UNIVERSIDADE FEDERAL DO ESPÍRITO SANTO

DEPARTAMENTO DE INFORMÁTICA

DOUTORADO EM CIÊNCIA DA COMPUTAÇÃO

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A COMMITMENT-BASED REFERENCE ONTOLOGY FOR SERVICE: HARMONIZING SERVICE PERSPECTIVES

DOCTORAL THESIS

VITÓRIA-ES, BRAZIL
DECEMBER 2014

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Tese de doutorado apresentada ao Programa de Pós-Graduação em Informática da Universidade Federal do Espírito Santo como requisito parcial para obtenção do grau de Doutor em Ciência da Computação, sob orientação do Prof. Dr. Ricardo de Almeida Falbo e co-orientação do Prof. Dr. João Paulo A. Almeida.

VITÓRIA-ES, BRASIL
DEZEMBRO, 2014

Dados Internacionais de Catalogação-na-publicação (CIP)
(Biblioteca Setorial Tecnológica,
Universidade Federal do Espírito Santo, ES, Brasil)

Nardi, Julio Cesar, 1980-
N223c A commitment-based reference ontology for service : harmonizing service perspectives / Julio Cesar Nardi. – 2014.
243 f. : il.

Orientador: Ricardo de Almeida Falbo.
Coorientador: João Paulo Andrade Almeida.
Tese (Doutorado em Ciência da Computação) – Universidade Federal do Espírito Santo, Centro Tecnológico.

1. Ontologia. 2. Arquitetura orientada a serviços (Computação). 3. Ciência de serviço. 4. Linguagem de modelagem de serviço. I. Falbo, Ricardo de Almeida. II. Almeida, João Paulo Andrade. III. Universidade Federal do Espírito Santo. Centro Tecnológico. IV. Título.

CDU: 004

A Commitment-Based Reference Ontology for Service: Harmonizing Service Perspectives

Julio Cesar Nardi

Tese submetida ao Programa de Pós-Graduação em Informática da Universidade Federal do Espírito Santo como requisito parcial para a obtenção do grau de Doutor em Ciência da Computação.

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Vitória-ES, 10 de dezembro de 2014

Dedication

To Felipe and Milena.

Agradecimentos

(*Acknowledgments*)

In Portuguese...

Penso que agradecer é uma tarefa ingrata tanto para quem agradece quanto para quem recebe os agradecimentos. É ingrata, pois quase sempre quem agradece não consegue expressar toda a sua gratidão e, por conseguinte, quem recebe os agradecimentos não os recebe no grau merecido. Entretanto, mesmo sendo ingrata tarefa, é também prazerosa e nos torna plenos, principalmente quem agradece...
Eu gostaria de agradecer a muitas pessoas que de uma forma ou de outra estiveram comigo ao longo desses quatro anos de doutorado e que contribuíram para o desenvolvimento deste trabalho. Primeiramente, agradeço ao Instituto Federal do Espírito Sando (Ifes), em especial aos meus colegas da Coordenadoria de Informática do Campus Colatina, por ter permitido que eu me afastasse das minhas atividades do Campus para me dedicar, exclusivamente, ao doutorado. Agradeço ainda às agências de fomento Capes, CNPq e Fapes pelo apoio financeiro dado a esta pesquisa. Agradeço aos meus colegas do Nemo - Ufes (Núcleo de Estudos em Modelagem Conceitual e Ontologias), com os quais tive momentos muito produtivos e também muito divertidos. Tais momentos, com certeza, tornaram mais suave a caminhada do doutoramento. Agradeço ainda aos professores membros Nemo, com os quais pude aprender e colaborar. Agradeço aos membros da banca de defesa deste trabalho pela disponibilidade e pelas importantes contribuições. Faço um agradecimento especial aos meus orientadores, os professores Ricardo de Almeida Falbo e João Paulo A. Almeida. A eles tenho muito a agradecer pela disponibilidade, pelos ensinamentos, pelas oportunidades que me proporcionaram e pela amizade. Agradeço ainda aos professores Giancarlo Guizzardi, Luís Ferreira Pires, Marten van Sinderen e Nicola Guarino, com os quais tive o prazer de trabalhar e que contribuiram muito para o desenvolvimento desta tese (*I would like to thank you all!*). Agradeço aos meus familiares (destaco aqui meus pais Paulo e Penha), amigos e colegas pelo apoio. Em especial, agradeço à Milena, minha esposa, pela paciência, companheirismo, carinho, e incentivo. Ao Felipe, agradeço pela experiência de ser pai e por tudo o que isso traz consigo... Finalmente, agradeço a Deus por trilhar comigo meus caminhos e por continuar a colocar perguntas onde tenho respostas e respostas onde tenho dúvidas...

Abstract

Nowadays, the notion of service has been widely adopted in the practice of economic sectors (e.g., Service, Manufacturing, and Extractive sectors), as well as, in the research focus of various disciplines (e.g., Marketing, Business, and Computer Science). Due to that, a number of research initiatives (e.g., service ontologies, conceptual models, and theories) have tried to understand and characterize the complex notion of service. However, due to particular views of these disciplines and economic sectors, a number of different characterizations of service (e.g., "service as interaction", "service as value co-creation", and "service as capability / manifestation of competence", among others) have been proposed. The existence of these various non-harmonized characterizations, and the focus on a terminological debate about the "service" concept, instead of about the service phenomena from a broad perspective, make the establishment of a unified body of knowledge for service difficult. This limitation impacts, e.g., the establishment of unified conceptualization for supporting the smooth alignment between Business and IT views in service-oriented enterprise architecture (SoEA), and the design and usage of service modeling languages. In this thesis we define a theoretical foundation for service based on the notion of service commitment and claims as basic elements in the characterization of service relations along service life cycle phases (service offer, service negotiation, and service delivery). As discussed in this work, this theoretical foundation is capable of harmonizing a number of service perspectives found in the literature. Such theoretical foundation is specified in a well-founded core reference ontology, named UFO-S, which was designed by adopting a sound ontological engineering apparatus (mainly, a well-founded ontology representation language, OntoUML, and approaches of model verification and model validation). As a kind of "theory", UFO-S was applied in the analysis of SoEA structuring principles in order to define a "commitment-based SoEA view", which remarks social aspects inherent in service relations usually underexplored in widely adopted service-oriented approaches (such as SOA-RM by OASIS, ITIL, and ArchiMate). Based on this, UFO-S was also applied in an ontological analysis of service modeling at ArchiMate's Business layer. Such ontological analysis showed some limitations concerned to semantic ambiguity and lack of expressiveness for representing service offerings (and type thereof) and service agreements in SoEA. In order to address these limitations, three service modeling patterns (service offering type pattern, service offering pattern, and service agreement pattern) were proposed taking as basis UFO-S. The usefulness of these patterns for addressing these limitations was evidentiated by means of an empirical evaluation. Finally, we can say that, beyond offering a broad and well-founded theoretical foundation for service able to harmonize service perspectives, UFO-S presented benefits as a reference model in the analysis of SoEA structuring principles, and in the (re)design of service modeling languages.

Keywords: core reference ontology for service; service science; service commitment; service-oriented enterprise architecture; service modeling language; and ArchiMate.

Resumo

A noção de “serviço” tem sido amplamente adotada tanto na prática de setores econômicos (p. ex., Serviço, Manufactura e Extrativismo) quanto nos estudos de disciplinas acadêmicas (p. ex., Marketing, Negócios e Ciência da Computação). Nesse contexto, iniciativas de pesquisa (p. ex., desenvolvimento de ontologias de serviço, modelos conceituais e teorias) têm buscado entender e caracterizar a complexa noção de serviço. Devido a visões particulares dessas várias disciplinas e setores econômicos, diferentes caracterizações (“serviço como interação”, “serviço como co-criação de valor” e “serviço como capacidade / manifestação de competência”, dentre outras) têm sido propostas. Entretanto, a existência não-harmonizada dessas caracterizações e o foco num debate terminológico acerca do conceito de “serviço” (em detrimento de uma visão mais ampla do fenômeno de serviço) tornam difícil o estabelecimento de um corpo de conhecimento abrangente e unificado. Essa limitação impacta, p. ex., no estabelecimento de uma conceituação sobre serviço que possa estabelecer um alinhamento mais adequado entre as visões de Negócio e Tecnologia da Informação em Arquiteturas Organizacionais Orientadas a Serviço (AOOS), e o projeto e uso de linguagens de modelagem de serviços. Nesta tese, é definida uma fundamentação teórica para serviços baseada na noção de compromentimentos e reivindicações como elementos básicos na caracterização das relações de serviço. Tal fundamentação teórica é capaz de harmonizar várias perspectivas de serviço encontradas da literatura. Ademais, essa fundamentação é especificada em uma ontologia de referência bem-fundamentada, chamada UFO-S, a qual foi desenvolvida com a adoção de um aparato consistente de Engenharia de Ontologias (uma linguagem bem-fundamentada para representação de ontologias – OntoUML - e abordagens de verificação e validação de modelos). Como um tipo de teoria, UFO-S foi aplicada na análise de princípios de estruturação de AOOSs a fim de definir uma visão de arquitetural baseada em compromentimentos de serviço. Tal visão destaca os aspectos sociais inerentes às relações de serviço. Tais aspectos são, usualmente, negligenciados pelas abordagens atualmente adotadas (tais como, o modelo de referência de Arquiteturas Orientadas a Serviço proposto por OASIS, ITIL, e a linguagem ArchiMate). UFO-S foi também adotada em uma análise ontológica de ArchiMate com foco na modelagem de serviços na Camada de Negócio. Tal análise evidenciou limitações na linguagem no que tange a ambiguidade semântica e falta de expressividade para representar ofertas de serviço (e os tipos dessas ofertas) e acordos de serviço em AOOSs. A fim de abordar essas limitações, três padrões de modelagem de serviço (modelagem de tipo de oferta de serviço, modelagem de oferta de serviço e modelagem de acordo de serviço) foram propostos. A adoção desses padrões mostrou-se positiva quando avaliada por meio de um estudo empírico. Por fim, pode-se dizer que, além de oferecer uma fundamentação teórica capaz de harmonizar várias perspectivas de serviço, UFO-S, como um modelo de referência, mostrou-se útil na análise/estruturação de AOOSs e no projeto de linguagens de modelagem de serviço (tal como ArchiMate).

Palavras-chave: ontologia de referência para serviços; ciência de serviço; comprometimento de serviço; arquitetura organizacional orientada a serviço; linguagem de modelagem de service; ArchiMate.

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Chapter 1. Introduction

This chapter presents an overview of this thesis as well as defines the basis for the subsequent chapters. It discusses the context in which the thesis is embedded, the motivation for conducting this piece of work, the research hypothesis, the objectives, and the methodological aspects that have guided this research work. Finally, the structure of this document is presented.

1.1 Context

Currently, the notion of service has been widely adopted, as can be noticed in the practice of economic sectors (e.g., Service, Manufacturing, and Extractive), as well as in the research focus of various disciplines (such as, Economics, Marketing, Business, and Computer Science) (SPOHRER; MAGLIO, 2010) (SPOHRER, 2010) (STAUSS, 2010).

In Economics and Marketing, the notion of service has been adopted mainly due to the growth of *service economy* in the past fifty years (SPOHRER, 2010). The *service sector* - or tertiary sector - (involving government, healthcare, education, retail, finance, business, communications, transportation, etc.) is the largest economic sector in developed countries, being responsible for over 70 to 80% of Gross Domestic Product (GDP) and employment (TIEN; BERG, 2006) (ENGELMANN, 2010). A similar trend can be observed in emerging markets (MAGLIO et al., 2009). This context has led enterprises (companies, government agencies, etc.) towards adapting themselves to new service-based business models, besides the traditional production-based ones (LANKHORST et al., 2012).

By encompassing Business and Computer Science, the notion of service has been adopted by the enterprises as a way to define and describe *Service-oriented Enterprise Architectures* (SoEA) aiming at aligning Business and Information Technology (IT) by means of services. In this setting, IT architectures are used to complement business architectures by providing computational services (e.g., back-end services, telecommunication services, and web services) in order to support business services (CASES; BODNER; MUTNURY, 2010). This movement has been mainly influenced by the *service-orientation paradigm*, which has often been considered the most important architectural paradigm that has emerged in the last few years (LANKHORST, 2005). In this context, the *service-oriented architecture* (SOA) arises as an important

architectural style that offers principles for organizing the enterprise IT assets in a set of computational services for supporting Business (GROUP, 2009).

The notion of service has also had a wide impact in software integration, mainly due to use of *web services* technology, which has been adopted as one of the most important technologies for software application integration, being also a basic building block in most service-oriented architecture approaches (FISCHER; WERNER, 2010). This is particularly important as the current globalized economy has forced enterprises to go beyond their boundaries and interoperate for achieving their business objectives (CHARALABIDIS et al., 2006) (KUTVONEN, 2013). To do so, integration of software applications is crucial to provide competitive value, by improving customer relationship (*business-to-consumer*) or inter-enterprise arrangements (*business-to-business*), streamlining internal processes, and reducing time to market (RUH; MAGINNIS; BROWN, 2001).

Due to its wide applicability, the interest in the notion of service has grown in academy, becoming the focus of various disciplines, which have as basic objectives understanding the notion of service and applying this understanding in practice (SPOHRER, 2010) (STAUSS, 2010).

However, each of these disciplines presents, due to particular aspects, a different characterization of the notion of service (SPOHRER; MAGLIO, 2010), which makes difficult the establishment of a unified service body of knowledge (even if the characterizations are related at some level). In this context, an important initiative of the *service community* (which involves members of industry and academy) concerns the creation of a new discipline, so-called *Service Science*, which acts as a point of convergence among other disciplines for sharing theory and practice around the notion of service.

Service Science has as one of its goals to harmonize the various notions of service, leading to some degree of unification, in order to contribute for theoretical and practical aspects associated with service phenomena (IFM; IBM, 2007) (SAMPSON, 2010a). Such discipline is based on three basic pillars (STAUSS et al., 2010): (i) transdisciplinarity (by addressing service problems through integration of various disciplines); (ii) collaboration between scientific and corporate world (by being also

viewed as an applied science capable of supporting solving practical problems); and (iii) qualification for academic service jobs (contributing for academic qualifications).

In summary, the context in which this thesis was developed is mainly characterized by: (i) the wide adoption of the notion of service in different academic disciplines and application sectors; (ii) a high degree of interdisciplinarity inherent to the notion of service; (iii) the necessity for establishing a unified view of the notion of service; and (iv) the necessity of establishing symbiotic relations between the theoretical basis and the solution of practical problems.

1.2 Motivation

By being widely adopted in various contexts (e.g., in economic sectors, in the definition and representation of enterprise architectures, and in software application development and integration), the notion of service has various characterizations. These characterizations are influenced by many aspects, such as the point of view and the level of maturity of the research areas (e.g., Economics, and Computer Science), and the practical problems faced by their respective target application areas (e.g., Manufacturing, Enterprise Architecture, and Enterprise Application Integration). The list of service characterizations include: "*service as interaction"* (QUARTEL et al., 2007), "*service as value co-creation"* (VARGO; LUSCH, 2004) (MAGLIO et al., 2009) (MAGLIO; SPOHRER, 2008), "*service as capability"* (OASIS, 2006) (RUOKOLAINEN, 2013), "*service as application of competences"* (VARGO; LUSCH, 2004), "*service as (production) process"* (SAMPSON; FROEHLE, 2006) (SAMPSON, 2010a), "*service as commitment"* (FERRARIO; GUARINO, 2012), and "*service as software"* (W3C, 2004a).

Given the variety of characterizations, some efforts have attempted to define foundations for general "theories" of service, such as: the "Unified Theory of Services" (SAMPSON; FROEHLE, 2006) (SAMPSON, 2010a), the "Service-Dominant Logic" (VARGO; LUSCH, 2004) (STEPHEN L. VARGO; AKAKA, 2009), and the ontological foundations for services discussed in (FERRARIO; GUARINO, 2008) (FERRARIO; GUARINO, 2012). These theories present important aspects inherent to the service phenomena, but they are not discussed in an integrated/harmonized way.

