An Ontological Analysis of Service Modeling at ArchiMate's Business Layer

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***Abstract*—ArchiMate is a widely-adopted enterprise architecture language based on the "service orientation" paradigm. Although its support for service orientation has had great impact in the representation of (service-oriented) enterprise architectures in the last 10 years, the representation of services in ArchiMate is not without problems. In particular, the predominance of the perspective of service as "unit of functionality" hides some important social aspects inherent to service relations and makes some of the models that the language produces ambiguous. In order to address some of these issues, in this paper we discuss an ontological analysis of service modeling fragments of ArchiMate's Business layer. This analysis is based on UFO-S, a reference ontology that characterizes the notion of service by applying the concepts of commitments and claims and harmonizing several views of services from a broad perspective. We contribute to: (i) providing real-world semantics to service modeling fragments in ArchiMate based on the notion of service commitments/claims; and (ii) offering recommendations in the form of modeling patterns to ensure expressiveness and to clarify the semantics of service elements.**

Keywords: Service-oriented Enterprise Architecture, service modeling; ontological analysis; ArchiMate.

I. INTRODUCTION

The "service orientation" paradigm has been considered one of the most important architectural paradigms that has emerged in the last few years [1]. Together with this paradigm, a number of service-based modeling languages and frameworks have been defined to describe and communicate enterprise architecture decisions [2]. One of the most prominent examples is ArchiMate (currently a technical specification maintained by The Open Group [3]), which adopts the "service" construct as a basic structuring element for its three enterprise architecture layers: Business, Application, and Technology [3].

Differently from other enterprise architecture frameworks (such as, e.g., ARIS, DODAF/MODAF), ArchiMate was conceived originally with the service orientation paradigm as a key structuring principle. As a consequence, it has become an important development for the representation of service-oriented architectures in practice.

Although its support for service orientation is significant and has had great impact in the representation of service-oriented enterprise architectures in industry in the last 10 years, the representation of services in ArchiMate is not without problems. We have observed that some of these problems are rooted in the dominance of a conceptualization of service as "unit of functionality" in ArchiMate. This underlying perspective disregards some important social aspects associated with the dynamics of service relationships which have become increasingly apparent with the establishment of more mature foundations for service science in last decade.

The importance of service relations in service science has been identified from a broad multidisciplinary view by Fisk and Grove [4], which state that "relationships are at the heart of service". Services are provided/consumed in a network of social relationships that, in fact, characterizes the complex notion of service [5]. As Ferrario and Guarino discuss in [6], service relations are based on the *social commitments and claims* established between service participants. These commitments/claims are established in service offer and service negotiation phases, and drive service delivery.

Our objective in this paper is to examine ArchiMate's service modeling from this broad service-orientation perspective and contribute to the improvement of the language's expressiveness and semantic clarity in the representation of service oriented enterprise architectures. We focus on ArchiMate's Business layer, which is especially characterized by social aspects, since the service relations in this layer are established between (social) agents (enterprises, organizations, and people).

In order to achieve our goal, we perform an ontological analysis of ArchiMate model fragments, taking as basis the UFO-S reference ontology for services [5], which accounts for services by means of commitments and claims between service participants, and is able to harmonize several perspectives for services in the literature [5].

The contributions of this work can be summarized as follows: (i) providing real-world semantics to service modeling in ArchiMate based on the notion of service commitments/claims (which is harmonized to the current perspective of service as "unit of functionality" in ArchiMate); and (ii) offering recommendations in the form of modeling patterns to ensure expressiveness and to clarify the semantics of some service model fragments (explicitly addressing the representation of service offering types, service offerings and service agreements).

This paper is organized as follows: Section II presents an overview of service-related elements at Business layer; Section III presents the UFO-S ontology; Section IV analyzes ArchiMate service modeling elements in light of UFO-S, identifying limitations of the language with respect to semantic clarity and expressiveness of service relations; Section V presents recommendations for the language in the form of modeling patterns; Section VI discusses related work; and Section VII presents final considerations.

II. An Overview of ArchiMate Service Modeling at Business Layer

Since its inception, ArchiMate has included service-related elements in its *Business layer*, which describe the provision of business services to enterprise customers. This layer comprises structural, informational, and behavioral elements [3]. The *structural elements* refer to entities that make up the organization (e.g., business actors) and their relationships. The *informational elements* are related to the purpose of communication (e.g., products and contracts). The *behavioral elements* are used to characterize the dynamic aspects of an organization (e.g., business services and processes) [3]. All these elements can be linked by means of several relationships.

Figure 1 shows the fragment of the ArchiMate's Business layer metamodel analyzed in this paper. Note that we focus on the relations between business services and the structural and informational elements. Further, we do not consider derived relations [3].

