stipulated Legal Moment or can be a violation of a stipulated Legal Moment (see Fig. 10). Service Delivery is composed of one or more Service Actions. If there is, for example, a Hired Provider Action that contravenes a Service Customer Entitlement, we say that Service Delivery is not compliant with the Legal Service Agreement. On the other hand, if the actions performed during the service

lifecycle comply with the legal positions established in Legal Service Agreement, we say that Service Delivery is compliant with the Legal Service Agreement.

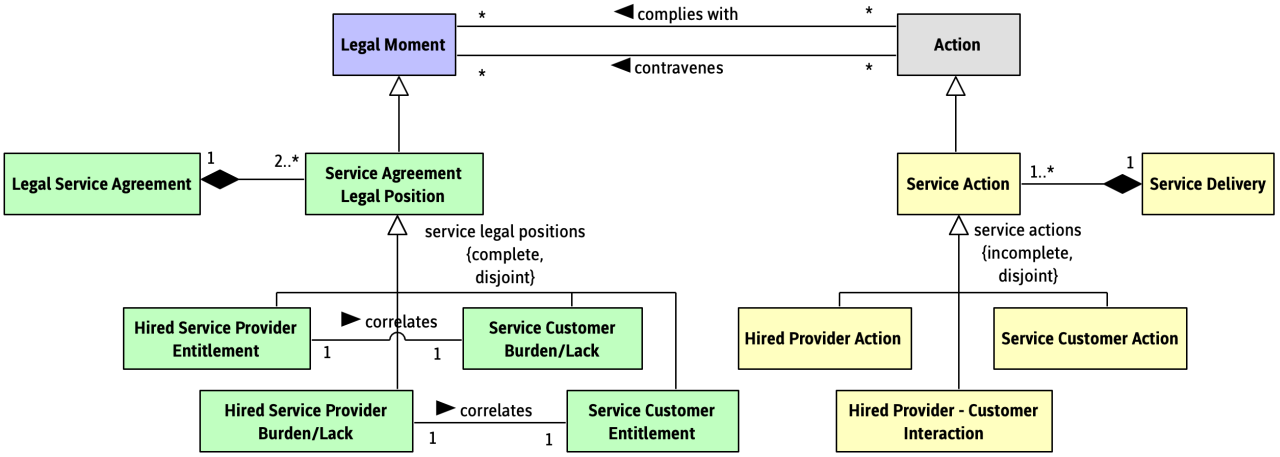

Fig. 10 SCO: Service Delivery Compliance

In the next section, we use the Service Contract Ontology presented in this section to review ArchiMate's support for the representation of services. The resulting modeling recommendations are applied in a case study in Section 7.

6. Modeling contracts and contract elements in ArchiMate

6.1. Overview of ArchiMate service modeling at the business layer

ArchiMate is an EA framework and language that offers concepts and constructs for the specification of enterprise-wide architectures. It covers a variety of architectural domains for enterprise description, include a Business layer, an Application layer and a Technology layer. We focus here on the Business Layer. Since ArchiMate's inception, this layer included service-related elements, describing the provision of business services to enterprise customers. This layer comprises passive structure, behavioral and active structure elements [4]. The *active structure elements* refer to entities that make up the organization (e.g., business actors) and their relationships. The *behavioral elements* are used to characterize the dynamic aspects of an organization [4]. The *passive structure elements* are the business objects (e.g., products and contracts) manipulated by behavior. All these elements can be linked by means of relationships. Fig. 11 shows a small fragment of ArchiMate's Business layer metamodel, focusing on the relations between business services and the structural elements. (We omit "generic" relations from ArchiMate, such as *association*, which can be used between any element. Further, we show some "derived" relations for the sake of simplicity. Derived relations are those abstracted from multiple relations with rules prescribed in the ArchiMate specification.)

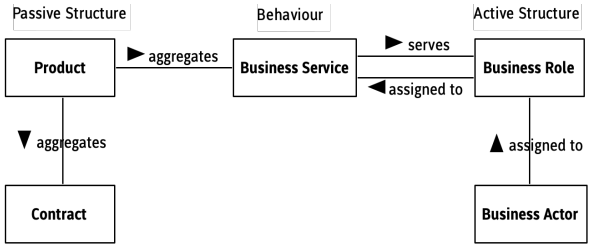

Fig. 11. ArchiMate's Business layer metamodel fragment.

In ArchiMate, a *service* is defined as "a unit of functionality that a system exposes to its environment, while hiding internal operations, which provides a certain value" [4]. A product is defined as "a coherent collection of services, accompanied by a contract/set of agreements, which is offered as a whole to customers" [4]. A contract is "a formal or informal specification of agreement that specifies the rights and obligations associated with a product" [4].

In this paper, we employ a small fragment of ArchiMate and reuse the service representation patterns defined in [14] : a *service offering pattern*, and a *service agreement pattern*. These modeling patterns were given real-world semantics based on UFO-S. The proposed modeling patterns use the existing service, product and contract modeling elements, as well as the association relationship [14]. Each pattern is composed by four groups of elements: (i) a product and related *services*, (ii) the

roles/actors that provide the product/service, (iii) the *roles/actors* that consume the product/service, and (iv) the respective *contracts*. The *contracts* are in the center of each modeling pattern. The associations in which a contract is involved establish the semantics of each pattern.

In the *service offering pattern*, the contract connects the provider actor with the service customer role. Fig. 12 shows an example of this pattern. The model illustrates a service offering between "Easy TV, Inc." (represented with the "Business actor" construct) as a service provider and potential service customers (represented with the "Business Role" construct). "Terms and Conditions" are established (using the "Contract" construct), with general clauses such as price, offer validity date, special conditions and applicable restrictions for usage. The service construct is used to capture that the "Special Cable TV" product bundles "Cable TV" and "Customer Support".

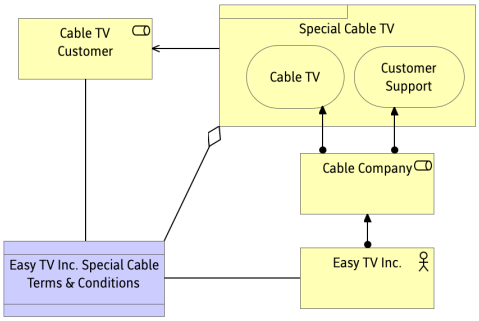

Fig. 12 Example of the service offering modeling pattern

In the *service agreement pattern*, the contract connects the (hired) provider actor with a particular customer actor (instead of a general role). Fig. 13 presents an example of this pattern. The model illustrates a service agreement between "Mary" and "Easy TV, Inc.", which play, in this service agreement, the roles of service customer and hired service provider respectively. The terms of this agreement are described in the "Mary-Easy TV, Inc. Contract", which associates the two individuals involved.

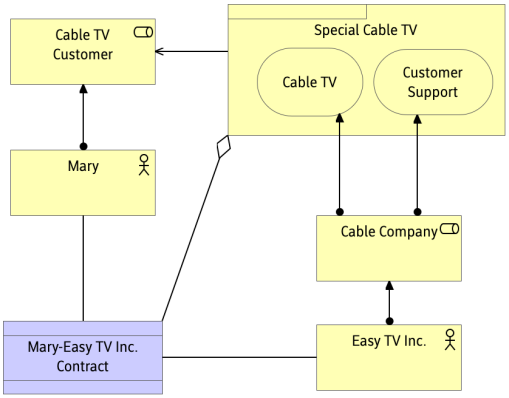

Fig. 13. An example of the service agreement modeling pattern [14]

The patterns can be used in tandem, as shown in Fig. 14. Here, conformity is required between the service offering and service agreement as discussed earlier.

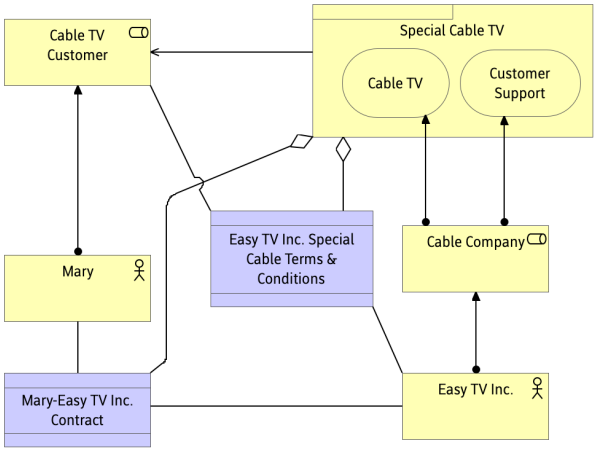

Fig. 14. An example of the combined use of service offering and service agreement patterns

Despite the usefulness of the contract element in service modeling, service elements revealing the various legal positions in the scope of a contract are not represented in ArchiMate. This motivates our extension which is discussed in the next section and applied to some Amazon service contracts in section 7.