Moreover, several conceptual models and ontologies of service have been proposed, including: OWL-S (W3C, 2004b), WSMO (W3C, 2006), The SOA Ontology by

The Open Group (THE OPEN GROUP, 2009), The Reference Ontology for Semantic SOA (OASIS, 2008), Healthcare SOA Ontology (MILOSEVIC et al., 2013), The Service Ontology (OBERLE et al., 2009), Goal-Based Service Ontology (GSO) (SANTOS, 2011), The Onto-ServSys (MORA et al., 2011), and the model of services of Bergholtz and colleagues (ANDERSON; BERGHOLTZ; JOHANNESSON, 2012). However, their focus is on particular applications and/or perspectives, none of them serving as a reference ontology capable of harmonizing the various service perspectives.

The lack of consensus or, at least, the lack of harmonization among the various notions of service makes it difficult to (i) establish *effective communication* (and *common understanding*) between the different profiles of practitioners (e.g., customers, business analysts, managers, enterprise architects, and developers) involved in the service phenomena, and (ii) develop a new science of services around which the many researches about "service" can be related (ALTER, 2008).

These limitations, especially those related to communication aspects, impact the practice of target application areas, such as Enterprise Architecture. The literature in this application area remarks the lack of a unified conceptualization for supporting the smooth alignment between Business and IT (CHEN; DOUMEINGTS; VERNADAT, 2008). Enterprise architectures, as blueprints, aim to enable enterprise members to understand the detailed structure and components of the enterprise and how they work together (KANG et al., 2010). The lack of a clear semantics in the definition of enterprise architectures may cause communication problems between humans, between systems, and between humans and systems (KANG et al., 2010). This can also hinder the definition/use of enterprise modeling languages that aim to harmonize different points of view (e.g., customers, business analysts, and IT team) in Business and IT views (CHEN; DOUMEINGTS; VERNADAT, 2008) (LANKHORST, 2005).

These limitations are too evident in the context of service-oriented enterprise architectures, in which the notion of service goes through the various enterprise architecture layers (from Business to IT infrastructure). Terlouw and Albani discuss in (TERLOUW, 2008) and (TERLOUW; ALBANI, 2013) difficulties in tasks of service specification due to the fact that the current approaches are too focused on technological aspects. According to them, this compromises the alignment between Business and IT by not "speaking the same language". In (CHERBAKOV et al., 2005), the

authors highlight the necessity of defining Business structures in such way to have a familiar representation to IT professionals.

In a typical SoEA, the concept of "service" is considered a link between different enterprise architecture layers, with "higher" layers accessing the resources of the "lower" ones by means of services (LANKHORST, 2005). This structuring principle can be noticed in widely adopted service-oriented approaches, such as the Reference Model for SOA (SOA-RM) by OASIS (OASIS, 2006), ITIL (ITSMF, 2007), and ArchiMate (THE OPEN GROUP, 2012). These approaches present particular characterizations of service (respectively, "service as capability" (GROUP, 2009), "service as mechanism to delivery value" (ITSMF, 2007), and "service as functionality" (THE OPEN GROUP, 2012)), which are mainly based on application of enterprise resources/capabilities.

Despite offering an important view about the service provision in SoEA, by being too focused on application of resources/capabilities, such approaches neglect important social aspects inherent to service relations (e.g., the commitments established between Business and IT practitioners towards guaranteeing, in certain level, the application of the resources/capabilities during the service delivery).

Especially in the case of SoEA modeling languages, the lack of a well-defined semantics regarding the notion of service in different enterprise layers (from Business to IT), and a good coverage about service relations along service life cycle compromises the task of SoEA representation. This is the particular case of ArchiMate (THE OPEN GROUP, 2012), which, despite being one of the most prominent and widely adopted service-oriented modeling languages, presents problems. ArchiMate has a number of limitations for differentiating, e.g., service offerings and service agreements between service providers and service customers (NARDI; FALBO; ALMEIDA, 2014).

In summary, the existing ontologies, conceptual models, and theories for service present particular (and non-harmonized) characterizations of service. Moreover, in practice, a number of problems, such as limitations in SoEA modeling languages in representing the service phenomena, are impacted due to the lack of a unified, broad, and well-founded notion of service around Business and IT views.

1.3 Hypothesis Construction

According to (FISK; GROVE, 2010), "relationships are at the heart of service". Indeed, in the literature, we can find a number of works in different disciplines that characterize the notion of services by using social concepts, such as commitments/responsibilities/obligations, claims/rights, agreements, dependence, delegation, proposition of value, and trust, among others (e.g., (MAGLIO et al., 2009), (ALTER, 2008), (TERLOUW; ALBANI, 2013), (SINGH; CHOPRA; DESAI, 2009), (ANDERSON; BERGHOLTZ; JOHANNESSON, 2012), (SICILIA; MORA, 2010), and (FERRARIO; GUARINO, 2012)). Even technological disciplines, such as Computer Science, have left behind a purely computational perspective about services, and have considered an interdisciplinary perspective that takes human/social aspects related to service relations into account (FISK; GROVE, 2010).

Among these various social aspects, the notion of commitment (or similar notions of "promise" and "obligation") plays an important role in characterizing "service", being explicitly mentioned in a number of works, such as (ALTER, 2008), (FERRARIO; GUARINO, 2012), (MINGMING; YOUBEI, 2010), (SANTOS et al., 2009), (O'SULLIVAN, 2006), (SICILIA; MORA, 2010), and (DUMAS et al., 2001).

In practice, the benefits of a service characterization based on commitments have been discussed from the Business (MINGMING; YOUBEI, 2010) and IT points of view (SINGH; CHOPRA; DESAI, 2009). Service commitments are useful to deal with service intangibility (by offering means to discuss service aspects in more customer/business-oriented terms) (MINGMING; YOUBEI, 2010), and as a means for raising the low-level of abstraction of existing service-oriented architectures, allowing to reduce the gap between the Business and the IT (SINGH; CHOPRA; DESAI, 2009).

Also, some service *business models*[1] cannot be suitably understood without the notion of commitments. In (FERRARIO; GUARINO, 2012), a car insurance service example is used to exemplify the case in which the customer pays for having someone (the insurer) committed to intervene in case of any accident. However, the customer hopes that the actions of the service delivery (e.g., car towing) are never to be

[1] Business model: "*a design for the successful operation of a business, identifying revenue sources, customer bases, products, and details of financing*" (OXFORD DICTIONATIES.COM, 2014).

performed. In this case, the car insurance service is fundamentally characterized by the existence of commitments even when no action is executed.

Finally, the notion of commitments, as an important aspect in characterization of service relations, cannot be taken in isolation, otherwise it would offer only a partial perspective of the service notion. It is necessary, therefore, to articulate the notion of commitments with other social/business-related concepts. Thus, concepts such as dependence, behavior, delegation, and capabilities, among others, must also be considered towards establishing a broad commitment-based foundation for service.

1.4 Research Hypothesis

Considering that, as mentioned in previous sections:

- The existing ontologies, conceptual models, and theories for service present particular (non-harmonized) characterizations of service;
- The lack of a unified view of service brings limitations to the practice of target application areas, such as the design and usage of SoEA modeling languages;
- The notion of commitments is an important aspect inherent to service relations that can be linked with other aspects in service relations (e.g., dependence, value, interactions, delegations, and capabilities);
- The notion of commitments can be applied as a way of raising the low level of abstraction of existing service-oriented architectures, allowing reducing the gap between the Business and the IT levels.

The research hypothesis of this thesis is:

A theoretical foundation for service based on the notion of service commitments (and related aspects) is capable of: (i) harmonizing different perspectives of service found in the literature, and, as a result, (ii) contributing to the improvement of SoEA modeling languages (increasing expressiveness and minimizing ambiguity) regarding representation of service relations, insofar it offers means to establish a commitment-based unified notion of service around Business and IT views.

1.5 Research Objectives

This thesis is based on two pillars of Service Science: theory and practice. Its general objective (GO) is *to define a theoretical foundation for service capable of harmonizing different perspectives of service (including that of service as commitment), and contributing to SoEA modeling by offering a unified and well-defined notion of service applicable to Business and IT views*.

From this general objective, some specific objectives (SO) are defined:

SO1. *Represent the proposed theoretical foundation in a well-founded core reference ontology of service*.

SO2. *Harmonize, by using the proposed theoretical foundation, different service perspectives found in literature*.

SO3. Apply the theoretical foundation in practice in order to:

(i) *Reveal, in light of service commitments, service relations aspects usually neglected in the current (capability-based) SoEAs*.

(ii) *Improve the semantics (increasing expressiveness and minimizing ambiguity) of a SoEA modeling language (ArchiMate) for better representing service relations along the service life cycle*.

1.6 Methodological Aspects

The necessity of improving the theoretical foundations around the notion of service, as well as of using these foundations towards solving practical problems in target application areas, characterizes the context of this research. This context is taken as basis for defining the methodological aspects.

According to (HEVNER et al., 2004), much of research conducted in Information System (IS) discipline is characterized by two paradigms: (i) behavioral-science paradigm; and (ii) design-science paradigm. The *behavioral-science paradigm* focuses on developing and justifying theories that explain and/or predict organizational and human phenomena. The *design-science paradigm*, in turn, focuses on creating new and innovative artifacts for addressing practical problems. These two paradigms are complementary in the sense that, whereas behavioral-science research provides theoretical foundation ("truth") for design-science research, the latter provides

feedback of artifact “utility” for improving/developing theories (HEVNER; CHATTERJEE, 2010).

By analyzing our research objectives in light of these two research paradigms, we can notice some correspondences. Our objective in defining a theoretical foundation for service is, at some level, related to behavior-science initiatives insofar we aim to develop and justify a kind of “theory”. On the other hand, the use of this theoretical foundation for solving service-related practical problems can be also characterized as a kind of design-science research effort. Thus, in this thesis, we adopt a research strategy inspired in the articulation between “theory and practice” as way of achieving our objectives. Figure 1 illustrates this strategy.

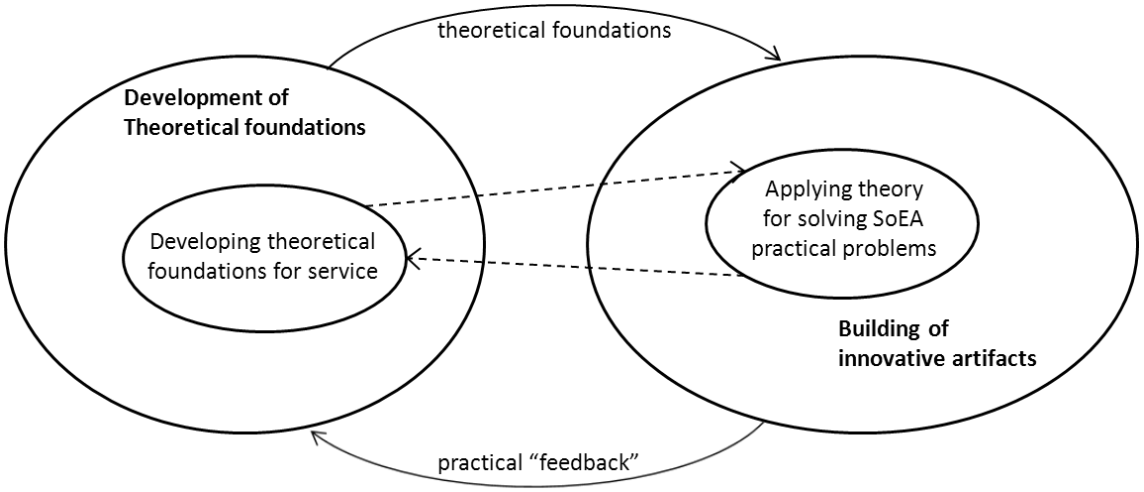


Figure 1 - The adopted research strategy (inspired in (HEVNER; CHATTERJEE, 2010)).

Along the research process towards developing the theoretical foundation for service and specifying it in an ontology, we accounted for three research elements (based on (HEVNER et al., 2004) (HEVNER; CHATTERJEE, 2010)): rigor, relevance, and design. *Rigor* is associated with the use of a reliable body of knowledge (e.g., theories, methods, models, experiences, and expertise) in the research effort. *Relevance*, in turn, is mainly related to (i) research motivation, which arises from business needs and/or possible improvement opportunities in current theories, as well as (ii) “good” articulation between the proposed solution and the motivation as a way to reinforce the contributions. Finally, *design* concerns the core activities of the research process towards achieving the research objectives and supporting the research hypothesis. As such, design takes into account relevance and rigor aspects.

1.6.1 Rigor

For guaranteeing a certain level of rigor to the theoretical foundation, we considered two strategies: (i) specifying the theoretical foundation in a core reference service ontology (designed by means of sound ontology engineering techniques), and (ii) grounding the service ontology in a foundational ontology, which offers consistent ontological distinctions and expressiveness to account for social phenomena.

The foundational ontology adopted in this research is the Unified Foundational Ontology (UFO) (GUIZZARDI, 2005a) (GUIZZARDI; FALBO; GUIZZARDI, 2008). This foundational ontology is used for supporting the development of the theoretical foundation and, as a consequence, grounding the service ontology. Differently from other foundational ontologies (such as DOLCE (MASOLO et al., 2003) or GOL/GFO (General Formalized Ontology) (HELLER; HERRE, 2004)), UFO was constructed with the primary goal of developing foundations for conceptual modeling. As a consequence, there are many aspects that are essential for designing the service ontology proposed in this thesis, but which have not received a sufficiently detailed attention in DOLCE and GOL/GFO. In this context, we remark the notion of "relator", which is crucial for characterizing the notion of service commitment, and, in general, the various relations between service participants (service providers and service customers). Moreover, UFO offers support for addressing social aspects (e.g., social commitments/claims, delegation, dependence, and agents), which are essential for characterizing the dynamics of service relations. Besides of the aforementioned characteristics of UFO, our choice of using UFO also relies on the fact that this foundational ontology has been successfully applied in previous works to evaluate, redesign, and ground ontologies, models, and frameworks of several research application areas, such as Software Engineering (GUIZZARDI; FALBO; GUIZZARDI, 2008) (BRINGUENTE; FALBO; GUIZZARDI, 2011), Enterprise Modeling (ALMEIDA; GUIZZARDI; SANTOS JR., 2009) (AZEVEDO et al., 2011) (SANTOS JR.; ALMEIDA; GUIZZARDI, 2012) (ALMEIDA; GUIZZARDI, 2012), and Business Process Modeling (FRANÇA et al., 2014).

The representation/specification of the theoretical foundation in a service ontology is achieved by using a sound ontological engineering apparatus that encompasses the use of a well-defined ontology modeling language - OntoUML

(GUIZZARDI, 2005a) - and an environment for building ontologies – OLED[2]. Whereas *OntoUML* is a UML profile that incorporates some of the foundational distinctions of UFO, *OLED* is an OntoUML editor that provides means for model verification (BENEVIDES; GUIZZARDI, 2009) and model validation via visual simulation (BENEVIDES et al., 2011), as well as model transformation into machine readable languages such as OWL (Web Ontology Language) (ZAMBORLINI; GUIZZARDI, 2010). Thus, besides the benefits that come from the explicit adoption of a foundational ontology, the choice of OntoUML was further motivated by the availability of a well-maintained tool with a substantial ontology engineering support.

In order to ensure (some) "precision" (BORGO et al., 2002) in the service ontology and thus avoid unintended model instantiations, the ontology engineering approach we employ includes the use of axioms in first-order logic to reflect important ontology constraints. The resulting axiomatization is assessed in an iterative model simulation approach (BENEVIDES et al., 2011), which consists, basically, in transforming OntoUML models (and OCL constraints) into Alloy specifications[3], by means of OLED, and generating conforming instantiations of the model automatically. Such automatically generated model instantiations are then examined manually, to decide whether they were in *conformance* with our conceptualization. If not, either the OntoUML model or the OCL constraints are changed. *Consistence* of the axiomatization and OntoUML models is guaranteed by checking the satisfiability of the corresponding Alloy specification. Further details about the process of formalization of the service ontology can be found in Appendix B.