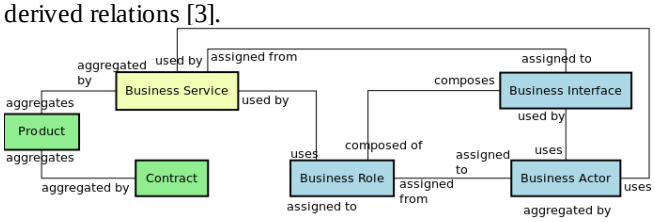

Figure 1. ArchiMate's Business layer metamodel fragment.

In ArchiMate, a *service* is defined as "as a unit of functionality that a system exposes to its environment, while hiding internal operations, which provides a certain value" [3]. A *business service* is "a service that fulfills a business need for a customer (internal or external to the organization)", and may be assigned to business interfaces. A *business interface* is a "point of access where a business service is made available to the environment" (e.g., phone, website, etc.), and it may be modeled as part of a business role. A *business actor* is "an organizational entity that is capable of performing behavior" (e.g., a person, an organization). A *business role* is "the responsibility for performing specific behavior, to which an actor can be assigned". Business actors and business roles can use business services through business interfaces [3].

Regarding informational elements, a *product* is defined as "a coherent collection of *services*, accompanied by a contract/set of agreements, which is offered as a whole to (internal or external) customers" [3]. A *contract* is "a formal or informal specification of agreement that specifies the rights and obligations associated with a product" [3].

Table I presents the notation of the aforementioned modeling elements. Table II describes the relationships that are especially important to model service relations.

TABLE I. BUSINESS LAYER ELEMENT NOTATIONS USED IN THIS WORK.

Elements	Notation	Relationship	Notation
Business actor	Business Actor	Used by	→
Business role	Business Role	Realization	⋯▷
Business Interface		Assignment	—
Business Service	Business Service	Composition	◆—
Product	Product	Aggregation	◇—
Contract	Contract		

TABLE II. SUBSET OF BUSINESS LAYER RELATIONSHIPS (BASED ON [3]).

Relationship	Definition
Used by	Used to model the use of services by structural and behavioral elements.
Assignment	Used to link structural elements to the behavioral elements performed by them; or to link business actors with the business roles played by them.
Aggregation	Used to indicate that an element groups a number of other elements.
Composition	Used to indicate that an object is composed of one or more other objects. Differently from aggregation, an object is part of only one whole.

Figure 2 shows an ArchiMate service model in the car insurance domain. This model exemplifies how the aforementioned elements are used, based on ArchiMate's metamodel, for representing service relations. The model shows two different companies ("ArchInsurance" and "XInsurance"), as "Insurers", offering two *services* ("Car Insurance" and "Roadside Assistance") that take part in a *product* ("Special Car Insurance"). The terms and conditions of the product are described in *contracts*, and "John" and "Mary", as "Insurants", are service users.

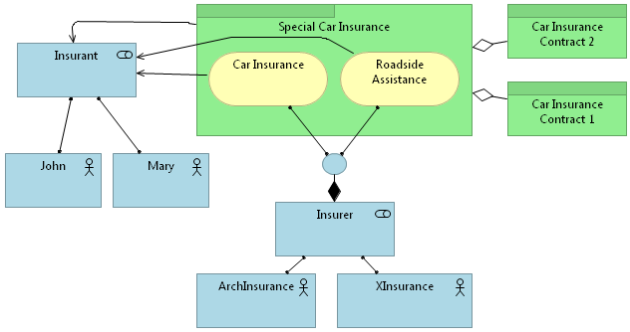

Figure 2. The running example: "Car Insurance".

As we shall see, this model leaves a number of questions unanswered: (i) Are "John" and "Mary" target potential customers (e.g., car owners) or are they actual service customers hiring services? (ii) Among which service participants ("John", "Mary", "ArchInsurance", and "XInsurance") is the "Car Insurance Contract 1" established? (iii) Does "Car Insurance Contract 2" represent a specific contract between a hired service provider and a service customer, or a type of service contract? These and other questions cannot be clearly answered due to limitations in ArchiMate. In order to discuss these limitations in details, in Section IV, we analyze fragments of this model in the light of UFO-S, and in Section V, we present recommendations in form of modeling patterns for addressing them.

III. ONTOLOGICAL FOUNDATIONS

UFO-S [5] is a core reference ontology for services based on the notion of social commitments. As a *reference ontology* [7], UFO-S is intended to assist humans in meaning negotiation and shared understanding. It is grounded in a foundational ontology (the Unified Foundational Ontology – UFO [8][9][10]), from which it reuses foundational notions of objects, types, object properties, object relations, events/processes, and further social concepts that specialize the more general notions and account for social reality. The social layer of UFO includes important notions of social agents (e.g., enterprises), the objectives they pursue, the roles they play, the social relations they establish (commitments and corresponding claims), etc. Our choice of using UFO for building UFO-S can be 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., [11][9][12][13]).

UFO-S focuses on the three basic phases of the service life-cycle, namely [5]: (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).