6.2. Service contract elements in ArchiMate

Based on the legal positions in the service contract ontology and the basic symbols/colors used in traffic signs, we defined a set of symbols for service contract elements as shown in Table IV and Table V. Table IV shows the concrete syntax for legal positions reflecting norms of conduct and Table V shows the concrete syntax for positions in power relations. These symbols decorate the current contract symbol, resulting in a symbol for each kind of legal position that can be represented.

TABLE IV. CONCRETE SYNTAX OF CONDUCT POSITIONS

LEGAL POSITIONS	
Right	Duty to act
	Duty to omit (prohibition or duty-not)
NoRight	Permission (no-duty)
	Liberty

TABLE V. CONCRETE SYNTAX OF POWER POSITIONS

LEGAL POSITIONS	
Power	Subjection (Liability)
NoPower (Disability)	No-Subjection (Immunity)

Service contract elements are represented as parts of a contract (e.g., using nesting), and assigned to a party associated with the contract. Fig. 15 shows an example of service contract element in the *service offering pattern*, expanding on the example presented in Fig. 12. It represents that customers of the Special Cable TV Product are prohibited to share cable TV with neighbors. In terms of the Service Contract Ontology, the service offering represented stipulates a type of Service Customer Legal Burden/Lack that will be instantiated in every agreement with an actor playing the Cable TV Customer role. Thus, every Cable TV Customer will have a Duty to Omit sharing cable TV with neighbors. Here, the position of the Service Customer is emphasized, and the correlative position of Easy TV can be inferred. (Easy TV Inc. has a Right that a Cable TV Customer omits sharing cable TV with neighbors, a Right to an Omission).

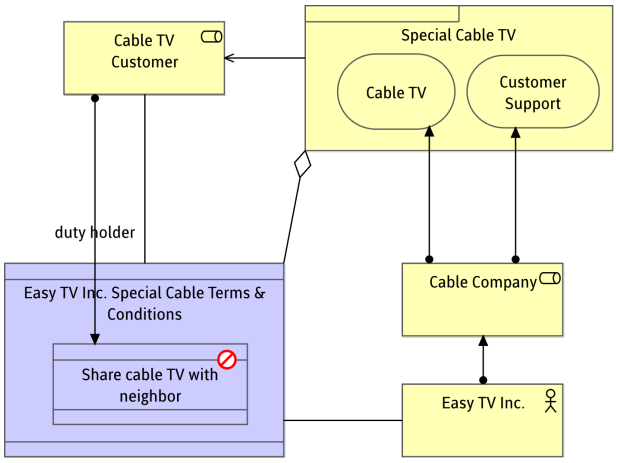

Fig. 15. A service contract element in the service offering pattern

When used to relate service contract elements, an *assignment* relationship represents *inherence* of a legal position (in Fig. 15, when instantiated, the stipulated duty will inhere in an actor playing the role), and an *association* relationship represents *external dependence* (the duty of the customer depends on the service provider). Although a service contract element is, strictly speaking, a structural element and not a behavioral element, the use of this relation is analogous to that between roles and behaviors in standard ArchiMate. This is because, similar to role assignment, there are behavioral consequences of the assignment of contract elements.

As we have discussed in section 5, applicable legal provisions for service offerings are also integral parts of the offering, and thus can be represented in the service offering pattern similarly to the conditions made explicit in a "Terms & Conditions" document. Fig. 16 augments Fig. 15 showing two contract elements which are typical of consumer protection legislation: (i) the Power of a service customer to require price reduction in case of non-compliance (corresponding to a Subjection of service provider), and (ii) the Duty of the service provider to Omit refusing service arbitrarily (corresponding to the Right of customers that the provider shall not refuse service arbitrarily). The legal relations represented in these provisions are established by a primitive legal relation between State (who has the power to create meta norms to regulate consumer relations) and social community subject to it. Thus, by law, within certain jurisdiction assumed by the model, any consumer (including Cable TV Customers) have the represented power, and any service provider (and Easy TV, Inc. particularly) have the represented duty.

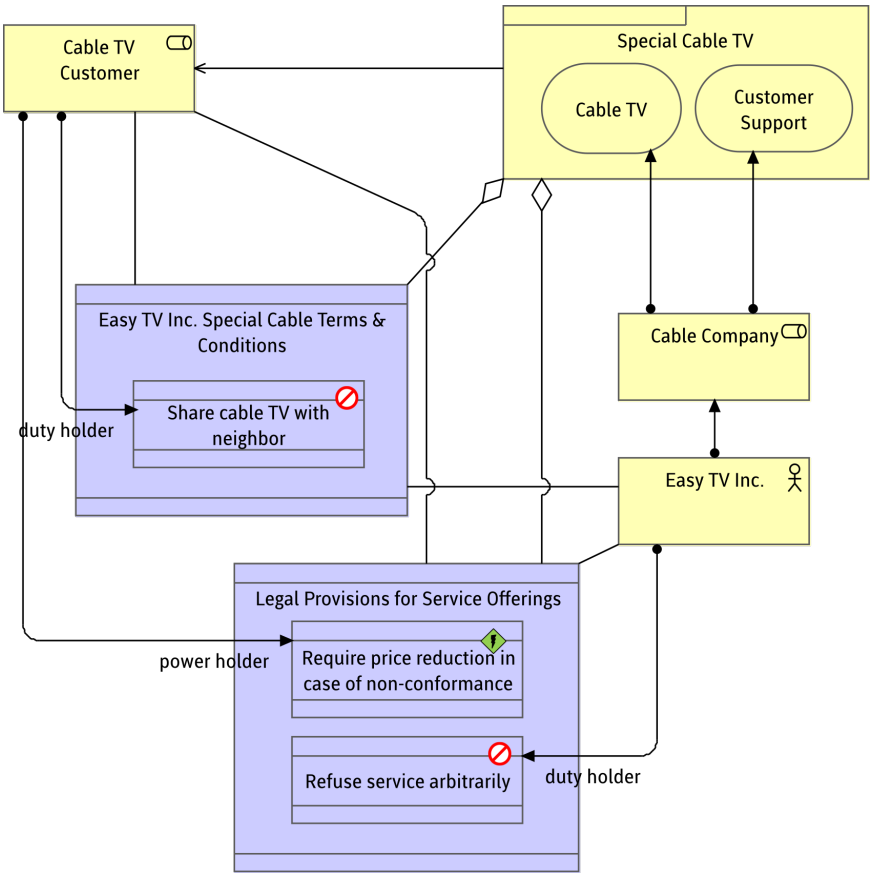

Fig. 16. Legal provisions represented as contract elements in the service offering pattern.

Once a customer assents to the terms and conditions offered by Easy TV Inc., a Service Agreement is in place. Similarly to the representation of service offerings, service contract elements are represented as parts of a contract in the service agreement pattern (e.g., using nesting). Fig. 17 shows the case presented in Fig. 13 with the representation of the following legal relation in a Legal Service Agreement between Mary and Easy TV Inc. In the agreement, *Mary is prohibited to share her cable TV with a neighbor*, therefore Mary's legal position is a position of Duty to Omit and Easy Inc.'s legal position is a position of Right to an Omission. This follows closely what was represented in the service offering. The represented legal position instantiates the corresponding legal position type captured in the "Terms and Conditions".