1.6.2 Relevance

In order to ensure the relevance of the research results, two strategies are employed. The first one concerns the articulation of the theoretical foundation with existing approaches. The second one regards the application of the theoretical foundation in the solution of practical problems (more specifically in SoEA application area). These two strategies are described as follows.

[2] Available at: https://code.google.com/p/ontouml-lightweight-editor/.

[3] Alloy specifications are used as input to Alloy Analyzer 4.2 tool, which generates instances of the model and represents these instances in a graphical representation.

Relevance Strategy #1 (articulation with current approaches): it consists of an analysis (i) of how suitable is the theoretical foundation for harmonizing other service perspectives, and (ii) of the benefits brought by the designed service ontology in comparison to other service ontologies and conceptual models. This analysis was conducted by means of a "descriptive evaluation"[4], and can be found in sections 3.4 and 3.5.

Relevance Strategy #2 (application in practical problems): since this thesis is based on the symbiosis between "theory-and-practice", the relevance of the proposed theoretical foundation is also analyzed taking as basis its applicability in the solution of practical problems, more specifically, in SoEA initiatives. Thus, the theoretical foundation was applied for supporting:

- The analysis of SoEA structuring techniques in order to reveal social aspects (related to the notion of service commitments) usually neglected in current service-oriented approaches (such as, SOA Reference Model by OASYS (OASIS, 2006), ITIL (ITSMF, 2007) and ArchiMate (THE OPEN GROUP, 2012)).
- The ontological analysis of service modeling in ArchiMate's Business layers towards showing limitations of this modeling language, and proposing service modeling recommendations in a form of service modeling patterns.

For empirically evaluating the applicability of these modeling patterns, and ratifying (by a "third-party" analysis) the limitations of ArchiMate identified during the ontological analysis, an "experimental evaluation"[5] is conducted. Such evaluation was designed taking as basis (TEIXEIRA; FALBO; GUIZZARDI, 2013) and (JURISTO; MORENO, 2001), which offered methodological support for designing and conducting the empirical evaluation in a systematic fashion. Regarding its design, briefly, the evaluation was structured in two parts. In Part 1, the participants have access to ArchiMate models that were built without adopting the modeling patterns. In Part 2, the participants have access to ArchiMate models that were built applying the modeling patterns. From that, we analyzed the participants' interpretations about the

[4] *Descriptive evaluation* is conducted from an argumentative discussion based on current related approaches ("knowledge base") and application scenarios (HEVNER et al., 2004).

[5] *Experimental evaluation* regards a controlled experiment in which the artifact is evaluated concerning quality aspects (e.g., usability) (HEVNER et al., 2004).

analyzed models contrasting the interpretations given in Part 1 of the evaluation against the interpretations given in Part 2.

The analysis of the relevance of the proposed theoretical foundation was inspired (i) in the technique of ontology evaluation, so-called "application-based evaluation" (BRANK; GROBELNIK; MLADENIC, 2005), and (ii) in the correlation between ontology and modeling language design (discussed, e.g., in (WAND; STOREY; WEBER, 1999) (GUARINO, 2009) (TEIXEIRA; FALBO; GUIZZARDI, 2013) and (CARVALHO; ALMEIDA; GUIZZARDI, 2014)). Thus, taking into account the correlation between the designed service ontology and the modeling patterns (which were defined based on this ontology), and by evaluating the applicability of these patterns in SoEA modeling tasks, we believe to be possible to indirectly analyze the benefits of this service ontology as a reference model used (i) in the task of consensus establishment (towards minimizing ambiguity), and (ii) for enriching expressiveness of service models (by incorporating "real-world" semantics). Details of the evaluation design, the collected data, and the complete discussion about the results can be found in Chapter 6. The material used during the empirical evaluation can be found in Appendix A.

1.6.3 Design

The research design concerns the effort towards articulating all the activities related to building, evaluating and incorporating (possible) feedbacks. As such, in this research, the design encompassed the definition of the theoretical foundation and its specification in a well-founded core reference service ontology, and the application of this ontology in the analysis of SoEA structuring principles as well as in the improvement of ArchiMate modeling language. In this context, two important aspects regarding the ontology design remark. The first one concerns the expressiveness of the ontology towards being able to specify the underlying theoretical foundation. The second one refers to the ontology's capability in accounting for the service phenomena in a broad and general perspective, being then applicable to a wide range of service scenarios.

Finally, the design reflects the main cycle that articulates the other two cycles - rigor and relevance - towards conducting a research project. Figure 2 summarizes the

aforementioned discussion about design, rigor, and relevance, and highlights the main elements of each cycle in the context of this thesis.

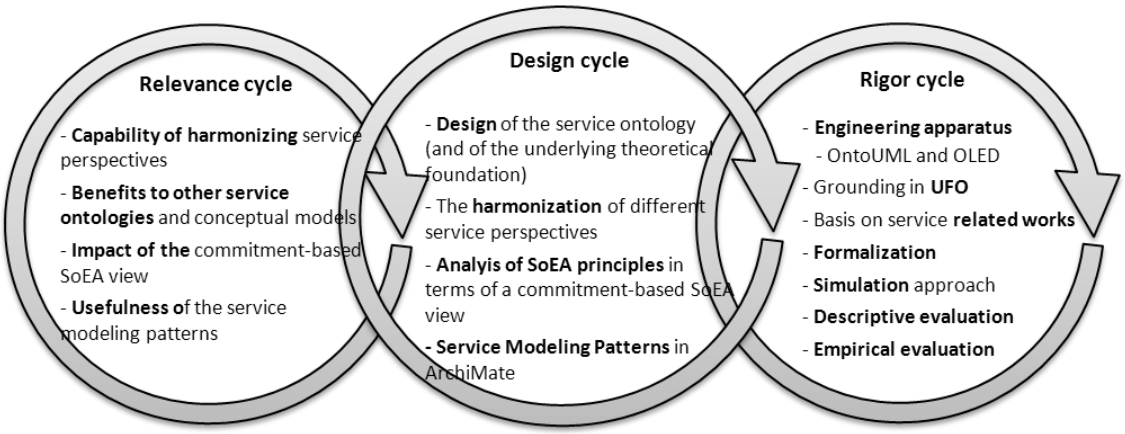


Figure 2 - Research cycles in this thesis (based on (HEVNER; CHATTERJEE, 2010)).

Finally, in order to offer a general view about the achievement of the research objectives, Table 1 presents the correspondence between the specific research objectives and the outcome(s) related to the achievement of such objectives. The general research objective is indirectly achieved by means of the specific objectives.

Table 1 – Achievement of the research objectives.

Objective	Achievement (outcome)
SO1. Represent the proposed theoretical foundation in a well-founded core reference ontology of service.	- Design of the service ontology.
SO2. Harmonize, by using the proposed theoretical foundation, different service perspectives found in literature	- Harmonization of UFO-S with different service perspectives ("service as behavior", "service as value co-creation", "service as capability / manifestation of competences", and "computational services")
SO3. **(i)**. Reveal, in light of service commitments, service relations aspects usually neglected in the current SoEAs.	- Analysis of SoEA structuring principles in light of UFO-S - Definition of a "commitment-based SoEA view" (to be harmonized to the "prevailing capability-based view")
SO3. **(ii)**. Improve semantics of a SoEA modeling language (ArchiMate) for better representing service relations along service life cycle.	- Identification of limitations in service modeling at ArchiMate's Business layer - Proposal of three service modeling patterns

1.7 Organization of this Thesis

This chapter presents the Introduction of this thesis, in which the general aspects are described, namely: the context of the research, the motivation for performing it, the

research hypothesis, the research objectives, and the methodological aspects. The content of this thesis is further organized as follows:

- **Chapter 2. Background: Service and Ontology**: this chapter presents an overview of the state of the art necessary for grounding the ideas of this thesis. The content encompasses Service and Ontology as the main background subjects addressed in this thesis, describes the impact of these subjects in SoEA, and presents some related works found in literature.
- **Chapter 3. UFO-S: A Reference Ontology for Services**: this chapter presents the theoretical foundation for service proposed in this thesis in the form of a well-founded core reference ontology of service: UFO-S. Also, this chapter discusses how this theoretical foundation is able to harmonize different perspectives of service, and highlights the improvements brought by UFO-S in comparison to other service ontologies and conceptual models.
- **Chapter 4. Revealing Service Commitments in Service-Oriented Enterprise Architecture**: this chapter presents an analysis about the structuring principles underlying SoEA in light of UFO-S. The analysis reveals social aspects inherent to the service phenomena in SoEA that remain underexplored due to the current prevailing "capability-based SoEA view". We advocate for a "commitment-based SoEA view", which can be harmonized with the capability-based SoEA view for establishing richer SoEA structuring principles. Implications of our analysis are discussed taking as basis widely adopted service-oriented approaches, such as, SOA-RM by OASIS, ITIL, and ArchiMate.
- **Chapter 5. An Ontological Analysis of Service Modeling at ArchiMate's Business Layer**: this chapter presents an ontological analysis of service modeling fragments at ArchiMate's Business layer taking as basis UFO-S and considering the "commitment-based SoEA view" discussed in the Chapter 4. As a result, we provide "real-world" semantics to service modeling fragments in ArchiMate based on the notion of service commitments/claims. Also, we offer recommendations in the form of modeling patterns to ensure expressiveness and to clarify the semantics of some service modeling elements.
- **Chapter 6. An Empirical Evaluation of the Service Modeling Patterns**: this chapter presents an empirical evaluation of the modeling patterns proposed in

Chapter 5. This evaluation was conducted by means of an empirical study that aimed at substantiating the ontological analysis described in Chapter 5 (from which limitations in service modeling in ArchiMate's Business Layer were identified), and assessing the benefits in adopting the proposed modeling patterns.

- **Chapter 7. Final Considerations**: this chapter summarizes the ideas discussed in this thesis, presents the research contributions and the impacts of this work, and finally describes the future perspectives.
- **Appendix A. The Material Used in the Empirical** Evaluation**:** this appendix presents the material used in the empirical evaluation (described in Chapter 6.) including questionnaires, analyzed models, instructional material, etc.
- **Appendix B. Formalization of UFO-S**: this appendix presents the detailed formalization of UFO-S.
- **Annex A. The Unified Foundation Ontology (UFO)**: this annex presents the main parts of the Unified Foundational Ontology (UFO) focusing on the fragments used in this research work for grounding UFO-S. Further, it presents OntoUML, a UML profile that incorporates ontological distinctions of UFO to support conceptual modeling. This profile was used to build UFO-S models.

Chapter 2. Background: Service and Ontology

This chapter presents the background knowledge about Service and Ontology that is necessary for grounding the ideas discussed along this thesis.

2.1 Introduction

The various existing service characterizations in the literature present particularities that are influenced by the point of view of the academic disciplines (e.g., Business, and Computer Science) and of the economic sectors (e.g., Service, and Manufacturing, and Extractive) wherein the notion of service is applied. In Computer Science, we can notice the use of the notion of service, e.g., in Enterprise Architectures, more specifically, in Service-oriented Enterprise Architectures. In this context, the notion of service has been influenced by, at least, two views: Business and IT. These two different (but complementary) views have been reflected in the design of service-oriented languages and approaches.

Due to their wide applicability, ontologies have also been characterized by different ways, e.g.: (i) by the level of generality, and/or (ii) by the purpose of usage. Similarly to service, these characterizations are influenced, at some level, by the target application areas wherein the ontologies are applied. For illustrating this, we discuss the use of ontologies in (Service-oriented) Enterprise Architecture. As a reference model, we discuss the use of ontologies for promoting common understanding, as well as for supporting analysis and design of enterprise modeling languages. As implementation artifacts, we discuss the use of ontologies for promoting semantic interoperability among software applications that are used to support business strategies. We also discuss how the different purposes of ontology usage (e.g., as a reference model, or as an implementation artifact), influence the design and usage of ontology representation languages/formalisms. Finally, we briefly introduce the Unified Foundation Ontology (UFO) and the OntoUML language, and present some service ontologies and service-based conceptual models found in literature.

In order to discuss the aforementioned in details, this chapter is structured as follows: Section 2.2 (“Service”) discusses service characterizations, service and the

notion of commitments, the idea of service life cycle and the influence of commitments, Service-oriented Enterprise Architectures (SoEA), and ArchiMate as the service-oriented enterprise modeling language addressed in this thesis; Section 2.3 ("Ontology"), in turn, presents an overview about fundamental aspects of ontology (such as, definitions, types, and classifications regarding generality level and purpose of usage), introduces the Unified Foundational Ontology (UFO) and OntoUML, discusses the adoption of ontologies in SoEA, and finally presents some service ontologies and service-based conceptual models found in literature.

2.2 Service

In the literature, we can find a number of service definitions that present different characterizations for the concept of "service". Such characterizations reflect, at certain level, the point of view of the academic disciplines and/or of the economic sectors, wherein they were defined.

According to (THE OPEN GROUP, 2009), a service is "*a logical representation of a repeatable activity that has a specified outcome. It is self-contained and is a 'black box' to its consumers*". In the Reference Architecture Foundation for Service Oriented Architecture (SOA-RAF) (OASIS, 2011), a service is defined as "*a mechanism to access an underlying capability*". In ArchiMate modeling framework (THE OPEN GROUP, 2012), a service is a "*unit of functionality that a system exposes to its environment, while hiding internal operations, which provides a certain value (monetary or otherwise)*". These definitions are established for being applicable to both Business and IT views, since these approaches are used in the context of service-oriented architectures, where the alignment between Business and IT is important.

In a more technological perspective, service is explicitly referred to as a piece of software. Thus, the W3C Working Group defines a web service as *"a software system designed to support interoperable machine-to-machine interaction over a network"* (W3C, 2004a). In this case, service descriptions are specified in machine-processable languages, e.g.: WSDL, OWL, OWL-S, and WSMO.

In the context of the Marketing discipline, Vargo and Lusch define service as "*the application of specialized competences (knowledge and skills) through deeds, processes, and performances for the benefit of another entity*" (VARGO; LUSCH, 2004).

Spohrer and colleagues go further and consider a service as "*the application of resources (including competences, skills, and knowledge) to make changes that have value for another (system)*" (MAGLIO et al., 2009). Thus, these authors also highlight aspects of "value co-creation" between the parties involved in service relations.

In (QUARTEL et al., 2007), a service is defined as "*the establishment of some effect through the interaction between two or more systems*". The notion of service is then mainly characterized by interactions between the user and the service provider. The external behaviors of the provider and of the user are defined and put together in a whole interaction. A particular aspect of this work regards to the "(de)decomposition" of services. According to the authors, "the service concept defines a unit of composition and decomposition". This aspect is strongly influenced by the context in which this work applies, i.e., definition (refinement) of business processes and their realizations by software applications.

In (SAMPSON, 2010a), the notion of service is characterized by the concept of "production process", suffering evident influence of the Manufacturing sector. Thus, a service is defined as a "*production process wherein each customer supplies one or more input components for that customer's unit of production*". In a production process, inputs are resources (tangible resources (e.g., a car) or intangible resources (e.g., information)) that are used by the process to produce some benefit.

Table 2 summarizes the above discussion by presenting the identified service characterizations. With this, we do not aim at stressing the analysis of the existing service characterizations, neither starting a terminological discussion around the concept of "service". We intend to evidentiate how complex is the notion of service and how diverse is the understanding about it.

Table 2 – Some service characterizations.

Service Characterization	General Description	Reference(s)
Service as interaction	Focuses on the interactions between service participants to achieve results or generate effects.	(QUARTEL et al., 2007)
Service as activity/functionality	Focuses on a behavior that is exposed to the environment and that produces outcomes.	(THE OPEN GROUP, 2009) (THE OPEN GROUP, 2012)
Service as capability	Focuses on the capability of a provider to produce benefits to customers.	(OASIS, 2006) (RUOKOLAINEN, 2013)

Service as application of competences	Focuses on the manifestation of the capability of a party to act in benefit of another party.	(VARGO; LUSCH, 2004)
Service as value co-creation	Focuses on services as the basis of economic exchange.	(MAGLIO; SPOHRER, 2008) (MAGLIO et al., 2009)
Service as (production) process	Focuses on the customer input as a necessary and sufficient condition to define a production process as a service process.	(SAMPSON; FROEHLE, 2006) (SAMPSON, 2010a)
Service as software	Takes pieces of software as services that can be accessed through well-defined interfaces.	(W3C, 2004a)

2.2.1 Service and the Notion of Commitment

Besides the different service characterizations discussed in the previous section, the notion of commitment (also referred by "obligation" and "responsibility", among others) plays an important role towards enriching the understanding about "service".