Figure 3 presents a UFO-S model fragment regarding service offer. 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, which mediates the social relations between 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. 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).

Service provider is the role played by agents (e.g., physical agents such as persons, and social agents such as organizations [9]) 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, as a consequence, have claims for the fulfillment of the commitments established by the agent playing the role of service provider.

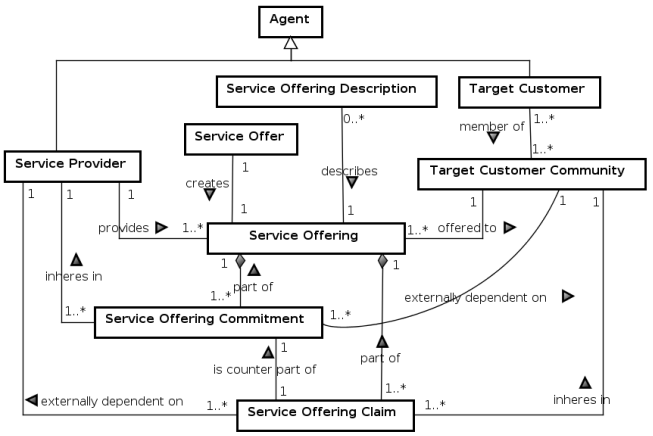

Figure 3. Service Offer.

Once a service is offered, service negotiation may occur. Figure 4 presents UFO-S model fragment of this phase. Service negotiation is an event involving a target customer and a service provider. 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.

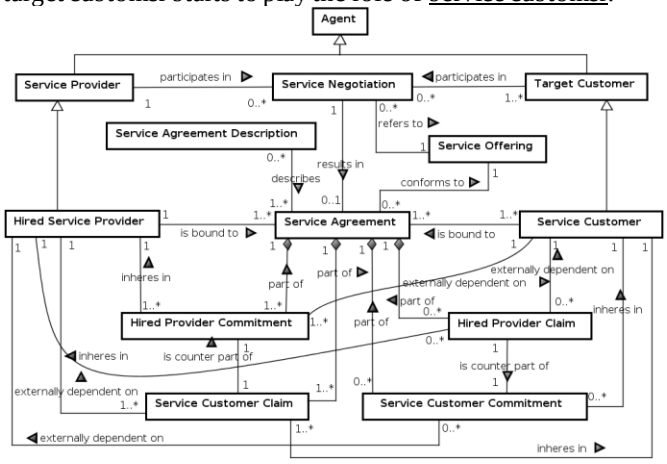

Figure 4. Service Negotiation.

A service agreement 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 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 (e.g., contract).

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 works, service delivery concerns the execution of actions aiming at fulfilling the commitments established in service agreements.

IV. ONTOLOGICAL ANALYSIS AND INTERPRETATIONS

In this section, we analyze the semantics of some service model fragments in ArchiMate, using the concepts of UFO-S. We start the analysis with small fragments of the running example model (Section II) and increase their complexity progressively. Some limitations of ArchiMate for service modeling are identified and labeled (as "L#").

A. *Service and Structural Elements*

Initially, we analyze the model fragment of Figure 5, which we take as the minimum service modeling fragment amenable to semantic analysis. In this fragment, a "Car Insurance" *service* is *assigned to* the "Insurer" *business role* (through an *interface*). Following [14], we assume that *business roles* in ArchiMate represent social roles (e.g., manager, insurer) that may be instantiated by agents (e.g., a person or an organization).

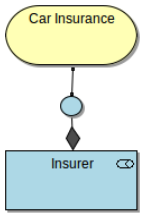

Figure 5. Service offering type.

In our point of view, even this minimum fragment presents ambiguity. Does this model fragment represent a service offering of an agent playing the role of "Insurer" (who is not represented in the fragment), or, does it represent a service offering type (that would potentially be instantiated for a specific agent playing the role of "Insurer")? We identify this ambiguity as limitation "L1". In order to continue with our analysis, we assume the latter interpretation, i.e., that no specific service offering of a particular insurance company is implied by this fragment, and only a type thereof is represented. This type may be later instantiated by a service provider playing the "Insurer" role.

The model fragment of Figure 6-A augments the previous fragment with the "ArchInsurance" *business actor assigned to* the "Insurer" *role*. Following [14], we consider that, a *business actor* in ArchiMate is an agent that, when *assigned to* a *business role*, plays this *role*. In this case, the "ArchInsurance" *business actor* is interpreted as an actor playing the service provider role ("Insurer") in a service offering (instance of the service offering type).

The model of Figure 6-B [1] includes a second service provider ("XInsurance"). Following the previous interpretation, we can say that the model implies the existence of two service offerings: a car insurance service offering by "ArchInsurance", and a car insurance service offering by "XInsurance". We assume both service offerings instantiate the same service offering type (from Figure 5).