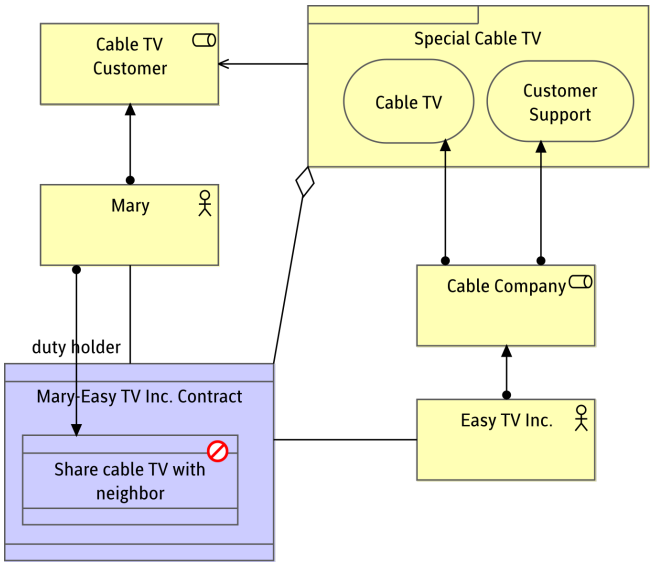

Fig. 17. An example of the service contract element modeling.

6.3. Recommended modeling steps

Starting from a model fragment that employs the service offering pattern and/or the service agreement pattern, the following modeling steps are recommended to apply the proposed extension:

1. Identify norms applicable to products and represent them as contracts. These contracts should be aggregated into the products they regulate. Aggregation is used (as opposed to composition) since legal norms as well as enterprise-wide terms and conditions often apply to a multitude of products.

2. Identify and classify legal relations established in norms and contractual clauses. In order to ensure traceability to the normative text, fragments of textual clauses should be individually associated with a type of legal relation, e.g., using a table with a column for the textual clause and a column for the corresponding legal relation type in the extension (Right-Duty to Act, Right-Duty to Omit, NoRight-Permission, NoRight-Liberty, Power-Subjection, Immunity-Disability). Relevant fragments are typically marked by modal verbs (may, may not, must, must not, will, shall, etc.), verbs related to regulated conduct (denoting action or omission) and verbs that establish new legal relations.

3. For each legal relation:

    a. Identify the legal position emphasized in the legal relation. The normative text itself is a possible source of emphasis. For example, “the customer will pay the applicable fees” emphasizes the duty to pay in a Right-Duty to Act relation. Nevertheless, the modeler may also choose to emphasize a different position (such as the provider’s right to receive the applicable fees). This may be the result of building a model from the viewpoint of the interests of a particular actor or role (such as the provider or the customer).

    b. Introduce a specialized contract element to model the emphasized legal position. Use the symbols in Table IV and Table V as adornments to identify the type of legal position.

    c. Assign the contract element to the bearer of the legal position. Use the assignment relationship to connect the legal position emphasized in step 3.a with its correspondent bearer.

    d. Represent relationships between contract elements. Use the trigger relation when the violation of a position creates a second one (e.g. violation of the customer’s payment obligation may trigger the provider’s permission to suspend service provisioning). The trigger relation is also used to represent the positions that are affected by a Power-Subjection or protected by an Immunity-Disability.

These steps are applied in the next section to the modeling of cloud computing service contracts.

7. Modeling cloud computing service contracts

In this section, we apply the proposed extension to ArchiMate to model the Amazon Web Services Agreements (AWS Agreements). AWS is a collection of cloud computing service provided by Amazon, Inc. We selected contracts related to two services: *Simple Notification Service (SNS)* and *Amazon CloudFront.* Specific legal provisions concerning each of the services are provided respectively in clauses 2 and 17 of the *AWS Service Terms* [52]. Further, both services are governed by the universal terms described in clause 1 of this contract. Moreover, the services are also governed by the *AWS Acceptable Use Police* [53] and *AWS Customer Agreements* [54]. We have also considered legal service provisions of the UK Consumer Rights Act 2015 (UKCRA) [50].

STEP 1: First, we designed a general diagram relating the various contracts with the products they govern (Fig. 18). This fragment is supported by ArchiMate with no extension.

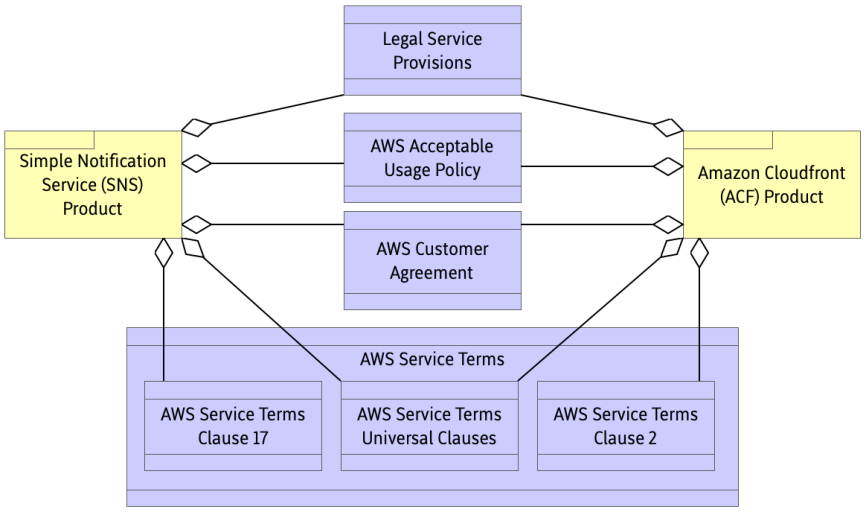

Fig. 18. AWS Services and its contractual objects.

Second, we detailed each legal position stipulated in the service offering with the service contract elements described in Section 6. The resulting model was created by employing the following steps:

STEP 2: Extract legal relations from contractual clauses (Table VI and Table VII) and legal sources (Table VIII). For some clauses, more than one legal relation was extracted (Table VI).

TABLE VI. SOME CLAUSES OF THE AWS SERVICE TERMS CONCERNING THE AMAZON SNS PRODUCT

Clauses	Legal Relation
17.1 You may only use Amazon SNS to send notifications to parties who have agreed to receive notifications from you.	Right – Duty to Act
17.2 We may throttle or restrict notifications if we determine, in our sole discretion, that your activity may be in violation of the AWS Acceptable Use Policy or the Agreement.	NoRight – Liberty
17.3 Your notifications sent through Amazon SNS may be blocked, delayed or prevented from being delivered by destination servers and other reasons outside of our control and there is no warranty that the service or content will be uninterrupted, secure or error free or that notifications will reach their intended destination (…) we may not be able to provide the service if a wireless carrier delivering SNS notifications by short messaging service (SMS) terminates or suspends their service. Your payment obligations may continue regardless of whether delivery of your notifications is prevented, delayed or blocked.	NoRight – Permission Disability – Immunity

17.4 You may not use Amazon SNS to send SMS messages that include Premium Content (…). You must advise recipients receiving Amazon SNS notification by SMS that wireless carriers may charge the recipient to receive Amazon SNS notifications by SMS (…). You must obtain our prior written consent before using Amazon SNS to send SMS messages for (…)	Right – Duty to Omit Right – Duty to Act Power – Subjection NoRight – Permission

TABLE VII. A CLAUSE OF THE AWS CUSTOMER AGREEMENT CONCERNING PAYMENT FOR SERVICES RENDERED

Clauses	Legal Relation
5.1 Service Fees. We calculate and bill fees and charges monthly. (…) You will pay us the applicable fees and charges for use of the Service Offerings as described on the AWS Site using one of the payment methods we support.	Right – Duty to Act

TABLE VIII. SOME CLAUSES OF THE UK CONSUMER RIGHTS ACT 2015 CONCERNING PRICE REDUCTION

Clauses	Legal Relation
54. Consumer's rights to enforce terms about services. (…) (3) If the service does not conform to the contract, the consumer's rights (…) are: (a) (…) (b) the right to a price reduction (see section 56). 56. Right to price reduction. (1) The right to a price reduction is the right to require the trader to reduce the price to the consumer by an appropriate amount (including the right to receive a refund for anything already paid above the reduced amount). (2) The amount of the reduction may, where appropriate, be the full amount of the price	Power – Subjection

STEP 3. ITEM A: Identify which legal position is emphasized in the legal relation (Table IX). In most cases, the emphasis in the text was preserved. In one case (clause 17.3), concerning payment obligations, we have opted to represent the right of Amazon to receive payment as this right is protected by an immunity.