According to the Oxford Dictionary, a commitment is: (i) "*the state or quality of being dedicated to a cause, activity, etc.*"; (ii) "*a pledge or undertaking*"; and (iii) "*an engagement or obligation that restricts freedom of action*". By these definitions, we can notice important aspects (e.g., "being dedicated", "pledge", "undertaking", "obligation", "restricts freedom of action") that are inherent to some social relations.

In fact, due to its suitability for characterizing business-related aspects, the notion of commitment has been adopted by a number of works, even not directly related to service. For example, in (KHALFALLAH et al., 2013), the authors uses the concept of "obligation" as basis for a formal theory that allows product engineers to model cross-organizational process (so-called "contracts") using concepts more related to the Business view. The authors advocate that the usage of business-related aspects, such as "obligation", favor the approach in contrast to the computational-related ones, such as "data" and "control flows". In (TELANG; SINGH, 2009), the notion of commitment is used in order to capture the business intent underlying the business process interactions. As a result, the approach addresses the business modeling task by considering the commitments established between business agents. In (GEERTS; MCCARTHY, 2000), Geerts and McCarthy define the conceptual accounting framework of the REA (Resource-Event-Agent) model. In this work, the authors adopt the notion of commitment for characterizing what is so-called "economic agreements". Thus, commitments are an important element towards guaranteeing, at certain level, the

execution of the actual "economic event" (e.g., production), as well as the necessary inflow and outflow of resources.

In the case of service relations, the notion of commitment has also been adopted. Service relations have been more and more taken, mainly in the context of the Service Science discipline, from a broad and multidisciplinary view, since, as Fisk and Grove state (FISK; GROVE, 2010): "relationships are at the heart of service". In fact, services are provided and consumed in a network of social relationships. Thus, commitments are an important social aspect that contributes for the understanding of the service provision dynamics.

According to Ferrario and Guarino, service is "*a complex temporal entity (a complex event) consisting of a service commitment and the corresponding process*" (FERRARIO; GUARINO, 2012). In their approach, a temporal entity is considered a *perdurant*, which includes events, states and processes. In (DUMAS et al., 2001), the authors consider that a "service instance" (created from a service offer), "*is essentially a promise by one party (the provider) to perform a function on behalf of another party (the consumer) at some time and place and through some channel*". The execution of this promise is indeed the service delivery. Santos and colleagues define service as "*a temporal entity related to the commitment (a service agreement) that a service provider will perform a task (a type of action) on behalf of a service client whose outcome satisfies a service client's goal*" (SANTOS et al., 2009).

Terlouw and Albani define service as a "*universal pattern of coordination and production acts, performed by the executor of a transaction for the benefit of its initiator, in the order as stated in the standard pattern of a transaction*" (TERLOUW; ALBANI, 2013). According to this approach, by performing "coordination acts" (e.g., requests, promises, and acceptances), actors enter into and comply with commitments regarding production acts. "Production acts", in turn, bring about the function of the organization (e.g., the actual service deliver). Sullivan (O'SULLIVAN, 2006), by analyzing non-functional properties of service, remarks the notions of "obligation" and "right" as characterizing the relationships between service provider and service customer.

The benefits of considering commitments in service characterization have also been discussed from the point of view of Business (MINGMING; YOUBEI, 2010) and IT (SINGH; CHOPRA; DESAI, 2009). Service commitments are discussed as useful to deal

with service intangibility, being therefore "*an important communication tool because it makes services more perceptible and trustworthy, reduces the perceived risk and therefore leads more successful and smooth purchasing*" (MINGMING; YOUBEI, 2010). Also, commitments are acknowledged as a means for raising the low abstraction level of the existing service-oriented architectures, promoting the reduction of the gap between Business and IT (SINGH; CHOPRA; DESAI, 2009).

It is important to remark that some kinds of service business models cannot be suitably explained without the notion of commitments. In (FERRARIO; GUARINO, 2012), an insurance service business model is used for illustrating the case in which the customer pays for having someone (an insurer) committed to intervene in case of an accident. Arguably, the customer hopes that the actions of the service delivery are never to be performed. In this context, the service is provided by the existence of a commitment even if no actions are executed.

As aforementioned, the notion of commitment indeed plays an important role in the characterization of the notion of service. However, despite this importance, it cannot be taken in isolation. For offering a broad account for the notion of service, the notion of commitment needs to be harmonized with the other existing characterizations in a broader view.

2.2.2 Service life cycle

The balance of the (co)responsibilities, and the establishment of commitments towards governing service delivery are important aspects for characterizing the dynamics of service relations (ALTER, 2008). This dynamics happens in the context of the service life cycle, and can be analyzed in light of how the commitments established between service participants (service provider and service customers) affect the service life cycle.

In general, the service life cycle encompasses phases, such as (OBERLE et al., 2009) (FERRARIO; GUARINO, 2012): service design (or innovation), service offer, service search, service negotiation (or matching), service delivery (or usage), service feedback (or after sale). In this thesis, however, we have established as scope of investigation the minimum service life cycle composed by service offer, service negotiation, and service delivery phases, as shown in Figure 3.

Figure 3 – The analyzed service life cycle.

Service offer is the initial phase in which services are presented to target customers, and service aspects such as provider availability, pricing, payment, security, quality of service, and reputation (DUMAS et al., 2001) are described and published. *Service negotiation* is characterized by the interaction between customer and provider in order to establish an agreement about their responsibilities (FERRARIO; GUARINO, 2012). If service negotiation is successfully achieved, a service agreement is established, determining what has been settled between service participants for service delivery. Finally, *service delivery* concerns the execution of actions to fulfill the commitments established in the service agreement (DUMAS et al., 2001).

2.2.3 Service-oriented Enterprise Architecture

Enterprise Architecture, as a discipline or application area, attempts to integrate, govern and analyze enterprise elements. The consistent alignment of these elements creates synergy in achieving enterprise objectives (RAJABI; MINAEI; SEYYEDI, 2013). As blueprints, enterprise architectures provide a holistic view of the enterprise, and captures the essential of Business and IT (LANKHORST, 2005). Thus, enterprise architectures systematize constituent units of an enterprise, such as business processes, organizations, data, and information technologies. From this, enterprise members are able to understand detailed structure and components of the enterprise and how they work together (KANG et al., 2010).

With the increasing adoption of the “service orientation” paradigm in the last decade (LANKHORST, 2005), the service notion has being adopted as part of the enterprise architecture practices defining what has been called *Service-oriented Enterprise Architecture* (SoEA) (KISTASAMY; MERWE; HARPE, 2010).

In a typical service-oriented enterprise architecture, the service concept acts both as a means to structure elements within an architectural layer (e.g., relating organizational units or departments through internal business services), as well as a means to link different layers, with “higher” architectural layers (e.g., Business layer)

accessing the resources of the "lower" layers (e.g., Technology layer) by means of services (LANKHORST, 2005). As such, IT services (e.g., software application services, and network services) are defined to support the realization of business services (CASES; BODNER; MUTNURY, 2010). Thus, the notion of service has also been considered as an important means towards establishing Business-IT alignment (ABDI; DOMINIC, 2010)(HRGOVCIC; UTZ; KARAGIANNIS, 2011).

For representing and communicating all the aspects related to the definition of service-oriented enterprise architectures, suitable modeling languages are necessary. Following, we present ArchiMate, the SoEA modeling language addressed in this thesis.

2.2.4 ArchiMate

Together with the wide adoption of the "service orientation" paradigm, a number of service-based modeling languages and frameworks have been defined to describe and communicate enterprise architecture decisions (ISO/IEC/IEEE, 2014), and ArchiMate (THE OPEN GROUP, 2012) is one of the most prominent examples.

ArchiMate is currently a technical specification maintained by The Open Group (THE OPEN GROUP, 2012). 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 such, it adopts the "service" construct as a basic structuring element for its three enterprise architecture layers: Business, Application, and Technology.

The *business layer* deals with, among others, business processes, people (human resources) and organizational structure, aligning these elements to the enterprise strategy, and offering/hiring products and services to the external environment. The *application layer* supports the business layer with application services realized by software applications. The *technology layer*, in turn, supports the higher layers by providing infrastructure services (e.g., storage and communication services) realized by software and hardware (e.g., network devices, application servers, and database management systems) (THE OPEN GROUP, 2012).

Figure 4 presents an ArchiMate's metamodel fragment, which encompasses the main elements addressed in this thesis. Such elements are organized in the three aforementioned enterprise layers.

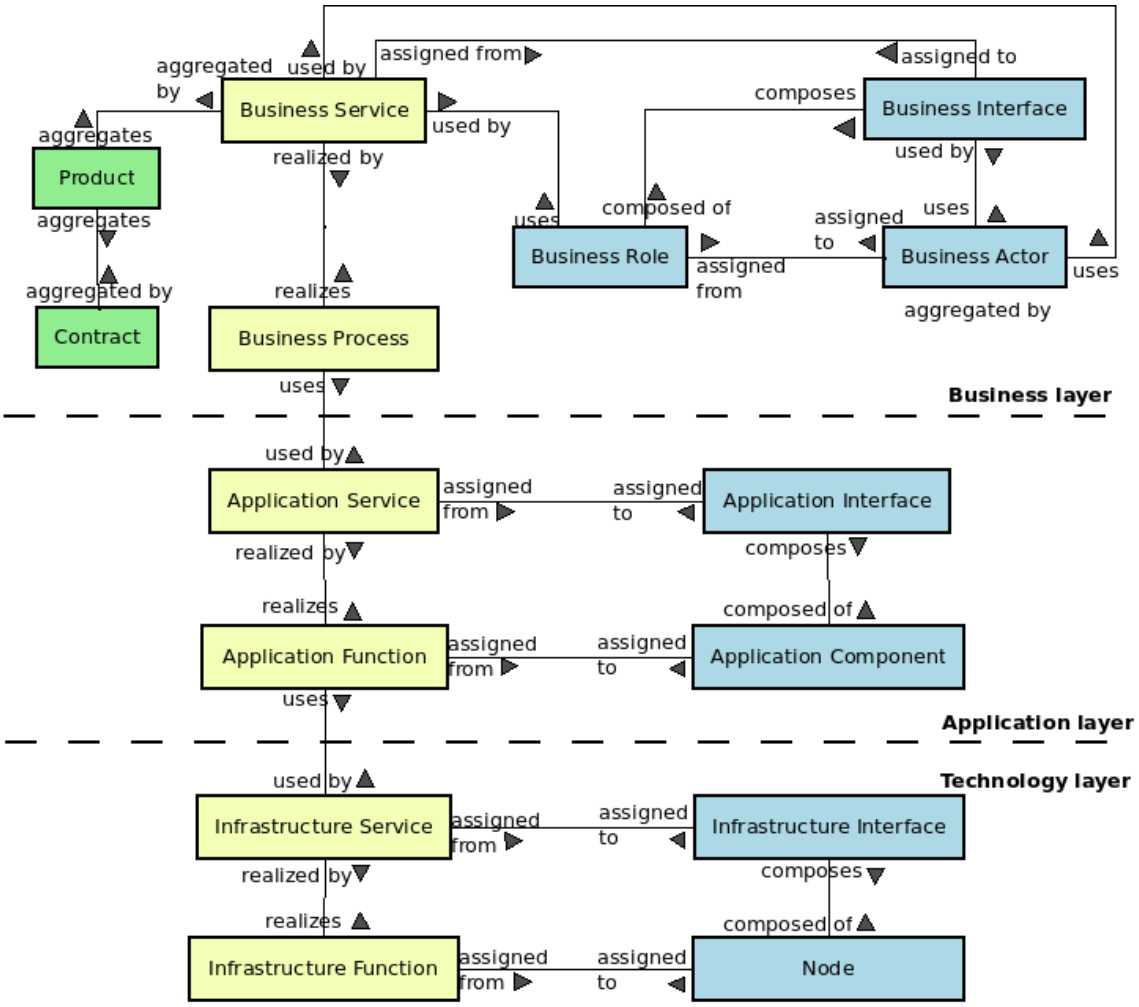
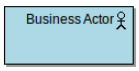
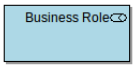
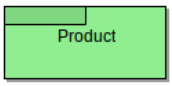


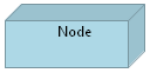
Figure 4 - An ArchiMate's metamodel fragment (based on (THE OPEN GROUP, 2012)).

In ArchiMate, these elements are classified as structural, informational and behavioral elements. *Structural elements* (in the right-hand side of Figure 4) refer to entities that make up the organization (e.g., business roles, business actors, interfaces, application components, and nodes). *Informational elements* (in the left-hand side of Figure 4) are related to the purpose of communication (e.g., products, and contracts). Finally, *behavioral elements* (in the center of Figure 4) are used to characterize the dynamic aspects of an organization (e.g., business services, business processes, application function, and infrastructural function) (THE OPEN GROUP, 2012).

Table 3 presents the notation and the definition of each ArchiMate's modeling element addressed in the aforementioned metamodel.

Table 3 – Notation and definition of the ArchiMate's elements addressed in the metamodel fragment (based on (THE OPEN GROUP, 2012)).

Elements	Notation	Definition
Business Layer		
Business actor		"An organizational unit that is capable of performing behavior".
Business role		"The responsibility for performing specific behavior, to which an actor can be assigned".
Business Interface		"Point of access where a business service is made available to the environment". "An interface provides an external view on the service provider and hides its internal structure".
Business Service		"A service that fulfills a business need for a customer (internal or external to the organization)".
Product		"A coherent collection of service, accompanied by a contract/set of agreements, which is offered as a whole to (internal or external) customers". "'Buying ['hiring'] a product gives the customer the right to use the associated services [to the product]".
Contract		"A formal or informal specification of agreement that specifies the rights and obligations associated with a product".
Application Layer		
Application Service		"A service that exposes automated behavior".
Application Component		"A modular, deployable, and replaceable part of a software system that encapsulates its behavior and data and exposes these through a set of interfaces".
Application Interface		"A point of access where an application service is made available to a user or another application component".
Application Function		"A behavior element that groups automated behavior that can be performed by an application component".
Technology Layer		
Infrastructure Service		"An externally visible unit of functionality, provided by one or more nodes, exposed through well-defined interfaces, and meaningful to the environment".

Node		"A computational resource upon which artifacts may be stored or deployed for execution".
Infrastructure Interface		"A point of access where infrastructure services offered by a node can be accessed by other nodes and application components".
Infrastructure Function		"A behavior element that groups infrastructural behavior that can be performed by a node".

As shown by Figure 4, the ArchiMate modeling elements can be linked by means of several relationships. Table 4 presents the notation and definition of each one of these ArchiMate's relationships.

Table 4 – Notation and definition of the ArchiMate's relationships addressed in the metamodel fragment (based on (GROUP, 2012)).

Relationship	Notation	Description
Used by		"The 'used by' relationship models the use of services by processes, functions, or interactions and the access to interfaces by roles, components, or collaborations". It is also used to model the direct access of roles to business service.
Realization		"The realization relationship links a logical entity with a more concrete entity that realizes it". Thus, it is used to model the realization of service by behavioral elements (e.g., business process, application functions, and infrastructure functions).
Assignment		"The assignment relationship links units of behavior with active elements (e.g., roles, components) that perform them, or roles with actors that fulfill them".
Aggregation		"The aggregation relationship indicates that an object groups a number of other objects".
Composition		"The composition relationship indicates that an object is composed of one or more other objects".