In this case, however, we have two possible interpretations: (i) the two service offerings are identical, except by the fact that they are offered by different agents; or (ii) they are different (e.g., they differ with respect to particular policy terms). We conclude that differences between service offerings cannot be properly represented in ArchiMate ("L2") [2]. This lack of expressiveness limits detailing service offerings that instantiate the same service offering type.

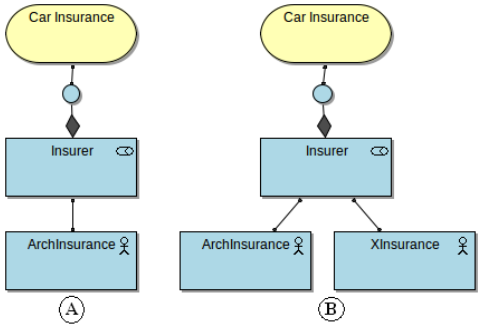

Figure 6. Service offerings.

The fragment of Figure 7-A enriches the fragment of Figure 6-A by relating the "Insurant" *business role* to the "Car Insurance" service through a "uses" relationship of ArchiMate. We consider two possible interpretations for this fragment: (i) the "Insurant" *role* represents the target customer role to which the service offering refers to (i.e., for which the service offering is intended to reach), or (ii) the "Insurant" role represents the service customers (not represented in the fragment) that are allowed to use the service as result of a service agreement (possibly with "ArchInsurance").

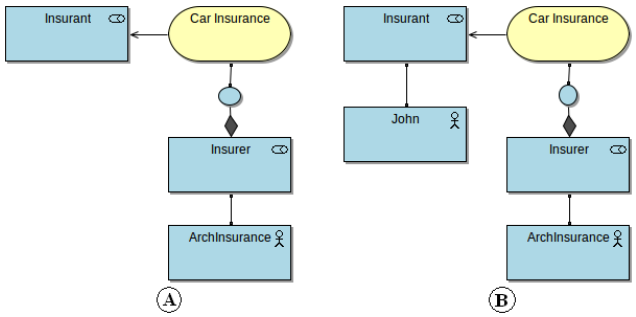

Figure 7. "*Used by*" relationship.

Consider, further, the model fragment of Figure 7-B, which extends the fragment of Figure 7-A by including the *business actor* "John" assigned to the "Insurant" *role*. What does "John" represent? "John" could be interpreted as: (i) an individual that plays the role of target customer in a service offering; or (ii) an individual that plays the role of a specific

[1] We assume this is possible, since no cardinality constraints are specified for relationships in ArchiMate's metamodel.

[2] The *contract* element could be used to differentiate service offerings. But, it cannot be used directly with *services*, only by means of *products*. Section IV.B discusses this in details.

service customer in a service agreement (possibly with "ArchInsurance"). Based on that, we can notice that this "*used by"* relationship is overloaded ("L3"), since it leads to two possible interpretations: a service offering towards target service customers ("John" as a potential service customer) or a service agreement with a specific service customer ("John" as a service customer) regarding the use of the service.

Let us suppose, however, that "John" in the model fragment of Figure 7-B represents a specific service customer. This assumption, according to UFO-S, implies the existence of a service agreement (possibly established with "ArchInsurance" as hired service provider). Now, consider that the fragment of Figure 7-B is augmented, as presented in Figure 8, by adding two new *business actors*: "Mary" (as a new service customer), and "XInsurance" (as a new hired service provider). This new fragment could imply the existence of another service agreement. However, although we could imagine the existence of different service agreements, we cannot assert between which actors the service agreements are established. Indeed, there are at least four possible service agreements between: "John-ArchInsurance", "John-XInsurance", "Mary-ArchInsurance", and "Mary-XInsurance". This analysis points out that ArchiMate lacks a sound way to represent which individuals (as service customers and as hired service providers) are involved in each service agreement ("L4").

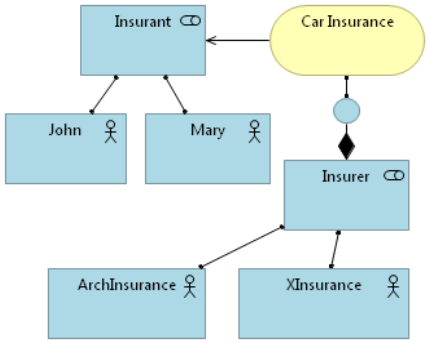

Figure 8. Service agreements.

B. *Product and Contracts*

As a way to capture the content of service-related commitments, ArchiMate proposes the use of contracts, as part of a product. As aforementioned, a *product* is "a coherent collection of *services*, accompanied by a *contract*/set of agreements, which is offered as a whole to (internal or external) customers" [3]. A *contract*, in turn, is "a formal or informal specification of agreement that specifies the rights and obligations associated with a product" [3]. As such, at first glance, these elements seem to be suitable for representing the aspects related to service offerings, and service agreements. However, despite being clearly useful, the use of the elements *contract* and *product* does not address the limitations concerning the representation of service offering types, service offerings and service agreements, as discussed below.