TABLE IX. LEGAL POSITIONS EMPHASIZED IN THE IDENTIFIED LEGAL RELATIONS

Clauses	Identified Legal Relation	Emphasized Legal Position
17.1	Right-Duty to an Omission	Duty to Omit (Fig. 19)
17.2	NoRight-Liberty	Liberty (Fig. 19)
17.3	NoRight-Permission Disability-Immunity	NoRight (Fig. 19) Immunity (Fig. 21)
17.4	Right-Duty to an Omission Right-Duty to an Action Power-Subjection Permission-NoRight	Duty to Omit (Fig. 19) Duty to Act (Fig. 19) Power (Fig. 20) Permission (Fig. 20)
5.1	Right-Duty to an Action	Right (Fig. 21)
UKCRA 54, 56	Power-Subjection	Power (Fig. 21)

STEP 3. ITEM B: Design the corresponding *contract element* and include the corresponding visual construct of legal position emphasized in the relation (Fig. 19-Fig. 21).

STEP 3. ITEM C: Verify which legal subject is the bearer of the most salient legal position and connect the holder with the contract element using an *assignment relationship*. The other subject is related to the contract element (or the contract as a whole) using a simple *association link.* Name each relationship with the corresponding UFO-L legal roles categories (Fig. 19-Fig. 21).

STEP 3. ITEM D: Represent relationships between contract elements. Use the *trigger relationship* to represent legal positions that are triggered by violations of a legal position (see Fig. 19) as well as those legal positions that are affected by powers and immunities (see Fig. 20 and Fig. 21).

Fig. 19 shows the resulting model focusing on part of the AWS Service Terms Clause 17, which concerns the Simple Notification Service (SNS) offering.

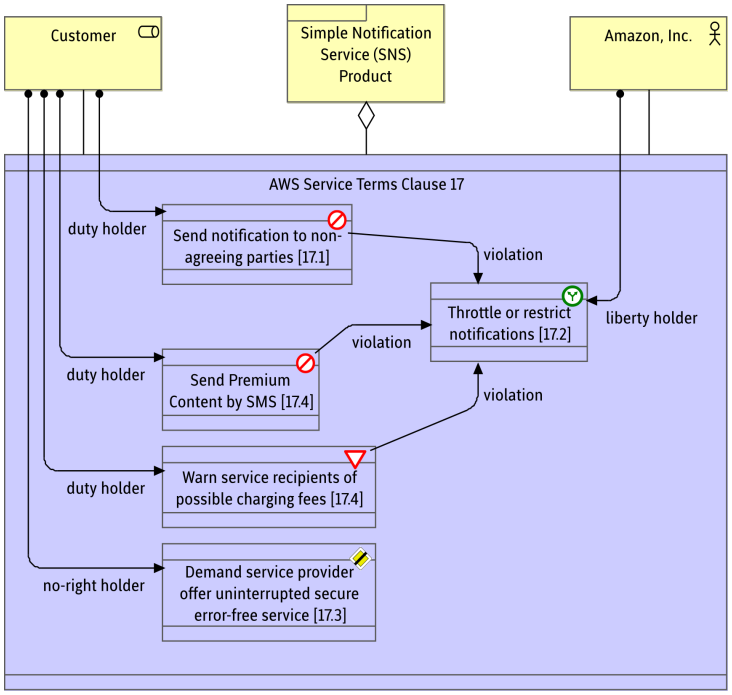

Fig. 19. Fragment of AWS Service Terms – Clause 17.

Fig. 20 focuses on some other positions of the AWS Service Terms Clause 17. The service provider has the Power to authorize service customers to send SMS messages when concerning certain specific purposes, possibly creating a permission. In this fragment, a *trigger* relation captures the conditional nature of the customer's permission.

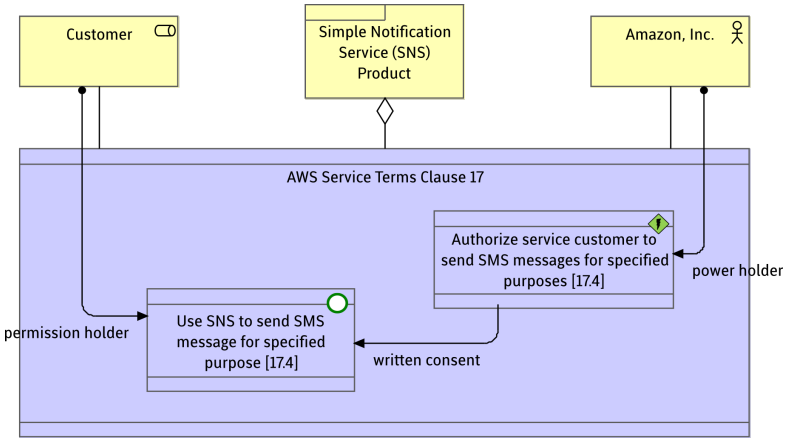

Fig. 20. Fragment of AWS Service Terms – Clause 17.

Fig. 21 reveals the positions arising out of legal texts that are more general than the AWS Service Terms Clause 17. These include the AWS Customer Agreement (applicable to all service offerings of Amazon, Inc. including the SNS Product), and the UK Consumer Rights Act (assuming the consumer is in its jurisdiction). The interactions between legal positions in these various legal sources is made explicit: the Right Amazon has to receive payment according to contractual clause 5.1 is protected by Immunity in clause 17.3 (in case of technical problems outside of Amazon's control); and the same right may be affected by the Power granted by the UK Consumer Rights Act (in case of non-compliance to the contract).

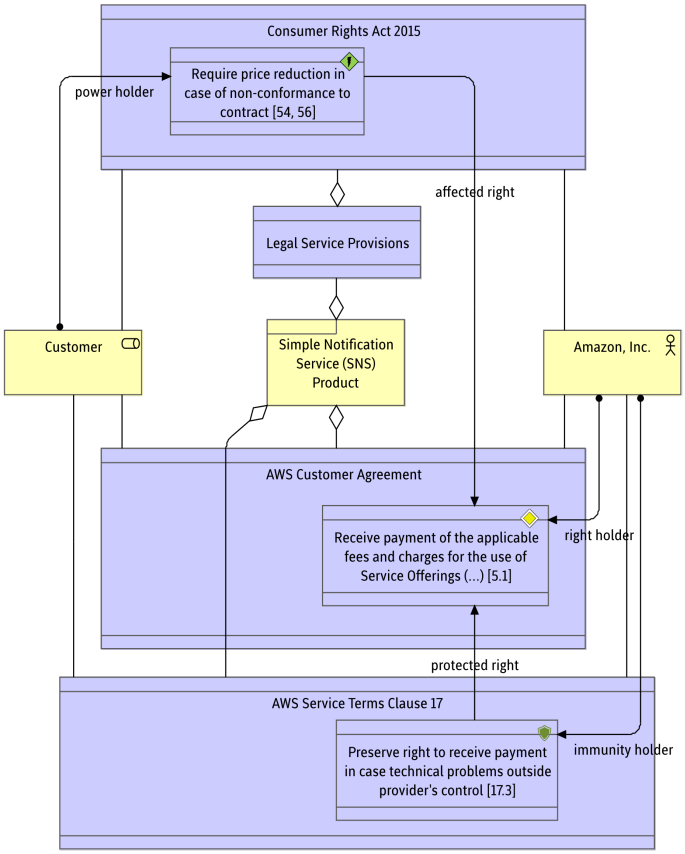

Fig. 21. Fragment of AWS Customer and AWS Service Terms

In applying the method for extracting and representing legal relations, one can visually identify whether a contract is unbalanced, that is, if a party is more protected than her counterpart. This is due to the nature of the existing legal positions in these contracts, i.e.: right, permission, liberty, and power to the detriment of their correlated positions: duty, no-right and subjection. For instance, Figs. 19-21). show fragments involving the AWS Service Terms. Note that most clauses are written to protect the service provider (differently from the consumer legislation). Usually, cloud service agreements have the legal nature of *adhesion contract*. This means that the economically stronger party establishes the contractual clauses, leaving to the weaker party no opportunity for bargaining. At first sight, this kind of contract seems to benefit the service provider, however, courts often tend to interpret adhesion contracts restrictively, applying, for example, the Reasonable Expectations Doctrine [55] as basis for nullifying contractual clauses or the entire contract.