For exemplifying the use of these modeling elements, Figure 5 illustrates the adoption of ArchiMate in a typical layered SoEA. In this example, a DBMS (Database Management System), as a resource at the technology layer, realizes the "Data access" infrastructure service. This service is used by an enterprise information system, the "Complaint System", at the application layer. This system, in turn, offers, via a website, the "Record Complaint" application service. Such service is used in the context of the "Handling Complaint" business process by the "Attendant" business role. This role is

played by “John”, a business actor that is responsible for the execution of this process. The “Complaint” business service, which is realized by the “Handling Complaint” business process, together with “Cable TV” business service, takes part in the “Cable TV Product”. These business services are used by “Customer(s)”, and the terms and conditions of usage are described in the “Contract” element.

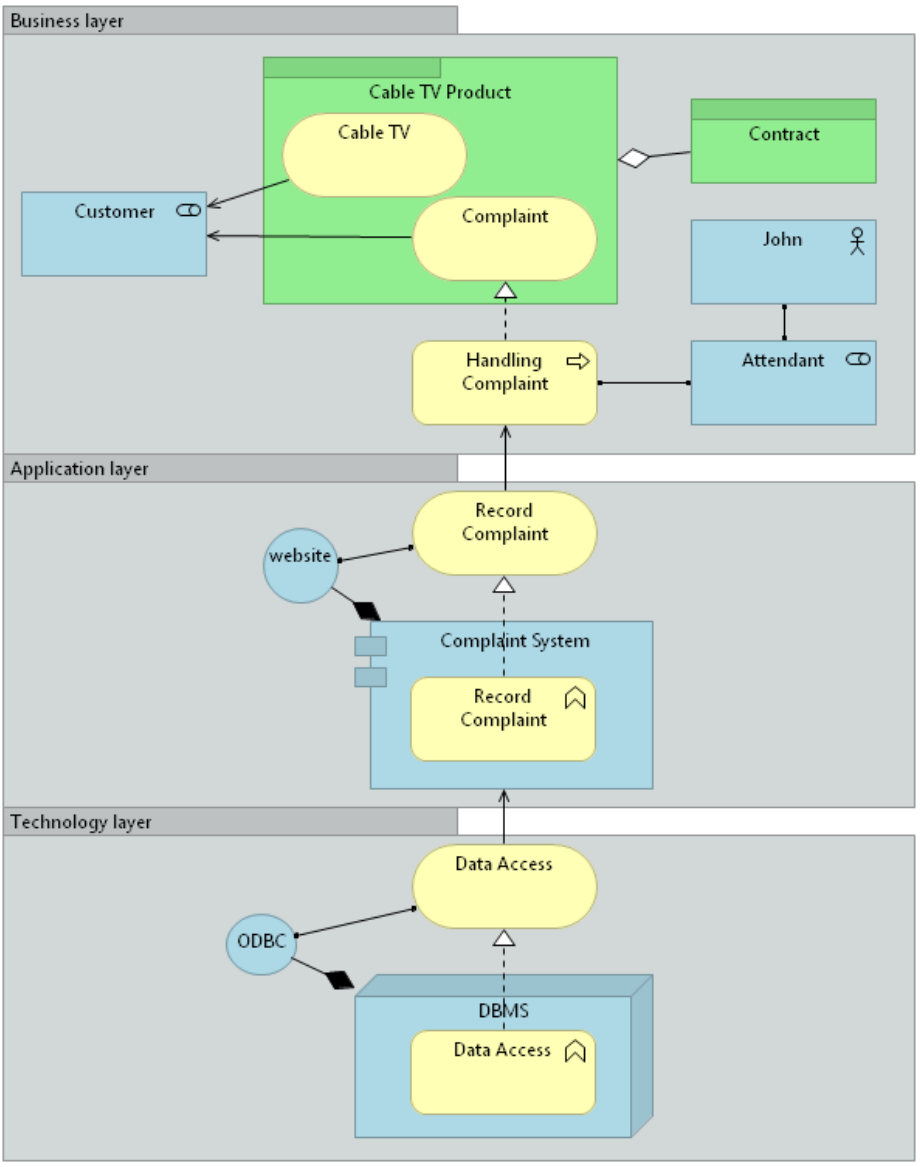


Figure 5 - Exemplifying the usage of ArchiMate in a typical layered SoEA.

2.3 Ontology

The term “ontology” has been used in many ways. “Ontology” (with the capital "o") refers to the philosophical discipline, namely the branch of philosophy that deals with the nature and structure of “reality” (GUARINO, 1998) (GUIZZARDI, 2007). As a

philosophical discipline, Ontology studies the most general features of reality, dealing with relations between entities that belongs to distinct domains of science (e.g., Physics, Chemistry, Biology), as well as between entities recognized by common sense (GUIZZARDI, 2007). With the lowercase "o", “ontology” can be used in a philosophical perspective, referring to a system of categories or a kind of theory independent of language; or in an engineering perspective, referring to an artifact for a specific purpose, and represented in a specific language (GUARINO, 1998) (GUIZZARDI, 2007).

In this thesis, we use the term “ontology” according to the engineering perspective. As such, an ontology specifies a theoretical foundation (i.e., a “world view”) in a specific representation language. Anyway, these two perspectives - philosophical and engineering – are present along the ontology engineering process, i.e., in the elaboration of a *conceptualization*[6] about an investigated phenomenon/domain/field, and in its specification in an artifact.

Ontologies are developed in different generality levels, and with different purposes of usage. In practice, ontologies have been applied in a number of target application areas for addressing semantic conflicts. Depending on the context and on their purpose, ontologies can be represented by different languages/ formalisms (taking into account, e.g., the trade-off between expressiveness vs. computational requirements). These issues are addressed in details in the following subsections.

2.3.1 Types of Ontologies

Regarding the level of generality, ontologies can be classified as follows (GUARINO, 1998):

- *Top-level ontologies* (also called *foundational ontologies*): which describe very general concepts independently of a particular problem or domain, such as object, event, action etc. DOLCE (MASOLO et al., 2003), SUMO (SUMO, 2012), YAMATO (MIZOGUCHI, 2009) and UFO (GUIZZARDI, 2005a) are examples of top-level ontologies.
- *Domain ontologies*: which describe a conceptualization related to a generic domain (e.g., Law, Biology, and Software Process).

[6] Here we adopt an informal and broad view about the notion of “conceptualization”. For a deeper discussion about it, see (GUARINO; OBERLE; STAAB, 2009).

- *Task ontologies*: which describe a conceptualization related to a generic task (e.g., Diagnosis, and Planning).
- *Application ontologies*: which describe concepts dependent on a particular domain and task (e.g., a medical ontology that is defined by the specialization of a disease domain ontology and a diagnosis task ontology).

As shown in Figure 6, these four types of ontologies are structured in such way that foundational ontologies are at the most general level, whereas the application ontologies are at the most specific level. In the middle, we have the domain and task ontologies, which are developed taking as basis top-level ontologies, and are specialized in application ontologies.

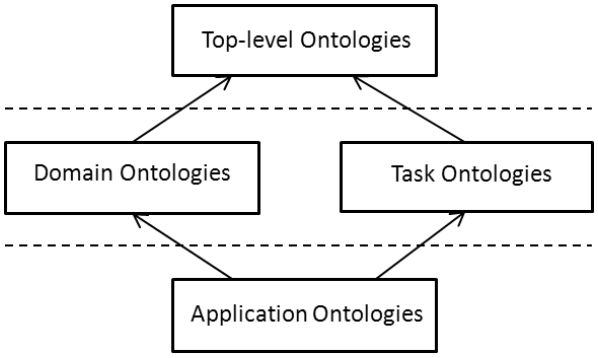


Figure 6 - Types of ontology by generality level (GUARINO, 1998).

In (SCHERP et al., 2011), this classification is extended by admitting the so-called *core ontologies* as a generality level between foundational ontologies and domain/task ontologies. In this sense, core ontologies provide a precise definition of structural knowledge in a specific field that spans across different domains. Examples of core ontologies are the Event-Model-F ontology (which describes different aspects of events), and the Core Ontology on Multimedia (COMM) (which is designed for describing arbitrary digital media data) (SCHERP et al., 2011).

Despite the importance of these discrete types of ontologies, sometimes can be difficult to classify an ontology in one of those specific types, since the ontology could better fit in the boundary region of two types. Thus, as illustrated by Figure 7, we see these types of ontologies (foundational, core, domain/task ontologies, and application ontologies) as regions in a spectrum with fuzzy boundaries between them (FALBO et al., 2013a). By using this continuum, we can have a more precise classification of ontologies along the spectrum.

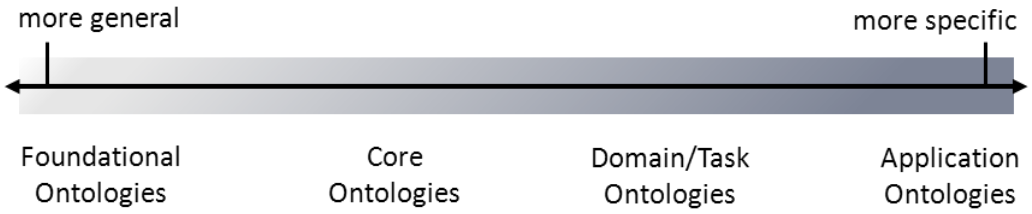


Figure 7 – Generality level of ontology as a continuum (FALBO et al., 2013a).

Another important ontology classification regards the purpose of usage. Based on that, ontologies can be classified as *reference ontologies* or as *operational ontologies* (FALBO et al., 2013b).

Reference ontologies are designed to be used in an off-line manner to assist humans in tasks of meaning negotiation and consensus establishment. These ontologies should be constructed with the sole objective of making the best possible description of the domain in reality (GUIZZARDI, 2007) (FALBO et al., 2013b). Due to their level of expressiveness and to incorporation of ontological distinctions, well-founded ontology representation languages are suitable for specifying reference ontologies (GUIZZARDI, 2007). OntoUML is an example of this type of language (GUIZZARDI, 2005a).

Once users have already agreed on a common conceptualization, specialized versions of a reference ontology can be created for run-time use. These versions are classified as *operational ontologies*, which sacrifice representation adequacy and theoretical foundation to guarantee desirable computational properties (e.g., expressiveness, and tractability) (GUIZZARDI, 2007) (FALBO et al., 2013b). Thus, ontology representation languages used for specifying operational ontologies tend to emphasize the inferential process, and the structure of the knowledge, being independent on the meaning of the concepts themselves (GUIZZARDI, 2007). Examples of this type of languages are FLogic (Frame Logic), RDF (Resource Description Framework), and OWL (Web Ontology Language).

By having complementary characteristics, these two types of ontologies (reference ontology and operational ontology) can be used in tandem in an ontological engineering approach organized in conceptual modeling, design, and implementation phases (FALBO et al., 2013b)(GUIZZARDI, 2007). Reference ontologies, as conceptual models, produced in the conceptual modeling phase, when it is necessary to promote

meaning negotiation and consensus establishment about a target domain. Operational ontologies, as implementation artifacts, are generated by taking design decisions applied over reference ontologies. Thus, from a reference ontology and by applying different design decisions, it is possible to generate different operational ontologies (FALBO et al., 2013b).

2.3.1 The Unified Foundational Ontology and OntoUML

As justified in Section 1.6.1, the foundational ontology adopted in this thesis is the Unified Foundational Ontology (UFO) (GUIZZARDI, 2005a) (GUIZZARDI, 2006) (GUIZZARDI; FALBO; GUIZZARDI, 2008) (GUIZZARDI et al., 2013).

UFO is developed with an interdisciplinary approach inspired by Formal Ontology, Philosophical Logic, Linguistics, and Cognitive Psychology, being also based on other foundational ontologies, such as DOLCE (MASOLO et al., 2003), and GFO/GOL (HELLER; HERRE, 2004).

Similarly to other foundational ontologies, such as DOLCE (MASOLO et al., 2003), and GFO/GOL (HELLER; HERRE, 2004), UFO is inspired in the so-called "Aristotelian Square", which allows for the construction of an ontology that is able to account both for natural science as well as linguistic and cognitive phenomena (GUIZZARDI, 2005a). However, differently from these other two foundational ontologies, which have been developed with different primary foci, UFO was constructed with the primary goal of developing foundations for conceptual modeling. As a consequence, there are many aspects that are essential for conceptual modeling, but which have not received a sufficiently detailed attention in DOLCE and GOL/GFO.

A major difference with respect to DOLCE and GOL/GFO is a detailed account of so-called *universals*, which refines and extends the OntoClean distinctions (GUARINO; WELTY, 2002). In particular, concerning binary relations, an important distinction is made between *formal* and *material* relationships, since in order for the latter to hold the existence of a specific truth-making individual (the so-called "relator") is required. Finally, UFO offers a broad and consistent support for addressing social aspects, such as social commitments/claims, delegation, dependence, and agents, among others.

Regarding its structure, UFO consists of three main parts: UFO-A, an ontology of endurants (objects) (GUIZZARDI, 2005a), UFO-B, an ontology of events (perdurants)

(GUIZZARDI; FALBO; GUIZZARDI, 2008), and UFO-C (GUIZZARDI; FALBO; GUIZZARDI, 2008) (GUIZZARDI, 2006), an ontology of social entities built on the top of UFO-A and UFO-B. All of these three parts follow the fundamental distinction in UFO, which is established between *individuals* (entities that exist in reality and possess a unique identity (e.g., Pelé, and Maracanã)) and *universals* (patterns of features that can be realized in a number of different individuals (e.g., the kinds Person, and Soccer Stadium)) (GUIZZARDI, 2005a).

OntoUML is an UML profile designed for incorporating the ontological distinctions of UFO (UFO-A and UFO-B). As such, OntoUML favors modeling decisions, insofar they are no longer based on heuristics, but on ontological distinctions incorporated in the meta-model of the language (GUARINO, 1994) (GUIZZARDI, 2007). As a result, in terms of (GUARINO, 1994), OntoUML can be considered an *ontological level* language, in contrast to *epistemological level* ones (e.g., OWL, and RDF).

Further details about the UFO's constituent parts (UFO-A, UFO-B, and UFO-C), as well as an overview of OntoUML can be found in Annex A.

2.3.2 Ontologies in (Service-oriented) Enterprise Architecture

As discussed in Section 2.2, enterprise architectures aim to enable enterprise members to understand the detailed structure and components of the enterprise and how they work together (KANG et al., 2010). Thus, the lack of clear semantics in the definition of enterprise architectures may cause communication problems between humans, between systems, and between humans and systems (KANG et al., 2010). Also, the lack of a unified conceptualization about (service-oriented) enterprise architectures compromises the smoothly alignment between business and IT architectures (CHEN; DOUMEINGTS; VERNADAT, 2008). These issues can also make difficult the design/usage of enterprise modeling languages that aim to harmonize different enterprise views (such as Business and IT) (CHEN; DOUMEINGTS; VERNADAT, 2008).

In this context, ontologies arise as an important means for addressing semantic problems in Enterprise Architecture application area, since they offer a formal way for making explicit a shared conceptualization, avoiding the solely use of natural languages for defining and communicating enterprise architectures (which can lead to misunderstandings) (KANG et al., 2010).

A number of works (such as, (KANG et al., 2010), (RAJABI; MINAEI; SEYYEDI, 2013), and (ALLEMANG; HODGSON; POLIKOFF, 2005)) have used ontologies as reference models for defining and evidentiating enterprise architecture concepts and relationships. Thus, ontologies have been applied as a means to establish a common understanding about the organizational context in order to avoid misunderstandings among human beings (and, as a consequence, between computational systems).

Other initiatives (such as (SANTOS JR.; ALMEIDA; GUIZZARDI, 2012), (ALMEIDA; GUIZZARDI, 2008), (AZEVEDO et al., 2011), and (SOFFER; WAND, 2005)) have applied ontologies, as a kind of "theory", for supporting semantic analysis of enterprise modeling languages. Thus, language constructs are analyzed in light of (foundational) ontologies with the aim at identifying limitations in the capacity of representing "real-world" semantics, contributing for semantics clarification and expressiveness improvements.

These two different types of usage of ontology in EA are complementary. Offering a better understanding about concepts and relationships in the organizational context benefits the improvement of enterprise modeling languages. On the other hand, by improving these languages, it is possible to better represent concepts and relations, avoiding (possible) misunderstandings.