Consider the model fragment of Figure 9. In this fragment, the "Special Car Insurance Product" aggregates two services ("Car Insurance" and "Roadside Assistance"), which are *assigned to* the service provider role ("Insurer"). Also, the product is related to a contract. Even by using the *contract* element, this fragment suffers of similar limitation of the fragment of Figure 5 ("L1"). Thus, it is not possible to assert if the fragment represent service offerings or service offering types. As a consequence, it is not possible to assert what kind of content the "Car Insurance Contract" describes: does this contract describe the terms and conditions of service offering types (i.e., the general terms and conditions independent of a specific service provider, and that will possibly be instantiated in a specific service offering), or does it represent the terms and conditions of specific service offerings (i.e., the terms and conditions associated with a specific service provider, not represented in the fragment)? Thus, ArchiMate does not provide a suitable way to differentiate contracts as service offering type descriptions or as service offering descriptions.

In order to continue our analysis, we consider for the fragment of Figure 9 an interpretation similar to the one of Figure 5, i.e., it is a complete model and represents service offering types. These two service offering types ("Car Insurance" service offering type, and "Road Assistance" service offering type) take part in a *product*. Thus, the contract describes the general terms and conditions independent of a specific service provider.

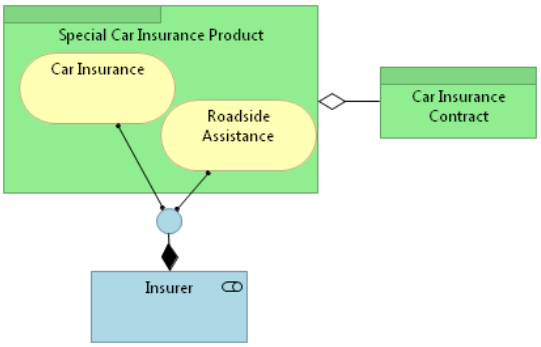

Figure 9. Service offerings and contract.

Consider the model fragment of Figure 10. Analogously to interpretation of Figure 6-B, this model fragment can be analyzed as representing service offerings by two service providers (both "ArchInsurance" and "XInsurance" offer the "Car Insurance" and "Roadside Assistance" services, possibly with different terms and conditions). Moreover, consider that, in this case, the "Car Insurance Contract 1" and the "Car Insurance Contract 2" represent service offering descriptions. By that, it is not possible to assert if the "Car Insurance Contract 1" refers to the offering by "ArchInsurance" or to the offering by "XInsurance". As such, contracts are not suitable to differentiate service offerings. As a consequence, limitation "L2" remains.

Now, consider the model fragment of Figure 11. Let us suppose that this fragment represents agreements between "John", "Mary", "ArchInsurance", and "XInsurance".

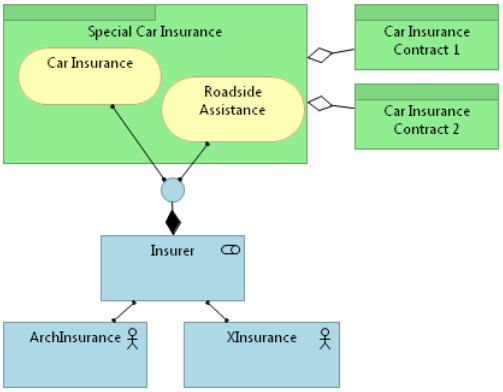

Figure 10. Different service offerings and contracts.

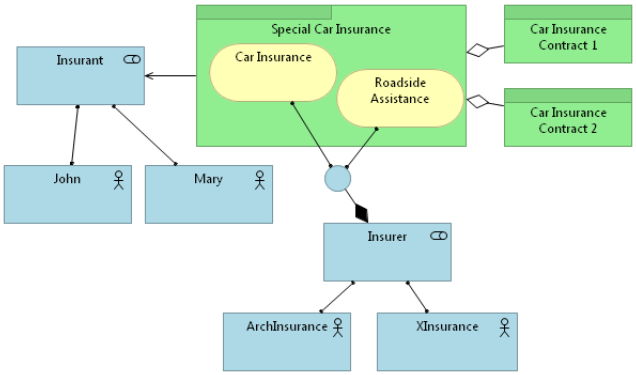

Figure 11. Product agreements and contracts.

In this case, the first question is: do the contracts ("Car Insurance Contract 1" and "Car Insurance Contract 2") represent service offering descriptions, or do they represent service agreement descriptions (i.e., the terms and conditions of an service agreement between service customers and hired service provider, e.g., between "John" and "ArchInsurance")? As a consequence, we cannot address the limitation "L3" by using contracts, and the "*used by*" relationship remains overloaded. Consider, however, that these contracts represent service agreement descriptions. Even when using the *contract* element, we can notice a similar problem to the one related to Figure 8. It is not possible to identify which actors are involved in each service agreement. We cannot know which service agreement is described by each contract. Limitation "L4" remains.