When constructing the concrete syntax for legal relationships based on the UFO-L ontology, it has been necessary to decide between the expressiveness and the simplicity of the visual constructs set. Firstly, we decide to represent a legal relationship as a whole by means of a relationship between *customer*, *provider* and *contract* (Fig. 13). Secondly, we chose to represent the contract elements - the existing legal relationships within a contract - in a partial way (Fig. 15). In other words, since each legal position correlates to another legal position, we represent the salient legal position in the text by means of an ArchiMate symbol (symbol for *contract*) and we extended it with the visual construct representing the legal position emphasized. Also, we represent the relation between contractual subjects and contract elements with the existing relationship notations in ArchiMate and name them using the UFO-L terminology. Finally, the proposed visual constructs refer to conventional symbols representing road traffic rules and suggest, by their appearance, their meaning. While the colors of the visual decorations added to the ArchiMate's symbols set are linked to their meaning, the colors of ArchiMate's symbols are independent, allowing modelers to use the colors

that best suits them for particular tasks.

8. Empirical support

As discussed in Section 2, in this paper, we have employed the ontology-based language engineering method proposed in [16] to analyze and redesign the service modeling support in ArchiMate. As discussed in depth there, this method relies on establishing an isomorphic relation between the modeling capabilities of a language and a given *reference ontology* of the domain. Hence, this method entails that the quality of the analyzed or (re)designed language at hand directly depends on the quality of the underlying reference ontology. The converse relation is also true, i.e., if one can show that a particular reference ontology is adequate to represent a subject domain, by following this method, one can systematically design a language that preserves this ontological adequacy.

The *reference ontology* used in this work is the *Service Contract Ontology (SCO)* proposed in Section 5. As we have previously argued, this ontology is based on the core ontologies UFO-S and UFO-L and, ultimately, in the foundational ontology UFO. As an additional assessment of these core ontologies, in the sequel, we report on two empirical studies conducted to (indirectly) evaluate their *expressivity* and *comprehensibility appropriateness* by evaluating these properties in terms of modeling artifacts extracted from them. These studies have been executed in the context of service contracts, a domain related both to UFO-S and UFO-L, and the derived service modeling facilities (service modeling patterns based on ArchiMate) and service contract text analysis. The aims of these studies are twofold: (i) evaluate UFO-S and UFO-L with respect to their ability to provide consensus about the domain each of them represents, and (ii) evaluate the usefulness and soundness of the proposed modeling facilities (patterns) designed in the light of these core ontologies.

UFO-S and the Derived Service Modeling Patterns. The work of [56] reports on an empirical study conducted to evaluate UFO-S as well as the derived ArchiMate service modeling patterns, which have been used as a basis for our proposal in Section 6. As previously discussed, these modeling patterns address a number of limitations of ArchiMate. These limitations are: (i) lack of a clear way to describe specific *terms and conditions of service offerings* that address the same set of services, (ii) lack of a clear way to represent service offerings and service hirings (and parts thereof), and (iii) lack of a sound way to represent actors involved in each service hiring. The general hypothesis of this study was that UFO-S, as a reference ontology, would bring benefits in tasks of ontological analysis of service modeling languages, and for the (re)design of such languages towards representing service phenomena consistently. The study consisted of two parts: part 1 was designed to verify whether the participants' interpretations (third-party interpretations) of service models in ArchiMate independently acknowledge the aforementioned limitations (i-iii); part 2, in turn, was designed to assess whether the proposed ArchiMate modeling patterns based on UFO-S would increase expressivity and clarity in service modeling, by addressing these limitations. In addition, the second part of this study aimed at (indirectly) evaluating UFO-S's ability in promoting consensus in service modeling. A total of 24 subjects participated in the study. These were students (both under-graduate and graduate), as well as Computer Science professionals, all of which possessed at least a basic knowledge of conceptual modeling. This study showed that the limitations (i-iii) were ratified by the analysis of the participant's answers in part 1. Besides, it confirmed that the use of the proposed patterns in part 2 addressed these modeling limitations and promoted a high-rate of consensus (88%) among the participants regarding the proper identification and modeling of the corresponding service phenomena. We refer to reader to [2] for all details of the study, including materials and questionnaires employed, along with disaggregated data.

The application of UFO-L for Service Contract Interpretation. The work of [12] reports on an empirical study designed to evaluate the UFO-L patterns for legal relations, which also served as a basis for our proposal in Section 6. In that study, models constructed by applying these UFO-L patterns were evaluated for their ability to facilitate the correct interpretation of contract text, improving question answering performance and perceived clarity. 37 subjects participated in the experiment (students and professionals in computer science and law, 92% of which indicated some experience in conceptual modeling, and 65% of which indicated no experience in legal aspects). First, the subjects were given Amazon Web Service (AWS) contract clauses solely in text and were prompted to answer a number of questions concerning the content of these clauses. After answering these questions, 20 subjects were given UFO-L-based models to represent the AWS contract relations. They were again prompted to answer questions on the legal aspects of the services. Also, the subjects' perception of clarity was considered. They were asked whether specific legal relations and positions were clearly expressed in the text (or diagram). With this result, it was possible to conclude that there is a relation between the increase in clarity and the introduction of UFO-L-based-models. Considering the quantitative results, it was possible to conclude that the UFO-L-based models added greater clarity and comprehensibility to the representation of service contract clauses. The full dataset is available in [57] (PhD thesis published in Portuguese; a translation of the chapter concerning the experiment can be found at http://purl.org/nemo/griffoch7).

9. Related work

In this work, we presented two artifacts: an ontology of service contracts (SCO) and an extension to the ArchiMate language systematically designed according to this ontology. These contributions are related to works in the following research topics: contract ontologies, contract languages, languages for legal norms and rules and e-contract frameworks.

With respect to contract ontology, several of them have been proposed in the last decades using a legal perspective. For example: the ontology for international contract law [58]; the Uniform Commercial Code (UCC) Ontology on legal contract formation [59]; the MPEG Media Contract Ontology (MCO) [60] to deal with rights concerning multimedia assets and intellectual property content; and, the contract ontology based on the SweetDeal rule-based approach [61]. Although not strictly speaking a contract ontology, a conceptual model for deontic concepts is also provided for RM-ODP in [62].

In relation to the use of legal theories and the differentiation of the meanings of the concept of law, with the exception of [58], none of these approaches employ Hohfeld's legal concepts or similar legal theory, failing thus to account for rights in a narrow sense. None of them explicitly address *powers*[3]. These are all cases of *construct deficit*, as discussed in section 2. Also, we observed cases of *construct overload* concerning the concept of *right* in some ontologies of contracts (e.g., [63]). In addition, all these approaches employ the *monadic operators* of deontic logics, not fully capturing the *relational aspect* that is at the basis of our service contract ontology.

In several of the non-relational approaches, the deontic operators apply to an object (typically an action or type of action) and an agent whose action is governed. For example, consider that "John" is permitted to "smoke outdoors". This is a convenient form of expression when deontic constraints apply in an absolute sense, i.e., to the legal system as a whole. Because of this, it leads to simpler formal treatment. Consider however, that deontic constraints may apply in the scope of some contractual relation but not in another. For example, "John" may be obliged as against his employer not to "drink alcohol while on duty call" but not against other agents. When the same agent is in different contracts, what is forbidden as against one agent may permitted as against another. For example, "Amazon, Inc." may be permitted to "store data in the U.S." for some agents but not to others. As Alexy discusses in [45], "someone who makes use of a permission in one relation need not be doing something permitted by the legal system as a whole". He concludes that "it is clear that relational modes cannot be replaced by non-relational modes, and in this sense reduced to them. However, everything that can be said by way of non-relational modes can be said by way of relational ones."

In addition to contract ontologies, several efforts on contract languages have been reported. In [5], a formal system for reasoning is proposed based on the representation of the *contrary-to-duty* concept in the Business Contract Language (BCL). The authors raised some issues for further investigation, such as an improved separation of subject and target roles in a policy expression and the expressiveness of BCL with respect to other legal concepts (right, authorization and delegation). Regarding the first issue, we have suggested in our work that roles are explicitly represented and their legal positions [12]. In this case, not only one party is modeled but two parties in the legal relation, each of which plays a different role in the scope of the legal relation. In [64], a contract language called Contract Language (CL) is based on deontic logic to represent concurrent actions. Despite the benefits of a formalism based on concurrent actions, the authors promote a case of *construct overload* when they do not distinguish right from permission. For instance, in the example cited to instantiate Postulate 3.8 ("Obligation to an action implies that the action is permitted") it is not correct to state that "the client has the right to pay". The correct assertion is that "the client has permission to pay". This is an instructive example of how the reduction of legal positions to a unique form of right-duty position (i.e., a case of *construct deficit*) results in loss of meaning and misunderstanding as discussed in [23]. In [65], the authors propose the transformation of contract constraints of BCL and Finesse into expressions in a service choreography language. In [66], the authors propose a Formal Language for Writing Contracts (FCL) that is based on monadic deontic logic operators of obligations and prohibitions. Obligations are considered the result of "promises" and permissions are considered the result of "not promises". Also, the authors propose a formalism for reparational clauses in contracts. In the last cited languages, we observe the use of monadic operators: obligation, prohibition and permission as the unique way to represent legal positions. There is no representation of *power norms* and other relevant legal concepts (such as right in a narrow sense) (again, a case of *construct deficit*).