As implementation artifacts, i.e., as *operational ontologies* (FALBO et al., 2013b), ontologies have also been applied in the context of Enterprise Architecture, especially for promoting semantic interoperability among enterprise software applications (BUSSLER, 2003) (IZZA, 2009) (NARDI; FALBO; ALMEIDA, 2013a) (NARDI; FALBO; ALMEIDA, 2013b). (Intra- and inter-) Application integration initiatives play an important role in EA, since software applications are integrated to support business strategies (VERNADAT, 2002)(VERNADAT, 2007). Thus, ontologies are used for solving semantic conflicts that arise due, among others, to the fact that the various heterogeneous applications do not share the same conceptualization (IZZA, 2009).

2.3.3 Service Ontologies and Service-based Conceptual Models

In the literature, we can find a number of service ontologies and conceptual models that were built from different characterizations of service and for different purposes of

usage, which have directly impacted their design. In this section, we present some of them with the aim at illustrating these differences.

Concerning service ontologies whose focus is on computational aspects, we can cite two of the most used ones: OWL-S and WSMO. Beyond being considered service ontologies, they also offer machine-readable service representation languages that can be used for promoting semantic interoperability between software applications.

OWL-S is a service ontology that offers constructs for service representation built on OWL (Ontology Web Language) (W3C, 2004b). The conceptual aspects offered by OWL-S together with the OWL language establish ways for representing semantic web services. OWL-S is composed by three main parts (W3C, 2004b), as shown in Figure 8: (i) the *service profile*, which is used for advertising and discovering services, (ii) the *process model*, which gives a detailed description of service operation, and (iii) the *grounding*, which provides details on how to interoperate with a service, via messages (usually specified in WSDL). Thus, in OWL-S, a service specification encompasses (i) "what it does" (service profile), (ii) "how it works" (service model), and (ii) "how to access it" (service grounding).

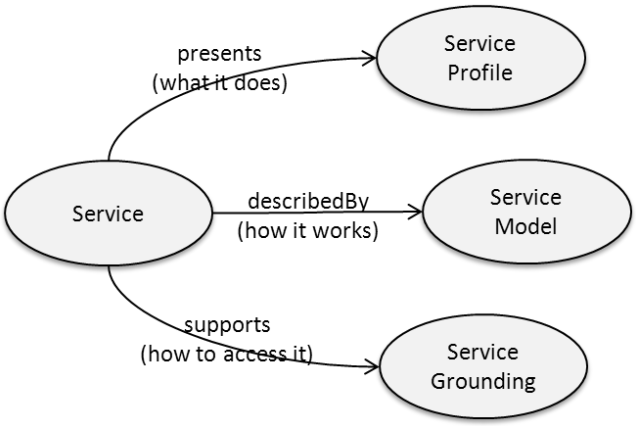


Figure 8 – The top-level of the OWL-S ontology (W3C, 2004b).

WSMO (Web Service Modeling Ontology) is a service ontology that, together with the Web Service Modeling Language (WSML), also offers means for representing semantic web services (W3C, 2006) (LARA et al., 2004). As Figure 9 shows, WSMO relies on four major components (LARA et al., 2004): (i) *Ontology*, which offers the terminology and formal semantics for describing the other elements; (ii) *Goal*, which specifies the requester-side objectives; (iii) *Web Service*, which describes functional and non-functional properties about the piece of software to be invoked; and (iv)

Mediator, which is used as a connector for addressing heterogeneity problems between the elements of different web services. These components are used in tandem for specifying semantic aspects related to web services and then promoting software application interoperability in tasks such as service discovery, service matching, and service invoking/execution.

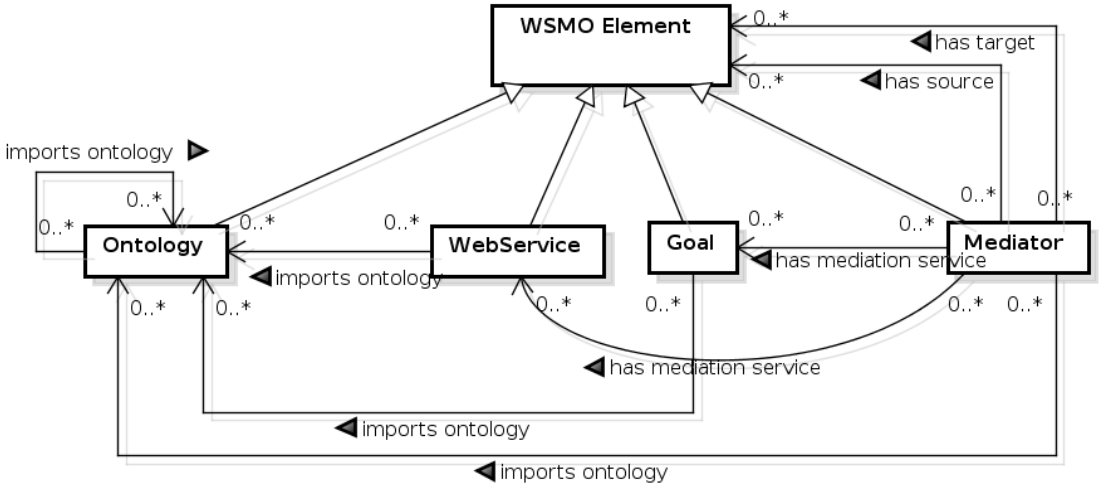


Figure 9 – Upper WSMO Elements (W3C, 2006).

Other service ontologies and (service-based) conceptual models are designed with the purpose of providing a conceptual reference for technical standards. This is the case of The Service-Oriented Architecture Ontology (SOA) by The Open Group (THE OPEN GROUP, 2009), and the Reference Ontology for Semantic SOA (OASIS, 2008).

The SOA Ontology by The Open Group (THE OPEN GROUP, 2009) aims to aid understanding the domain of service-oriented architectures, in order to contribute for the alignment between business and information technology communities. As Figure 10 shows, the ontology establishes that services can be performed by actors (human resources), by tasks (process execution), or by computational systems (such as, web services or software applications in general). The *ServiceContract* concept refers to the terms and conditions (comprising interaction and legal aspects) with regard to the provisioning and usage of the service, as well as to the roles and responsibilities of the involved actors.

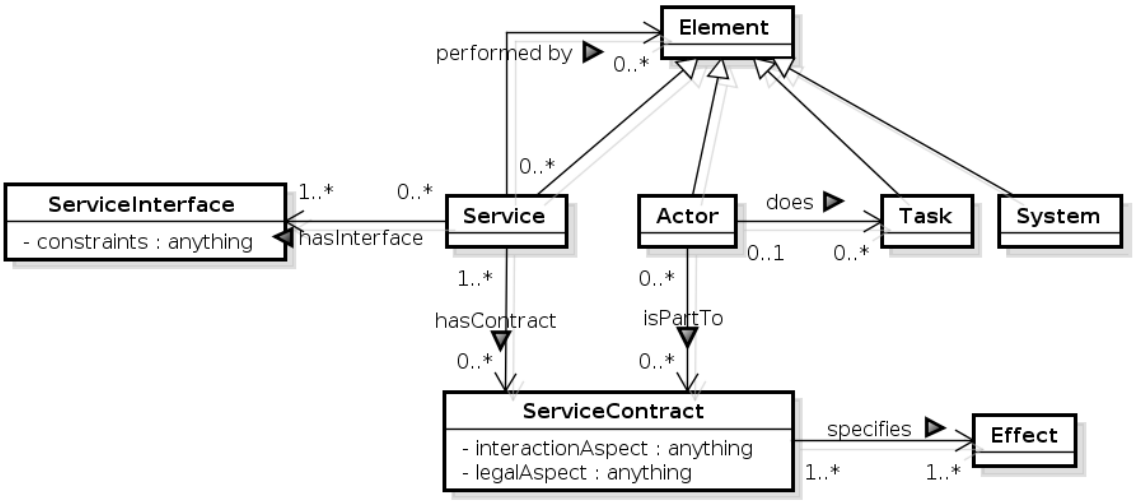


Figure 10 – A fragment of The SOA Ontology by The Open Group (THE OPEN GROUP, 2009).

The Reference Ontology for Semantic Service Oriented Architectures (OASIS, 2008) is an abstract framework for understanding concepts and relationships relevant for semantic service-oriented environments. Despite being useful for a number of service-based target application domains, this ontology focuses on software architectures. Figure 11 shows a fragment with the main elements of this ontology. By focusing on architectural aspects, the ontology deals with concepts related to service discovery (such as *ServiceDescription*, *CapabilityDescription*, and *GoalDescription*), and to behavioral specification (such as *BehavioralModel*, *ProcessModel*, and *ActionModel*). Also, the ontology defines the concept *Communicable*, which makes reference to the actual resources (e.g., web services, or software applications) that will be invoked for performing the expected behavior. This ontology is built on the OASIS Reference Model for SOA (SOA-RM) (OASIS, 2006).

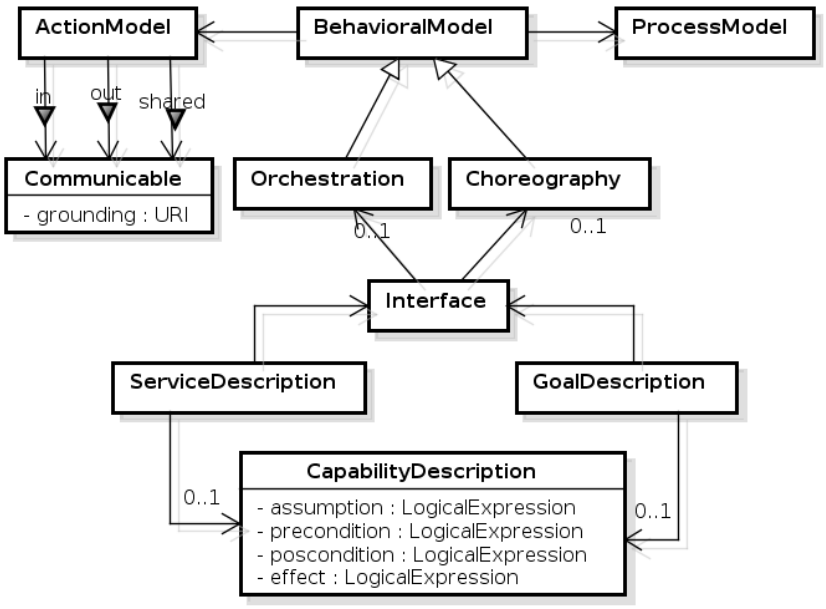


Figure 11 - A fragment of the Reference Ontology for Semantic SOA (OASIS, 2008).

The Healthcare SOA Ontology (MILOSEVIC et al., 2013), despite being a kind of technical reference for SOA-based initiatives, focuses on the eHealth domain. Therefore, it can be considered a service ontology in the domain of eHealth services that follows the tenet of SOA-based approaches. This ontology was designed to be consistent with a number of reference models, such as HL7 SAIF-CD (SAIF, 2012), ISO RM-ODP (ISO/IEC, 2009), SoaML (OMG, 2012), and OASIS SOA Reference Architecture Framework (OASIS, 2011). Figure 12 presents a fragment with the "core concepts" of the Healthcare SOA Ontology, which counts on concepts such as *Service*, *Service Description*, *Service User*, *Service Provider*, *Contract*, and *Object*. These concepts are refined in two viewpoints: enterprise and computational viewpoints. Thus, other concepts (not represented in Figure 12), e.g., Business Service and Computational Service, Business Service Description and Computational Service Description are also addressed by the ontology and organized in the corresponding viewpoint.

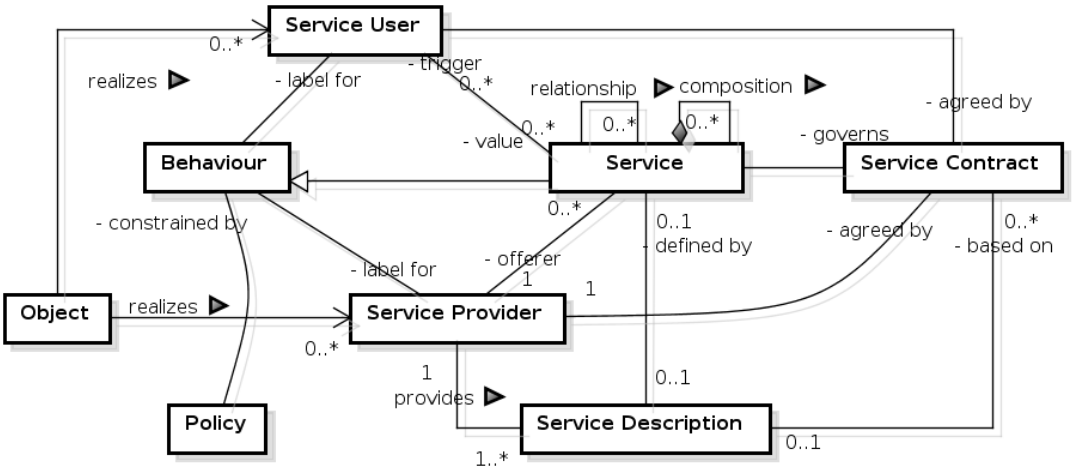


Figure 12 - Healthcare SOA Ontology fragment ("Core concepts") (MILOSEVIC et al., 2013).

The Service Ontology proposed by Oberle and colleagues (OBERLE et al., 2009) is a modular service ontology, so that the core modules span several application domains, such as healthcare, and automotive, as illustrated by Figure 13. This modular structure is the striking feature of this ontology when compared to the others. The more fundamental modules can be specialized in more specific ones dealing with particular application domains. The service foundation adopted in this ontology is based on the works of Ferrario and Guarino (FERRARIO; GUARINO, 2008) (FERRARIO; GUARINO, 2012). A central idea of this ontology concerns to "service description", which is structured in the *Core Service Description* module. The concepts of this module (e.g., *service description*, *service provider* and *service consumer*) are used for describing the elements of service provisions and also can be, as aforementioned, specialized for describing particular aspects inherent to specific application domains.

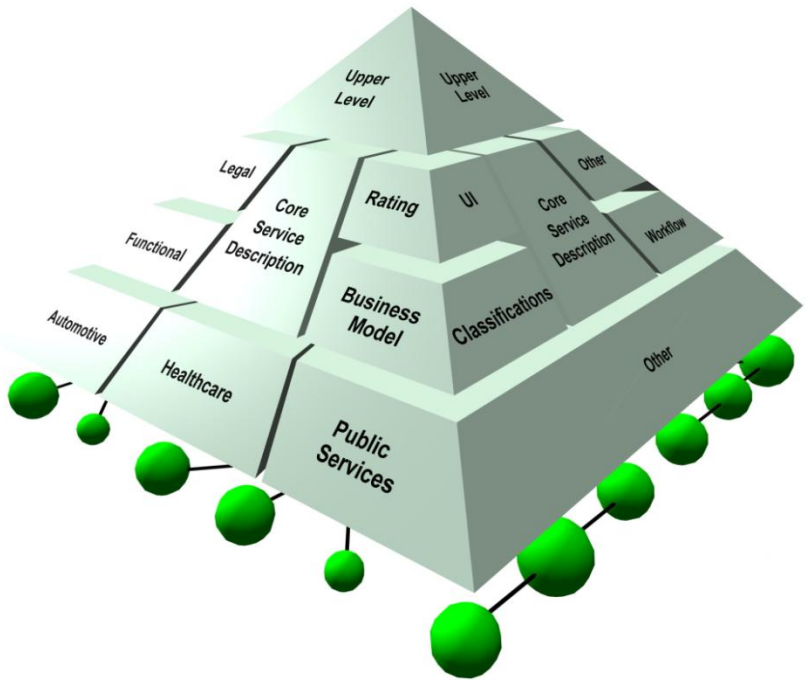


Figure 13 - Overview of the Service Ontology (OBERLE et al., 2009).