Despite being important elements, *product* and *contract* are not enough for addressing the limitations in representing service offering types, service offerings, and service agreements, as discussed in Section IV-A. In the next section, therefore, we describe some modeling recommendations in the form of modeling patterns for addressing these limitations.

V. MODELING RECOMMENDATIONS

The ontological analysis performed in the previous section points out some limitations of ArchiMate, which are summarized in Table III. These limitations arise from the fact that ArchiMate does not offer a suitable way for representing social aspects inherent to service relations, especially service offerings and service agreements.

TABLE III. SUMMARY OF LIMITATIONS.

Limitations
L1: The language is ambiguous for expressing service offering and service offering type.
L2: Differences between service offerings that instantiate the same service offering type cannot be properly represented.
L3: The "*used by*" relationship is overloaded. Thus, it may be interpreted in two ways: (i) as a service offering towards target service customers, or (ii) as a service agreement with a specific service customer.
L4: The language lacks a sound way to represent which individuals are involved in each service agreement (as service customers and as hired service providers).

In order to address these limitations without changing ArchiMate's metamodel, we propose three modeling patterns. The patterns are based on the existing *service*, *product* and *contract* elements, as well as on the *association* relationship. The *association* relationship is a general purpose relationship, defined as "a relationship between objects that is not covered by another, more specific" one [3]. If the patterns are employed, the models can be unambiguously interpreted.

More specifically, we propose the use of three patterns: service offering type pattern, service offering pattern, and service agreement pattern. Each pattern is composed basically by four groups of elements: (i) *products* and its *services*, (ii) the ones that provide the product/service, (iii) the ones that consume the product/service, and (iv) the respective *contracts*. *Associations* are used for linking *contracts* to the providers and to the customers. Thus, the *contracts* are in the center of each modeling pattern.

For exemplifying the use and the applicability of the patterns towards addressing the limitations, we applied them over the running example model of Figure 2. The resulting model is presented and discussed in three fragments corresponding, respectively, to the application of the service offering type pattern (Figure 12), service offering pattern (Figure 13), and service agreement pattern (Figure 14).

The model fragment of Figure 12 illustrates the use of the service offering type pattern. Similarly to what it is recommended in the other two patterns, the element *product* is used as a way to aggregate the element *contract* (even if only one service has been modeled, we recommend the use of *product* element). By the use of a *contract* ("Insurance General Terms and Conditions") and *associations*, we can link the services being offered, the service customer role ("Insurant"), and the service provider role ("Insurer"). Since this pattern characterizes a service offering type, the *contract* represents a service offering type contract. Thus, besides being related to the services, the contract relates the service provider role to the service customer role. This service offering type may be instantiated in specific service offerings, as presented in Figure 13.

Thus, Figure 13 illustrates the use of the service offering pattern twice: one for "ArchInsurance" and other "XInsurance". In this model, the "Insurant" role remains representing the service customer role. However, the "Insurer" role is instantiated by "ArchInsurance" and

"XInsurance", which are agents playing the role of service providers in the context of the service offerings ("ArchInsurance" service offerings and "XInsurance" service offerings).

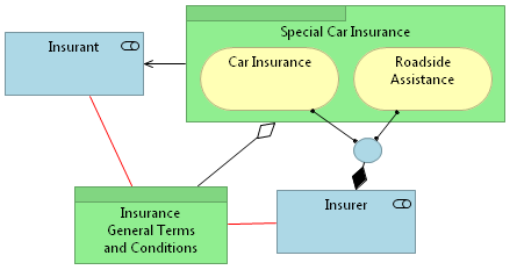

Figure 12. The use of service offering type pattern.

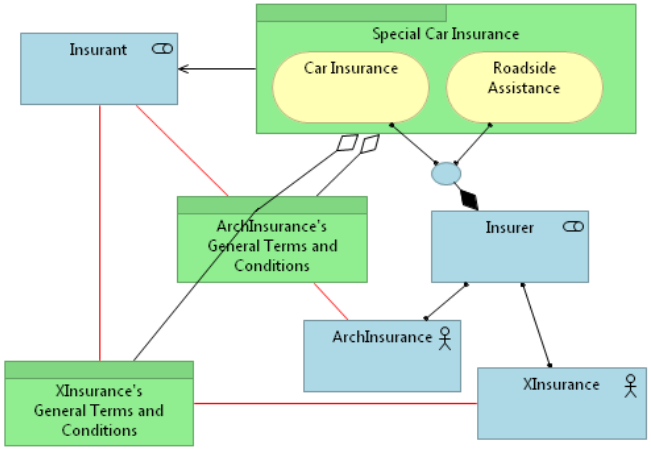

Figure 13. The use of service offering pattern.