The Web Service Level Agreement (WSLA) language allows to specify agreements between service provider and service customer by means of obligations established among them [67]. A WSLA specification complements a service definition but dealing with the agreed characteristics and the way to evaluate and measure them. In WSLA, an obligation is composed of

[3] RM-ODP does have a notion of "prescription" that is related to changes in deontic state. In RM-ODP, a "prescription" is "an action that establishes a rule" [76]. A power, in its turn, is a legal position in virtue of which a holder may perform some kinds of prescriptions. Powers have a constitutive nature, establishing the capacity to perform actions that alter legal positions (the prescriptions).

Service Level Objective and Action Guarantee. Both are considered Guarantees. Action guarantees represent promises of parties to do something, e.g.: to send a notification in case the guarantees are not met. We believe that it could be useful for WSLA incorporate some of the legal concepts proposed in UFO-L in order to increase its expressivity.

Other languages have been used to model legal aspects in the scope of contracts, enterprises and information systems, including, e.g., Rule*ML* [68], LegalRule*ML* [69], and Nòmos 3 [7]. LegalRule*ML* builds up on Rule*ML* using notions of defeasible logics to treat violation of obligations; in the treatment of violations (which we have only addressed incidentally here) it is more expressive than our ArchiMate extension. With respect to the legal positions that it is able to represent, it does not cover powers or rights in a narrow sense, capturing only the corresponding obligations (*construct deficit*). Note that the notion of "Right" that is adopted in LegalRule*ML* corresponds to the notion of protected liberty, which can be accounted for in our ontology with a complex relator composing an unprotected liberty with obligations, following Alexy [45]. In its turn, Nòmos 3 is a conceptual framework for representing laws and regulations that uses the conception of *goals* and Hohfeld's theory to reason about compliance of requirements. Consequently, its concept of liberty as synonym of privilege does not cover all the existing permissions such as negative and positive permissions (*construct deficit*).

In [70], Radha presents a contract lifecycle, which is summarized in three main stages: "Contract Preparation", "Contract Negotiation", and "Contract Fulfillment". The "Contract Negotiation", and the "Contract Fulfillment" stages, present similarities, respectively, to "Service Negotiation" (when contracting parties interact for achieving mutual agreement), and to "Service Delivery" (when provider and customers act and are responsible for actions that contribute for agreement fulfillment) phases in UFO-S. On the other hand, Radha addresses monitoring and management aspects as part of Contract Fulfillment (not yet addressed in UFO-S), not explicitly addressing service offering and service agreement conformity (as presented in UFO-S). Regarding contract elements, besides "commitments", Radha presents a notion of "clauses", which is then specialized in five types: obligation, payment, penalty, permission, and prohibition. Because of this, only the classical deontic operators (obligation, permission, and prohibition) are covered (*construct deficit*). As we have shown, in business contracts, it is often necessary to address rights, no-rights, liberties, powers, disabilities, liabilities and immunities. As discussed at length in [45], these legal positions cannot be reduced to the classical deontic operators at least due to their relational nature. In this sense, the use of UFO-L as a basis for the representation ensures greater expressivity.

10. Final considerations

This work presented a service contract ontology taking as basis both UFO-S and UFO-L. UFO-S addresses service commitments and claims to characterize service relations and their lifecycle. In turn, UFO-L addresses legal relations based on Hohfeld's seminal theory of fundamental legal concepts and Alexy's relational theory of constitutional rights, providing a comprehensive set of legal relations and corresponding legal positions. Both UFO-S and UFO-L leverage a key aspect of UFO, which is its ontological treatment of relations [34] [35].

The resulting service contract ontology has been used as a basis to derive a well-founded extension to the ArchiMate language to support the modeling of service contract elements. With the addition of contract elements, we can represent the relevant legal relations which are inherent to service phenomena in real-world business settings.

It is not the objective of Enterprise Architecture models to provide detailed formal representations of the enterprise, as that would conflict with the usage of EA models for visualization and communication purposes. Because of this, we foresee that the EA models shown here can still profit from additional in-depth representations of service contracts in special contract languages and formalisms. Note that prior to formalizing the contents of legal positions, one needs to identify them, classify them and to establish their relations with the involved organizational actors, products and services. This is the focus of the present paper and is aligned with the purpose of EA models. The implications of the SCO to more detailed formalisms ought to be examined, along with their integration with ArchiMate models. Such work is important to be pursued since it would facilitate relevant tasks such as automated analysis of contractual clause conflicts, automated checking of the observance of legal precepts and automated compliance monitoring. The integration of ArchiMate models with artifacts used in runtime contract management infrastructures (such as [71]) could provide a strategy to bridge the gap between conventional legal contracts and automated contract enactment.

Some other future work concerns the representation of the legal positions inside organizations (arising from internal regulations and compliance efforts). We indent to examine how legal positions interact with other elements in EA models such as behavior elements and motivational elements. Behavioral elements cover business processes, interactions, functions, etc., elements which are subject to regulation by the legal positions we have made explicit here. Motivation elements include goals, drivers, principles, constraints, requirements, all of which relate to *reasons* for the actions of business actors. Since compliance to legislation and to contractual obligations are an important source of (social, external) reasons for action, analyzing these using a common general framework may reveal tight relations. In this sense, this work can be positioned in our long-term research

agenda concerning the semantics of EA models, and ArchiMate in particular. Since previous work has also employed UFO (and its extensions) as a semantic foundation to revise a number of ArchiMate constructs (including Services [2], Goals [72] and Capabilities [43]), we envision all these efforts can be harmonized to provide a comprehensive well-founded enterprise modeling approach.

Other ongoing efforts in our research of legal aspects include: (i) the development of domain-specific visual languages for legal relations (beyond ArchiMate), (ii) the extension of UFO-L (and consequently SCO) with dynamic aspects (for instance, to account explicitly for change in legal positions as a result of the legislative process, of judicial decisions and of negotiation and dispute resolution processes), (iii) the support for the so-called legal principles in UFO-L. Legal principles, differently from legal rules, do not establish hard criteria for compliance, and are key to dealing with the inevitable openness (and 'fuzziness') of normative systems. For example, consider the GDPR principles (Chapter II, Article 5) [73] of "lawfulness, fairness and transparency", "data minimization", "accuracy", etc. Since UFO-L is based on Alexy's work, and Alexy has worked out a system that combines legal principles and rules, this should be feasible in a coherent strategy. This is an interesting research direction to pursue since the representation of legal principles have not yet received due attention in information systems research. Finally, we believe that UFO-L and the SCO may influence the semantic annotation of legal texts, as well as the automatic classification of legal clauses (in contract and in legislation). Having a rich semantic foundation should facilitate the application of machine learning approaches for these tasks.

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References

[1] R. Ferrario, N. Guarino, Commitment-based Modeling of Service Systems, in: Third Int. Conf. IESS, Springer Berlin Heidelberg, Geneva, 2012: pp. 170–185.

[2] J.C. Nardi, R.A. Falbo, J.P.A. Almeida, G. Guizzardi, L.F. Pires, M.J. van Sinderen, N. Guarino, C.M. Fonseca, A commitment-based reference ontology for services, Inf. Syst. 54 (2015) 263–288. doi:10.1016/j.is.2015.01.012.

[3] C. Griffo, J.P.A. Almeida, G. Guizzardi, J.C. Nardi, From an Ontology of Service Contracts to Contract Modeling in Enterprise Architecture, in: 21st EDOC 2017 Proc., 2017: pp. 40–49. doi:10.1109/EDOC.2017.15.

[4] The Open Group, Archimate 3.0 Specification, The Open Group, Berkshire, 2016.