The Goal-Based Service Ontology (GSO) (SANTOS et al., 2009) (SANTOS, 2011) is also a general purpose service ontology. A central element in this ontology is the concept of (client-side) *Goal*, which allows domain specialists to define service-oriented domain models taking as basis the notion of goal. Also, as illustrated by Figure 14, this ontology defines service-related concepts as types ("universals"). This favors domain specialists in tasks of application domain specification/modeling. For example, consider the "Dental Service" application domain. In this application domain, the "Patient" (*Service Customer Type)* owns the *goal* of "having their teeth repaired". The "Dentist" (*Service Provider Type*) offers the (type of) "Dental Service" in which some service tasks (*Service Task Type*) needed to be performed (after agreement), towards achieving that goal. Also, the ontology establishes that a type of service can have different *Service Offering Types* and *Service Agreements Types* (which will depend on the service business model adopted by, e.g., a particular dental clinic).

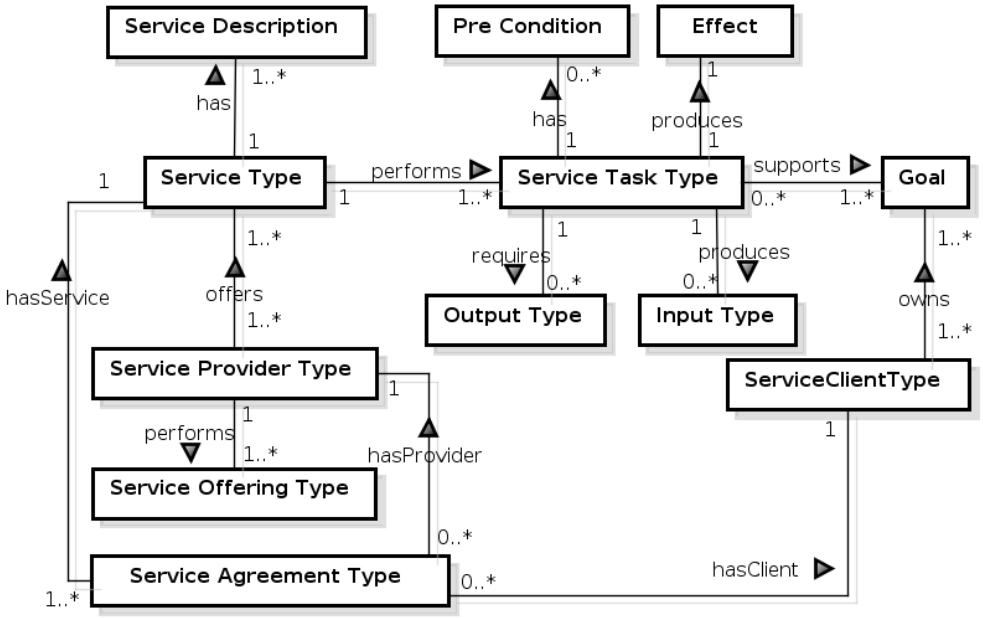


Figure 14 - Goal-Based Service Ontology fragment (SANTOS et al., 2009).

The Onto-ServSys (MORA et al., 2011) is a general purpose service ontology, but with focus on service system and other systems (e.g., organizational systems). The design of this ontology is influenced by the theories of systems, so that a service is seen as embedded in a wider organizational and systemic environment. Figure 15 shows a fragment of this ontology using the graphical representation adopted in (MORA et al., 2011). In this ontology, the *Service* concept is characterized by three facets: (i) *Service Interaction* (that regards the flow of interactions that involves people and other kinds of resources), (ii) *Service Measure* (that concerns objective metrics, being related to "efficiency" and "efficacy" issues), and (iii) *Service Outcome* (that concerns human-valued outcomes, such as "effectiveness", "ethical", or "aesthetical" issues). *Organizational services* are services generated in the context of a *service system*. Service systems count on *facilitator* and *appraiser* sub-systems that, in fact, are *service organizations*, i.e., organizations involved in service provisions.

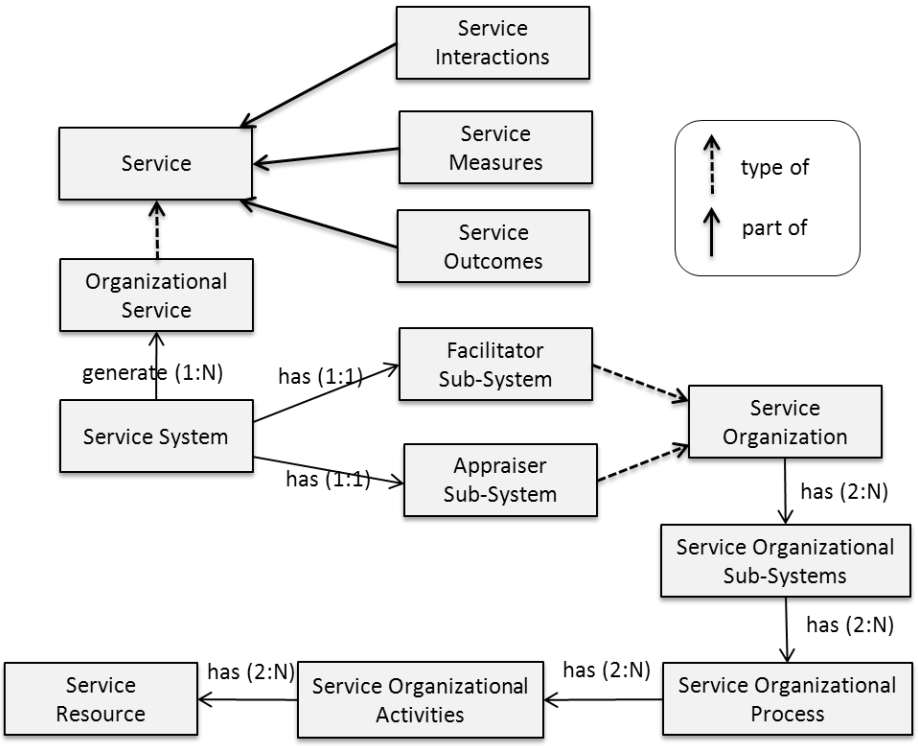


Figure 15 – A fragment of the Onto-ServSys Ontology (MORA et al., 2011).

Ferrario and Guarino propose an ontological model of services (FERRARIO; GUARINO, 2012) in which a service is taken as a complex temporal entity that occurs in a wider service system. According to them, the concept of *Service Commitment* and the concept of *Service Process* are the constituent parts of the *Service* concept. Thus, the commitments established between service customer and service provider guarantee the execution of some types of actions. Figure 16 shows a fragment of this ontology. In this model, the concepts of *Service System* (the mereological sum of all objects anyhow involved in a service) and of *Service System Life Cycle* (temporal entity corresponding to the dynamics of a service system) are central in the conceptualization. In this context, *Service Value Co-Production* is also a crucial part of the service system life cycle, being a complex process involving two symmetric value experiences: customer's value experience and provider's value experience.

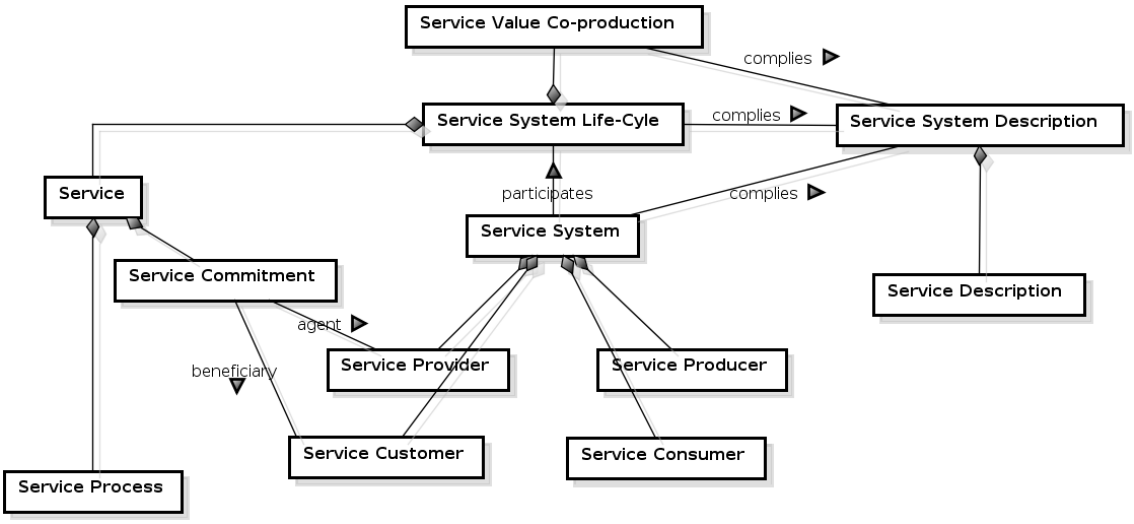


Figure 16 – A fragment of the ontological model of services by Ferrario and Guarino (FERRARIO; GUARINO, 2012).

The service conceptual model proposed by Bergholtz and colleagues (BERGHOLTZ; JOHANNESSON; ANDERSON, 2011) is based on three perspectives: "service as means for co-creation of value", "service as means for abstraction", and "service as means for providing restricted access to resources". Thus, the authors establish the notion of service by these three complementary perspectives. Figure 17 shows a fragment of this service model that puts together some concepts of these perspectives. A *Service Resource* can be used by a *Service Process* in which *Agents* (playing the roles of customer and provider) participate. The notion of *Abstract Resource* refers to the fact that sometimes, in a service provision, it may be necessary to refer to the effect brought by the use of the resource (e.g., "hair cut") instead of the resource in fact (the "scissors"). Also, service offerings make reference to *Resource Types* (e.g., "hairdresser") used in service provision. Thus, customers will have the right of count on resources (e.g., "John") that instantiate an offered resource type.

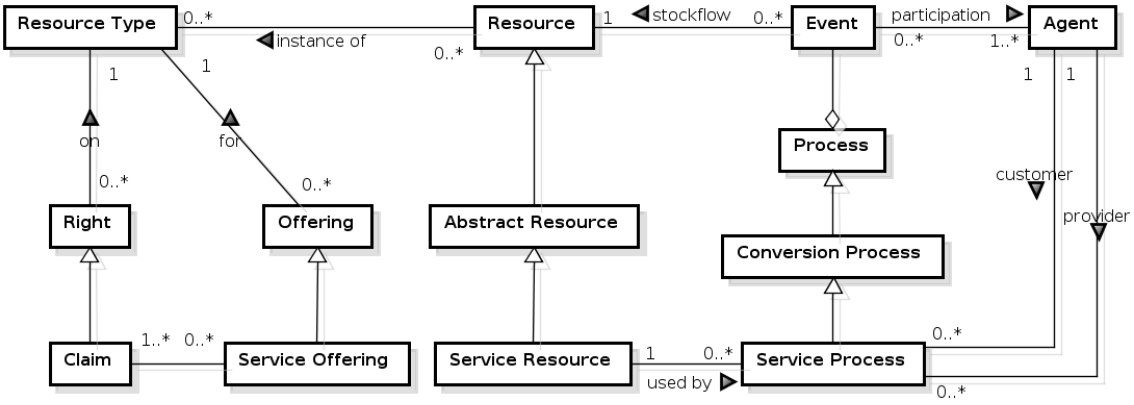


Figure 17 - Fragment of the model of service proposed by Bergholtz and colleagues (BERGHOLTZ; JOHANNESSON; ANDERSON, 2011).

Chapter 3. UFO-S: A Reference Ontology for Services

This chapter presents the well-founded core reference ontology for service developed in this thesis: UFO-S. This ontology is based on the notion of service commitments (and related aspects), and grounded in UFO (the Unified Foundational Ontology). UFO-S models are represented in OntoUML (a well-founded UML profile for ontology representation) and accompanied by a set of axioms that were defined from a formalization process based on a model simulation approach. This chapter also discusses how UFO-S (and the underlying theoretical foundation) is able to harmonize different perspectives of service, and remarks the improvements brought by UFO-S in comparison to other service ontologies and conceptual models.

3.1 Introduction

As a *core reference* ontology (SCHERP et al., 2011) (GUIZZARDI, 2007), UFO-S is designed to account for a conceptualization of services that is independent of a particular application domain, and to be applied in an off-line manner to assist humans in tasks such as meaning negotiation and consensus establishment. UFO-S intends to address the notion of service broadly, aiming at harmonizing different service perspectives found in literature, and at applying to a number of disciplines, such as Business, Service Science and Service Computing.

UFO-S is based on earlier works that treat services under the notion of *commitments* involved in the service relations, including (FERRARIO; GUARINO, 2008), (FERRARIO; GUARINO, 2012), (ALTER, 2008), (SINGH; CHOPRA; DESAI, 2009), and (MINGMING; YOUBEI, 2010). This perspective emphasizes that, throughout the service life cycle, commitments of several natures are established between service providers and service customers. We address three main aspects: (i) the characterization of commitments (and corresponding claims) in service relations; (ii) the roles played by agents in service relations, as a consequence of the established commitments; and (iii) the dynamics of the relationships between the agents along the service life cycle, in which commitments are established and fulfilled.

As a well-founded ontology, UFO-S is grounded in a *foundational ontology*, the Unified Foundational Ontology (UFO) (GUIZZARDI, 2005a) (GUIZZARDI; FALBO; GUIZZARDI, 2008) (GUIZZARDI et al., 2013). By grounding UFO-S in this foundational ontology, we are able to reveal important conceptual distinctions (e.g., objects and events, intentional and social concepts, relations and properties) that are otherwise ignored in informal characterizations of services. More specifically, by means of the notion of "relator" in UFO (as an individual that mediates parts involved in *material* relations), we could better characterize the service relations established between service participants along service life cycle. Finally, the social aspects offered by UFO were essential in the characterization of service relations as social phenomena.

UFO-S is represented in OntoUML (GUIZZARDI, 2005a), a UML profile that incorporates the foundational distinctions of UFO (UFO-A and UFO-B). Besides the benefits that come from the explicit adoption of a foundational ontology, the choice of OntoUML is further motivated by the availability of a well-maintained tool with a substantial ontology engineering support. This includes model verification (BENEVIDES; GUIZZARDI, 2009) and model validation via a visual model simulation approach (BENEVIDES et al., 2011).

For convenience, Table 5 presents the OntoUML stereotypes (and the correspondent concept in UFO) used in the following UFO-S models. In addition to the ontological concepts corresponding to such stereotypes, we further ground UFO-S with respect to the social and intentional aspects of UFO-C, which support our discussion in terms of social aspects inherent in service relations.

Table 5 - The subset of OntoUML stereotypes used in the UFO-S models.

Stereotype	Corresponding Concept in UFO
<<category>>	Category
<<kind>>	Kind
<<collective>>	Collective Universal
<<rolemixin>>	Role Mixin
<<role>>	Role
<<mode>>	Mode Universal
<<relator>>	Relator Universal
<<event>>	Event Universal

The following UFO-S models are accompanied by axioms in first-order logic that reflect relevant constraints that are not directly implied by the models. Such axiomatization was a result of a "build-and-assess" iterative model simulation approach (BENEVIDES et al., 2011), as briefly described in Section 1.6. Further details about the UFO-S formalization process can be found in Appendix B.

This chapter is structured as follows: Section 3.2 presents UFO-S by means of OntoUML models and the corresponding axiomatization; Section 3.3 presents a complete running example of UFO-S in the car rental service application domain; Section 3.4 describes how UFO-S (based on the perspective of "service as commitment") can harmonize other service perspectives; Section 3.5 compares UFO-S to other service ontologies and conceptual models; Section 3.6 discusses the polysemy associated to the term "service" and suggests a *core meaning* for the "service" concept; and, Section 3.7 presents the final considerations of this chapter.

3.2 A Commitment-based Service Ontology

UFO-S is a commitment-based service ontology whose conceptualization, in agreement with (FERRARIO; GUARINO, 2012), is based on the establishment and fulfillment of commitments and claims between *service participants* (service providers and service customers) along the service life cycle. We focus on the three main phases of the service life cycle, namely: *service offer*, *service negotiation*, and *service delivery*. Despite their relevance to certain areas of investigation (such as service marketing), we consider all service life cycle phases that occur before service offer and after service delivery as outside the scope of this work. Thus, aspects related, e.g., to service design and "after sale" actions are not taken in account by us.