These offerings are uniquely described by their respective service offering *contracts*, which are used to link the corresponding elements. For example, "ArchInsurance" as service provider is related to the "Insurant" service customer role by means of "ArchInsurance's General Terms and Conditions". These service offering *contracts* ("ArchInsurance General Terms and Conditions" and "XInsurance General Terms and Conditions") may specify in more details the terms and conditions of the *contract* that describes the service offering type ("Insurance General Terms and Conditions") (Figure 12). Thus, these service offering *contracts* represent commitments that specific agents playing the role of service providers establish towards the target customer. Following the service life-cycle model, these service offerings may result in service agreements between two specific agents, as illustrated in Figure 14.

Figure 14 shows the use of the service agreement pattern. The fragment presents a service agreement between "ArchInsurance" and "John", and other between "XInsurance" and "Mary". Each service agreement is described uniquely by a service agreement *contract*, which describes the commitments and claims established among the service participants as a result of a successful service negotiation. Thus, each service agreement *contract* associates the corresponding *business actors* involved in the agreement. So, the "John-ArchInsurance Contract" relates "John", as service customer, to "ArchInsurance", as hired service provider; and "Mary-XInsurance Contract" relates "Mary", as service customer to "XInsurance", as hired service provider. According to UFO-S, the terms of a service agreement contract should be in conformance to the corresponding service offering contract, as well as, the terms of a service offering contract should be in conformance to the correspondent service offering type contract.

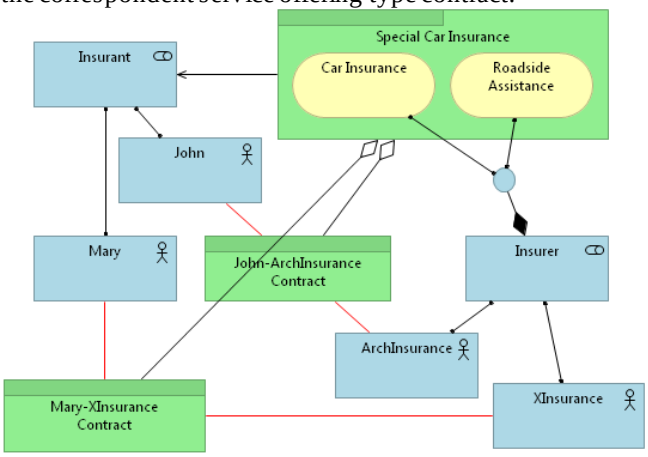

Figure 14. The use of service agreement pattern.

Figure 15 exemplifies the three modeling patterns applied in tandem (should all three aspects of the service lifecycle need to be represented). In this figure, the commitments and claims related to the service offering type, service offering, and service agreement can be clearly identified by means of different *contracts*. Each one of these three service relations can be properly identified through the relationships between the *contracts* (at the center of each pattern) and the related elements (*business roles* and/or *business actors*). The relations between service offering type, service offering, and service agreements can be represented by association links between them (with the <<conformance>> stereotype).

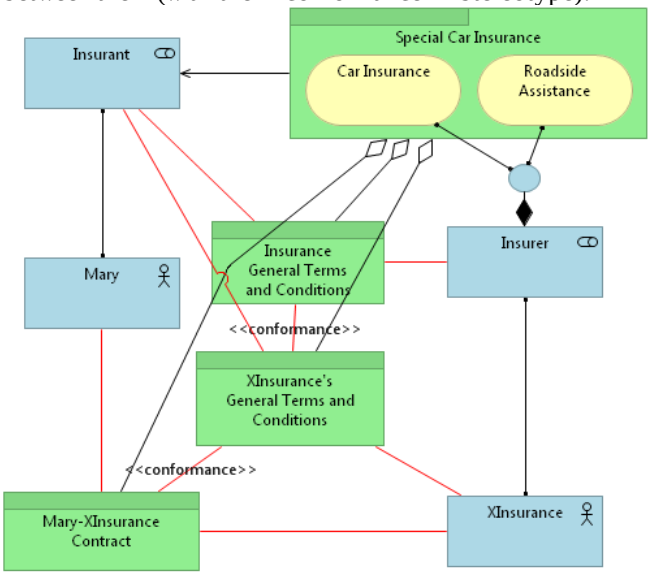

Figure 15. The use of the three modeling patterns in tandem.

VI. Related Work

As pointed out by Umapathy and Purao [15], in latest years, theoretical foundations have been applied in Service Computing as a means to provide adequate guidance and certain level of rigor in solution of practical problems. In this work, therefore, we have applied UFO-S as a kind of theory for supporting the semantic analysis of ArchiMate with emphasis on the notion of service commitments/claims. The notion of commitments/claims has been adopted in works of Service Science and Service Computing for characterizing the concept of service. Moreover, the benefits of this notion has been discussed in IT and Business scenarios [5]. As discussed in [5], by characterizing the notion of service by means of commitments and claims, it is possible to harmonize other service perspectives (e.g., "service as interaction", and "service as capability"). Thus, it is possible to contribute for addressing service semantic interoperability.