[5] G. Governatori, Z. Milosevic, A Formal Analysis of a Business Contract Language, Int. J. Coop. Inf. Syst. 6 (2006) 1–26.

[6] C. Prisacariu, G. Schneider, A Formal Language for Electronic Contracts, Lect. Notes Comput. Sci. 4468 (2007) 174–189. doi:10.1007/978-3-540-72952-5_11.

[7] S. Ingolfo, A. Siena, J. Mylopoulos, Goals and Compliance in Nomos 3, in: CAiSE 2014 Proc., 2014: pp. 1–6.

[8] V. Kabilan, Contract Workflow Model Patterns using BPMN, in: CEUR Workshop Proc., 2005: pp. 171–182.

[9] S.A. Bernard, An introduction to enterprise architecture, AuthorHouse, 2012.

[10] M. Lankhorst, Enterprise Architecture at Work, Springer, Berlin, 2013. doi:10.1007/978-3-642-29651-2.

[11] C. Griffo, J.P.A. Almeida, G. Guizzardi, A Pattern for the Representation of Legal Relations in a Legal Core Ontology, in: Front. Artif. Intell. Appl., 2016: pp. 191–194. doi:10.3233/978-1-61499-726-9-191.

[12] C. Griffo, J.P.A. Almeida, G. Guizzardi, Conceptual modeling of legal relations, in: ER 2018 Concept. Model. Lect. Notes Comput. Sci., Springer, 2018: pp. 169–183. doi:10.1007/978-3-030-00847-5_14.

[13] J.C. Nardi, R.A. Falbo, J.P.A. Almeida, A Panorama of the Semantic EAI Initiatives and the Adoption of Ontologies by these Initiatives, Lect. Notes Bus. Inf. Process. 144 LNBIP (2013) 198–211. doi:10.1007/978-3-642-36796-0-17.

[14] J.C. Nardi, R.A. Falbo, J.P.A. Almeida, An Ontological Analysis of Service Modeling at ArchiMate's Business Layer, in: 18th IEEE Int. Enterp. Distrib. Object Comput. Conf., 2014: pp. 92–100. doi:10.1109/EDOC.2014.22.

[15] J.C. Nardi, R.A. Falbo, J.P.A. Almeida, Revealing Service Commitments in Service-Oriented Enterprise Architecture, in: Sixth Work. Serv. Oriented Enterp. Arch. Enterp. Eng., Ulm - Germany, 2014: pp. 286–295.

[16] G. Guizzardi, Ontology-based evaluation and design of visual conceptual modeling languages, Domain Eng. (2013) 317–347. doi:10.1007/978-3-642-36654-3_13.

[17] R. Weber, Ontological Foundations of Information Systems, Melbourne: Coopers & Lybrand and the Accounting Association of Australia and New Zealand, 1997.

[18] R. Pergl, O. Pastor, F. Gailly, M. Verdonck, G. Guizzardi, B. Martins, Comparing Traditional Conceptual Modeling with Ontology-driven Conceptual Modeling: An Empirical Study, Inf. Syst. 81 (2018) 92–103. doi:10.1016/j.is.2018.11.009.

[19] M. Recker, J., Rosemann, M., Green, P., & Indulska, Do Ontological Deficiencies in Modeling Grammars Matter?, MIS Q. 35 (2011) 57–79.

[20] G. Guizzardi, On Ontology, ontologies, Conceptualizations, Modeling Languages, and (Meta)Models, in: FAIA, Databases Inf. Syst. IV. IOS Press. Amsterdam., IOS Press, Amsterdam, 2007: pp. 18–39. doi:10.1017/CBO9781107415324.004.

[21] G. Guizzardi, Ontological Foundations for Structural Conceptual Model, Universal Press, Veenendaal, The Netherlands, 2005. http://doc.utwente.nl/50826.

[22] G. Guizzardi, G. Wagner, J.P.A. Almeida, R.S.S. Guizzardi, Towards Ontological Foundations for Conceptual Modeling: The Unified Foundational Ontology (UFO) Story, Appl. Ontol. 10 (2015) 259–271. doi:10.3233/AO-150157.

[23] F. Verdonck, M., & Gailly, Insights on the Use and Application of Ontology and Conceptual Modeling Languages in Ontology-driven Conceptual Modeling, Int. Conf. Concept. Model. (2016) 83–97.

[24] C.L.B. Azevedo, M.-E. Iacob, J.P.A. Almeida, M.J. van Sinderen, L.F. Pires, G. Guizzardi, Modeling Resources and Capabilities in Enterprise Architecture: A well-founded ontology-based proposal for ArchiMate, Inf. Syst. 54 (2015) 235–262.

[25] P.S. Santos, J.P.A. Almeida, G. Guizzardi, An Ontology-based Analysis and Semantics for Organizational Structure Modeling in the ARIS Method, Inf. Syst. 38 (2013) 690–708. doi:10.1016/j.is.2012.09.004.

[26] J.P.A. Almeida, G. Guizzardi, An Ontological Analysis of the Notion of Community in the RM-ODP Enterprise Language, Comput. Stand. Interfaces. 35 (2013) 257–268. doi:10.1016/j.csi.2012.01.007.

[27] C.L.B. Azevedo, J.P.A. Almeida, M.J. van Sinderen, D. Quartel, G. Guizzardi, An Ontology-Based Semantics for the Motivation Extension to ArchiMate, in: 2011 IEEE 15th Int. Enterp. Distrib. Object Comput. Conf., Helsinki, 2011: pp. 25–34.

[28] R.S.S. Guizzardi, X. Franch, G. Guizzardi, R. Wieringa, Ontological Distinctions between Means-End and Contribution Links in the i* Framework, in: Int. Conf. Concept. Model., 2013: pp. 463–470. doi:10.1007/978-3-642-41924-9_39.

[29] G. Guizzardi, G. Wagner, Can BPMN be used for making simulation models?, in: Work. Enterp. Organ. Model. Simul., 2011: pp. 100–115. doi:10.1007/978-3-642-24175-8_8.

[30] G. Guizzardi, G. Wagner, Towards an Ontological Foundation of Discrete Event Simulation, Proc. - Winter Simul. Conf. (2010) 652–664. doi:10.1109/WSC.2010.5679121.

[31] T.P. Sales, F. Baião, G. Guizzardi, J.P.A. Almeida, N. Guarino, J. Mylopoulos, The common ontology of value and risk, in: Proc. Concept. Model. ER 2018, Lect. Notes Comput. Sci., Springer, Cham, 2018: pp. 121–135. doi:10.1007/978-3-030-00847-5_11.

[32] T.P. Sales, N. Guarino, G. Guizzardi, J. Mylopoulos, An Ontological Analysis of Value Propositions, in: 2017 IEEE 21st Int. Enterp. Distrib. Object Comput. Conf., 2017: pp. 184–193. doi:10.1109/EDOC.2017.32.

[33] T.P. Sales, J.P.A. Almeida, S. Santini, F. Baiao, G. Guizzardi, Ontological Analysis and Redesign of Risk Modeling in ArchiMate, in: Proc. - 2018 IEEE 22nd Int. Enterp. Distrib. Object Comput. Conf. EDOC 2018, 2018: pp. 154–163. doi:10.1109/EDOC.2018.00028.

[34] N. Guarino, G. Guizzardi, Relationships and Events: Towards a General Theory of Reification and Truthmaking., in: 15th Int. Conf. Ital. Assoc. Artif. Intell., 2016: pp. 1–13.

[35] N. Guarino, G. Guizzardi, “We need to discuss the Relationship”: Revisiting Relationships as Modeling Constructs., in: 27th Int. Conf. CAiSE 2015 Proc., Springer International Publishing, Sweden, 2015: pp. 279–294.

[36] B. Anderson, M. Bergholtz, P. Johannesson, Resource, Process, and Use – Views on Service Modeling, in: Springer-Verlag, 2012: pp. 23–33.

[37] S.L. Vargo, R.L. Lusch, Evolving to a New Dominant Logic for Marketing, J. Mark. 68 (2004) 1–17.

[38] S. Alter, Service System Fundamentals: Work System, Value Chain, and Life Cycle, IBM Syst. J. 47.1 (2008) 71–85.

[39] J. O’Sullivan, Towards a Precise Understanding of Service Properties, Queensland University of Technology, 2006.