In the case of business process and business rule modeling, Letsholo et al. [16] have evaluated modeling capabilities of process modeling techniques and propose a modeling integration framework for addressing the identified issues. Despite performing a modeling capability analysis, their work does not conduct an ontological analysis, since Letsholo et al. use the Zachman Framework as a reference model. On the other hand, in [17] and [18], Prezel et al. and Recker et al., respectively, performed ontological analysis of BPMN. They investigate the capabilities and deficiencies of BPMN and emphasize how existing deficiencies impact modeling practice. Although not directly related to service modeling, these works show the importance of ontological analysis for enterprise modeling languages.

Despite not focusing on service modeling, some other efforts have performed detailed ontological analysis of ArchiMate's fragments. In [14], Almeida and Guizzardi have performed a semantic analysis of the concept of "role" in a number of enterprise modeling languages, including ArchiMate. In [19], the concepts of "capability" and "resource" in ArchiMate are also ontologically analyzed. In [11], the ArchiMate Motivation Extension was semantically analyzed, which involves concepts such as goals, stakeholder, requirements, etc. These three works use UFO as a common reference ontology, which indicates that the interpretations provided for the various ArchiMate constructs can be harmonized in order to provide a comprehensive well-founded enterprise modeling approach.

VII. Final Considerations

This work presented a semantic analysis of service modeling fragments in ArchiMate taking as basis UFO-S [5], a reference ontology that is based on the notion of social commitments/claims for characterizing service relations. We have focused especially on model fragments representing service offerings (and types thereof), and service agreements. By this, we aim to clarify the semantics of service modeling in ArchiMate in such a way that this models are understandable and faithful to the phenomena they represent.

In fact, as discussed in [5], service phenomena are complex, and "service" terminology is laden with different meanings. This is clear when we see that the same "service" construct can lead to different interpretations (such as, service offering type, service offering and service agreement). The ambiguity and expressiveness limitations we revealed are significant since we have shown that the same model fragment may be interpreted in various ways (as a type of service offering, a service offering, a service agreement) by different modelers. Consequently, the ambiguity obscures service lifecycle aspects that have different implications in practice (e.g., service agreement has different implications from service offering as specific service customers are involved in a service agreement). Hence, ambiguity creates an immediate expressiveness problem and modelers are not able to represent more than one situation (e.g., service offering or service agreement) in the same model. Further, modelers may believe the language is serving its purpose (defining conventions for effective communication) while this is not the case (resulting in what is called "false agreement" [8][20], a miscommunication problem that is hard to detect). So, we believe the recommendations we propose should increase the value of the language as a means of communication.

The identified limitations have led us to formulate modeling recommendations in the form of modeling patterns. The patterns can be used for clarifying the semantics of model fragments and providing ways of representing service offering type, service offering and service agreement aspects, which are the basis of the dynamics of service relations. These patterns were defined with the "contract" element as the basic structuring element, which is linked to the other elements mainly by using ArchiMate "association" relations. This is a conservative or lightweight approach to addressing the language's shortcomings. A benefit of this is that no modification of ArchiMate's metamodel is required, and that modelers can adopt the proposed patterns obtaining benefits of expressiveness and clarity directly. Alternatively, we could have opted for specialized constructs to represent the various aspects of the dynamics of service relations. This alternative could benefit from the fact that specialized constructs are often more syntactically salient; further, it could avoid the liberal use of the unconstrained "association" relations of ArchiMate. However, since we consider that ArchiMate has a large user base and consolidated tools, and a heavyweight extension would impose a heavy toll, we have favored the prospects of (i) better user acceptance, (ii) lower barrier for incorporation in ArchiMate, and (iii) tool reuse, and hence we have explored the opportunity of a lightweight extension based on patterns. The patterns proposed here could be reflected in an appendix of the technical specification.

As future work, we intend to address other aspects of service modeling at the Business layer that were not addressed here, such as, e.g., the influence of behavioral elements (business process, and business interactions between service participants during service delivery). Further, we intend to analyze inter-layer service modeling aspects (when business elements are supported by application services, and ultimately by infrastructural services). Some initial results regarding inter-layer service

modeling aspects have been reported in [21] by applying the service commitments/claims notion to other layers of service-oriented enterprise architectures. Extending the modeling patterns to represent service commitments/claims also at the application and infrastructure layers is a topic for further investigation.

Finally, it is important to point out that, although there is significant empirical evidence that ontological deficiencies affect the usefulness and ease of use of conceptual modeling languages [22], we intend to conduct experiments (empirical studies) to gather explicit evidence for the suitability and usability of the proposed patterns.

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