[40] M.P. Singh, A.K. Chopra, N. Desai, Commitment-Based Service-Oriented Architecture, Comput. (Long. Beach. Calif). 42 (2009) 72–79. doi:10.1109/MC.2009.347.

[41] G. Guizzardi, R.A. Falbo, R.S.S. Guizzardi, Grounding Software Domain Ontologies in the Unified Foundational Ontology (UFO): The case of the ODE Software Process Ontology, in: CIbSE, 2008: pp. 127–140.

[42] N. Guarino, G. Guizzardi, T.P. Sales, On the Ontological Nature of REA Core Relations, in: 12th Int. Work. Value Model. Bus. Ontol. (VMBO 2018), Amsterdam, The Netherlands, 2018.

[43] J.C. Nardi, J.P.A. Almeida, M.C. Pereira, R.D.A. Falbo, M.E. Iacob, M. Van Sinderen, L.F. Pires, Service Commitments and Capabilities across the ArchiMate Architectural Layers, Proc. - IEEE Int. Enterp. Distrib. Object Comput. Work. EDOCW. 2016-Septe (2016) 139–148. doi:10.1109/EDOCW.2016.7584386.

[44] W.N. Hohfeld, Some Fundamental Legal Conceptions as applied in Judicial Reasoning, Yale Law J. 23 (1913) 16–59.

[45] R. Alexy, A Theory of Constitutional Rights, Oxford University Press, USA, 2009.

[46] J. Breuker, R. Hoekstra, A. Boer, K. van den Berg, G. Sartor, R. Rubino, A. Wyner, T. Bench-Capon, OWL Ontology of Basic Legal Concepts (LKIF-Core), ESTRELLA. Eur. Proj. Stand. Transparent Represent. Order to Extend Leg. Access. - Deliv. 1.4. D1.4 (2007).

[47] J. Breuker, R. Hoekstra, Core Concepts of Law: Taking Common Sense Seriously., Proc. Third Int. Conf. Form. Ontol. Inf. Syst. (FOIS), Front. Artif. Intell. Appl. 113 (2004) 210.

[48] A. Gangemi, Design Patterns for Legal Ontology Construction, Proc. 2nd Work. Leg. Ontol. Artif. Intell. Tech. (LOAIT), CEUR

Work. Proc. 321 (2007) 65–85.
[49] C. Griffo, J.P.A. Almeida, G. Guizzardi, Towards a Legal Core Ontology based on Alexy's Theory of Fundamental Rights., in: Multiling. Work. Artif. Intell. Law, ICAIL 2015, San Diego, CA, 2015.
[50] Consumer Rights Act 2015, Legislation.Gov.Uk. 1 (2015) 1–150. doi:10.11779/CJGE201606005.
[51] A. Obar, J. A., & Oeldorf-Hirsch, The Biggest Lie on the Internet: Ignoring the Privacy Policies and Terms of Service Policies of Social Networking Services, Information, Commun. Soc. (2016) 1–20.
[52] Amazon, AWS Service Terms, (2017) 1–493. https://aws.amazon.com/legal/ (accessed February 20, 2019).
[53] Amazon, AWS Acceptable Use Policy, (2016). https://aws.amazon.com/aup/?nc1=h_ls (accessed February 20, 2019).
[54] Amazon, AWS Customer Agreement, (2012) 1–7. https://aws.amazon.com/agreement/ (accessed March 23, 2018).
[55] L.K. Fett, The Reasonable Expectations Doctrine : An Alternative to Bending and Stretching Traditional Tools of Contract Interpretation, William Mitchell Law Rev. 18 (1992).
[56] J.C. Nardi, A Commitment-Based Reference Ontology for Service: Harmonizing Service Perspectives, Federal University of Espírito Santo, 2014.
[57] C. Griffo, UFO-L: Uma Ontologia Núcleo de Aspectos Jurídicos Construída sob a Perspectiva das Relações Jurídicas, Universidade Federal do Espírito Santo, 2018. http://www.informatica.ufes.br/pt-br/pos-graduacao/PPGI/detalhes-da-tese?id=11785.
[58] V. Kabilan, P. Johannesson, Semantic Representation of Contract Knowledge using Multi tier Ontology, in: First Int. Conf. Semant. Web Databases, 2003: pp. 395–414. doi:10.1.1.86.8206.
[59] J. Bagby, T. Mullen, Legal Ontology of Sales Law Application to eCommerce, Artif. Intell. Law. 15 (2007) 155–170. doi:10.1007/s10506-007-9027-3.
[60] V. Rodriguez-Doncel, J. Delgado, S. Llorente, E. Rodriguez, L. Boch, Overview of the MPEG-21 Media Contract Ontology, Semant. Web. 7 (2016) 311–332. doi:10.3233/SW-160215.
[61] B.N. Grosof, T.C. Poon, SweetDeal: Representing Agent Contracts with Exceptions Using XML Rules, Ontologies, and Process Descriptions, in: WWW '03 Proc., 2003: pp. 340–349. doi:10.1145/775152.775200.
[62] P.F. Linington, H. Miyazaki, A. Vallecillo, Obligations and Delegation in the ODP Enterprise Language, in: EDOCW'12, 16th Int. IEEE, 2012.
[63] G.J. Pace, F. Schapachnik, G. Schneider, Conditional Permissions in Contracts, Front. Artif. Intell. Appl. 279 (2015) 61–70. doi:10.3233/978-1-61499-609-5-61.
[64] C. Prisacariu, G. Schneider, A dynamic Deontic Logic for Complex Contracts, J. Log. Algebr. Program. 81 (2012) 458–490. doi:10.1016/j.jlap.2012.03.003.
[65] A. Berry, Z. Milosevic, Extending Choreography with Business Contract Constraints, Int. J. Coop. Inf. Syst. (2005) 1–48.
[66] W.M. Farmer, Q. Hu, FCL : A Formal Language for Writing Contracts, Inf. Reuse Integr. (IRI), IEEE 17th Int. Conf. (2017) 134–141.
[67] L. Heiko, A. Keller, D. Asit, R.P. King, R. Franck, Web Service Level Agreement (WSLA) Language Specification, 2003. doi:10.1109/WECWIS.2002.1021238.
[68] G. Governatori, A. Rotolo, Modelling Contracts using RuleML, in: T.G. (ed.) (Ed.), Jurix 2004 17th Annu. Conf. IOS Press, Amsterdam, 2004: pp. 141–150. http://espace.library.uq.edu.au/view/UQ:9612.
[69] M. Palmirani, G. Governatori, A. Rotolo, S. Tabet, H. Boley, A. Paschke, LegalRuleML: XML-based Rules and Norms, in: Rule-Based Model. Comput. Semant. Web 5th Int. Symp. RuleML 2011, Florida, USA, 2011: pp. 298–312.
[70] P.R. Krishna, E-Contract Modeling and E-Enactment, International Institute of Information Technology, 2010.
[71] T. Dimitrakos, I. Djordjevic, Z. Milosevic, A. Josang, C.I. Phillips, Contract performance assessment for secure and dynamic virtual collaborations, in: Seventh IEEE Int. Enterp. Distrib. Object Comput. Conf. 2003. Proceedings., 2003: pp. 62–74. doi:10.1109/EDOC.2003.1233838.
[72] C.L.B. Azevedo, M.-E. Iacob, J.P.A. Almeida, M.J. van Sinderen, L.F. Pires, G. Guizzardi, An Ontology-Based Well-Founded Proposal for Modeling Resources and Capabilities in ArchiMate, in: 17th IEEE Int. EDOC Conf., Vancouver, 2013.
[73] European Parliament and Council of the European Union, Regulation on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (Data Protection Directive), 2016. https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32016R0679 (accessed August 14, 2019).
[74] Y. Wand, R. Weber, An Ontological Model of an Information System, IEEE Trans. Softw. Eng. 16 (1990) 1282–1292. doi:10.1109/32.60316.
[75] V.A. Carvalho, J.P.A. Almeida, G. Guizzardi, Using reference domain ontologies to define the real-world semantics of domain-specific languages, in: Int. Conf. Adv. Inf. Syst. Eng., Springer, Cham, 2014: pp. 488–502. doi:10.1007/978-3-319-07881-6_33.
[76] ITU-IEC, Information technology – Open distributed processing – Reference model – Enterprise language Recommendation ITU-T X.911 (09/2014), 2014.