The following subsections present the UFO-S models (and the correspondent axioms) for each one of the service life cycle phases addressed in this thesis.

3.2.1 Service Offer

According to our commitment-based approach, at the beginning of a service relation there is a promise, a speech act that establishes a pattern of commitments and corresponding claims. We call such speech act *service offer*, and the resulting pattern of commitments and claims *service offering.*

Figure 18 shows an OntoUML class diagram with the main concepts and relations involved in a service offering, according to UFO-S. A *service offer* event results in the establishment of a *service offering* between a *service provider* and a *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.

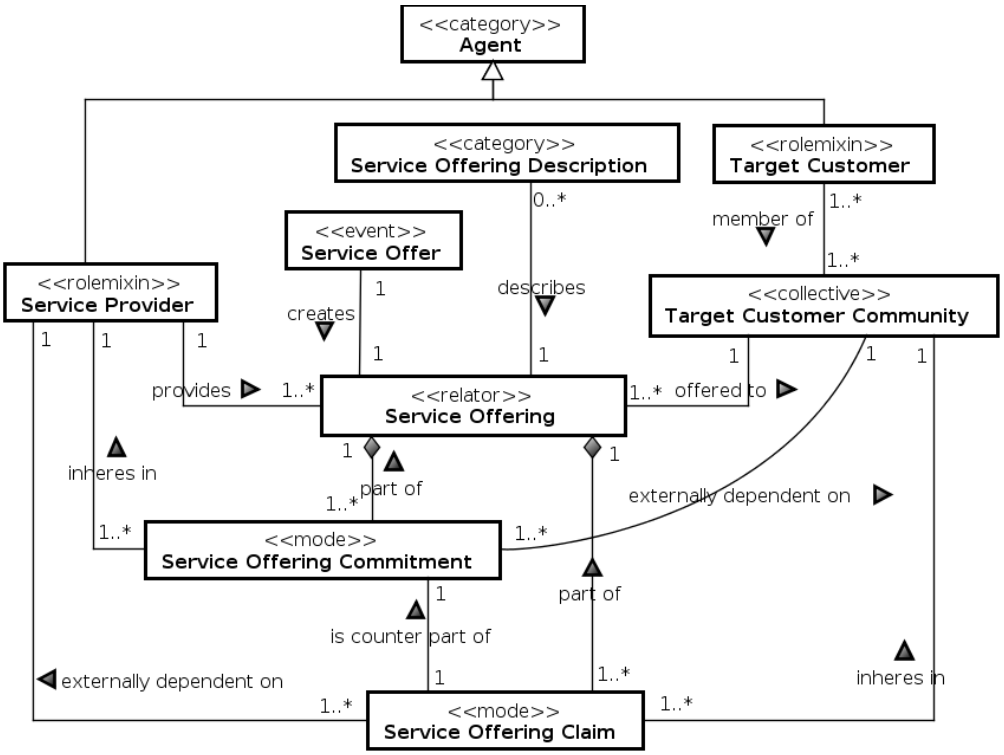


Figure 18 - Service Offer model.

According to UFO-C, a service offer is a communicative act, and what "counts as" a service offer depends ultimately on the (social) context in which services are offered. A service offer could thus be the registration of a service provider organization in a chamber of commerce, service advertisements, face-to-face communication, etc. The context will also determine the kinds of commitments that are established and the consequences that arise from a failure to fulfill such commitments. For example, in some legal systems, it is unlawful for an organization that has offered a service to refuse arbitrarily to deliver it to a particular customer unless legitimate business reasons are provided (in order to rule out arbitrary discrimination).

The actual content of service offering commitments (and corresponding claims) depends on the particular service business model, and, therefore, can refer to several

different elements, such as conditions and requirements for providing the service, types of actions to be performed in the scope of service delivery, constraints, required customer's commitments (such as payment), etc. These elements may be described in *service offering descriptions* (such as folders, registration documents in a chamber of commerce, artifacts in a service registry, etc.).

Take as example the case of a car rental service. When the service is offered by a particular car rental company, the car rental company plays the role of service provider. It commits, under certain conditions, to grant temporary use of a vehicle to a customer. Examples of such conditions include minimum period of rental, car availability, qualifications and properties of the renter (e.g., being a registered driver older than 21), expected payment guarantees, etc. The members of the target community are entitled to rent a car if all conditions are fulfilled.

What is established in a service offering also determines the level of flexibility for a subsequent service negotiation phase, in which a particular service customer and a service provider establish a particular service agreement. Because of that, *offering commitments* are in fact meta-commitments (CASTELFRANCHI, 1995) (i.e., they are commitments to accept commitments), because they refer to commitments that can be established later during the negotiation phase and that do not yet exist as a result of a service offer alone.

In UFO-S, *agent* is a category that represents the essential properties of any type of agentive substantial, such as person, organization, or software agent, which may have distinct principles of identity. *Service provider* is the role played by agents when these agents commit themselves to a target customer community by a service offer event. In terms of UFO, service provider is a role mixin, since it can be instantiated by agents of different kinds, e.g., persons and organizations. *Target customer community* is a collective that refers to the group of agents that constitute the community to which the service is being offered. The target customer community is originally established as a result of the service offer event. The agents that are members of this community play the *target customer* role. The community has a non-extensional principle of identity, in the sense that agents can enter or leave the community without altering the community's identity. The criteria for defining the target customer community membership are included in the content of the service

offering. This may range from offerings with no restrictions to strictly targeted service offerings.

A *service offering* is the social relator that arises from the *service offer* event, and that can be described by *service offering descriptions*, i.e., normative descriptions in UFO-C. A service offering is the aggregate of offering commitments and the corresponding claims. *Service offering commitments* and *claims* are social moments (in the sense of UFO-C), i.e., offering commitments are intrinsic moments, which inhere in the meta-committed agent (acting as service provider) and are externally-dependent on the target customer community. Offering claims, in turn, are intrinsic moments that inhere in the target customer community and are externally-dependent on the meta-committed agent (acting as service provider). Thus, the service provider is committed towards the target customer community to provide what is being offered to anyone of its members. As a result, we say that the target customers can claim (on behalf of the community) for the fulfillment of the service offering commitments.

Table 6 presents the axioms that accompany the UFO-S Service Offer model. These axioms ensure that the decomposition of a service offering relator into service offering commitments and claims is valid.

Table 6 - UFO-S Service Offer model axioms.

ID	Description
SO01	Service offering commitments and claims, which are counterparts, are part of the same service offering.
	∀*co*, *cl* ((ServiceOfferingCommitment(*co*) ∧ ServiceOfferingClaim(*cl*) ∧ isCounterPartOf(*cl*, *co*)) → (∃*so* (ServiceOffering(*so*) ∧ partOf(*cl*, *so*) ∧ partOf(*co*, *so*))))
SO02	Each service offering commitment that is part of a service offering inheres in the service provider that provides the service offering, and is externally-dependent on the target customer community to which this offering is offered.
	∀*co*, *so* ((ServiceOfferingCommitment(*co*) ∧ ServiceOffering(*so*) ∧ partOf(*co*, *so*)) → (∃sp, tcc (ServiceProvider(sp) ∧ TargetCustomerCommunity(tcc) ∧ provides(*sp*, *so*) ∧ offeredTo(*so*, *tcc*) ∧ inheresIn(*co*, *sp*) ∧ externallyDependentOn(*co*, *tcc*))))
SO03	Each service offering claim that is part of a service offering inheres in the target customer community to which the service offering is offered, and is externally-dependent on the service provider that provides the service offering.
	∀*cl*, *so* ((ServiceOfferingClaim(*cl*) ∧ ServiceOffering(*so*) ∧ partOf(*cl*, *so*)) → (∃*tcc*, *sp* (TargetCustomerCommunity(*tcc*) ∧ ServiceProvider(*sp*) ∧ offeredTo(*so*, *tcc*) ∧ provides(*sp*, *so*) ∧ inheresIn(*cl*, *tcc*) ∧ externallyDependentOn(*cl*, *sp*))))

3.2.2 Service Negotiation

Figure 19 shows an OntoUML class diagram with the main concepts and relationships involved in a service negotiation, according to UFO-S. Once a service offering is established, a service negotiation may occur. In general, a service negotiation is motivated by the interest of a target customer in the service offering, considering its contents (including the conditions to be satisfied by the service customer in case it hires the service provider).

During service negotiation, service provider and target customer interact in order to establish an agreement regarding their commitments and claims with respect to an eventual service delivery. 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*.

Like a service offering, a service agreement is composed of commitments and claims (which usually refer to conditions, constraints, rights, obligations, etc.). However, in contrast to the service offering, in a service agreement, service customers may also establish commitments to service providers (e.g., the commitment to pay for the service). Service agreement involves 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.

Thus, these two participants become co-responsible for the service delivery. In the case of the car rental service, when “John”, a particular target customer, goes to the “Highway Car” rental office, and rents a car, he becomes a service customer, whereas “Highway Car” acts as a hired service provider. “John” and “Highway Car” commit themselves to perform some actions and to respect certain conditions. Examples of these conditions include amount to be paid per day, period of rental, conditions of the vehicle, and so on.

A service agreement should conform to what was previously established in the corresponding service offering. A service offering is a bundle of pairs of meta-commitment/meta-claim such that each of these pairs has a propositional content of establishing (in case of agreement) pairs of commitment/claim of a given type. A conformant service agreement is a bundle of pairs of commitments/claims that

instantiate types that exists in the service offering. For example, consider that a restaurant establishes the meta-commitment of accepting the commitment of serving Caesar Salad in less than 10 minutes after order. When a customer sits down, checks the menu and orders a Caesar Salad via the waiter (an event which can be understood as a simplistic service negotiation leading to a service agreement), the restaurant becomes committed towards that customer to serve a Caesar Salad in less than 10 minutes. In that moment, we can say that the meta-commitment was fulfilled. Thus, an agreement *X* conforms to an offering *Y* if every pair of commitment/claim in *X* is of a type *T* that is referred to by a pair of meta-commitment/meta-claim in *Y*.

As in the case of a service offer, what is agreed between the parties (commitments and claims of both hired provider and service customer) depends on the context in which the service agreement is established (e.g., current laws), as well as on service business model performed by the service provider, and, therefore, can refer to several different aspects. These aspects may be described in *service agreement descriptions* (such as a service contract).

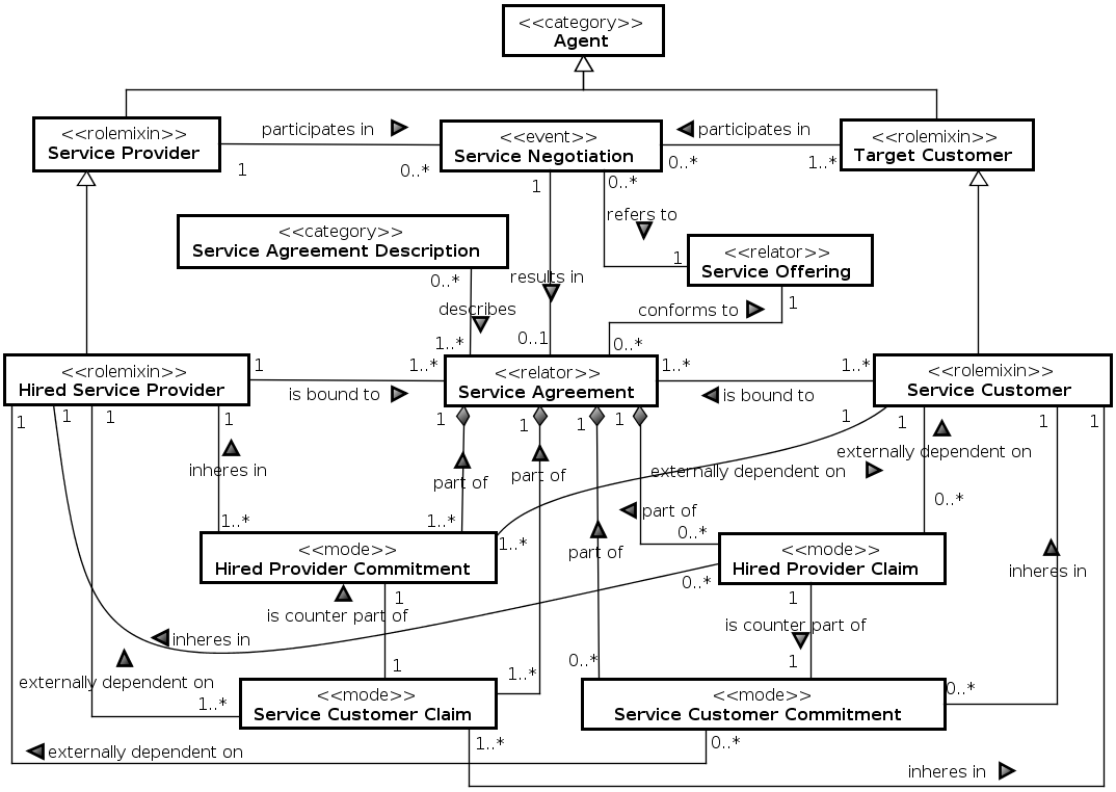


Figure 19 - Service Negotiation model.

In terms of UFO-C, a service negotiation is an *interaction* involving the participations of the service provider and the target customers. When a service negotiation (an *event*) succeeds, this event is the foundation for a service agreement (a *relator*). Hired provider and service customer commitments and claims are *social moments*. Hired provider commitments and claims are intrinsic moments that inhere in a hired service provider and are externally-dependent on a service customer. Service customer commitments and claims are intrinsic moments that inhere in a service customer and are externally-dependent on a hired service provider.

In a manner analogous to how a service offering (as a social relator) mediates the relation between a service provider and a target customer community by aggregating offering commitments and claims, a *service agreement* mediates the relation between a hired service provider and service customers. As such, a service agreement is also a social relator, but composed by the *hired provider commitments and claims* and the *service customer commitments and claims*.

The role of *hired service provider* is played by an agent *A*, when this agent commits itself to an agent *B* (playing the role of service customer) to perform actions or to achieve the results determined in the service agreement. This means that a service agreement includes a delegation relation (GUIZZARDI, 2006): when establishing a service agreement, agent *B*, who plays the role of service customer, delegates a goal/plan to the agent *A*, who plays the role of hired service provider. Thus, claims of *B* towards *A*, and commitments of *A* towards *B* are created, since *A* has committed to pursue the *delegated goal* or to execute the *delegated plan* in terms of UFO-S.

Depending on the business service model, this delegation may be open or closed (GUIZZARDI, 2006). In *open delegation,* the hired service provider is free to determine how a commitment is to be fulfilled, which may include further delegation (common in service systems and economic networks). On the other hand, in *closed delegation*, the hired service provider commits to the execution of a pre-defined plan (i.e., instantiating an agreed action universal).

When agent *B* delegates a goal/plan to agent *A*, *B* becomes (at some level) dependent on *A*. Thus, before hiring a service (and, therefore, establishing a delegation), the customer typically makes an analysis of feasibility, not only associated to monetary aspects, but also to aspects such as dependency, rights and commitments

to be established. Considering the notion of co-responsibility arisen by the mutual commitments, the hired service provider also depends on the service customers for the fulfillment of their own commitments (e.g., a consultancy firm needs access to information from customers in order to provide its services). Thus, in the context of a service agreement, the agent who plays the role of hired service provider (*A*) is also dependent on the agent who plays the role of service customer (*B*).

Table 7 presents the axioms that accompany the UFO-S Service Negotiation model. For the sake of brevity, we omit here the axioms that constrain the decompositions of agreements. These axioms are similar to those that were introduced to constrain the decomposition of offerings (SO01-SO03 in Table 6).

Table 7 - UFO-S Service Negotiation model axioms.

ID	Description
SN01	When a service negotiation results in a service agreement, that agreement must conform to the offering to which the negotiation refers.
	$\forall sn, sa$ ((ServiceNegotiation(sn) $\wedge$ ServiceAgreement(sa) $\wedge$ resultsIn(sn, sa)) $\rightarrow$ ($\exists so$ (ServiceOffering(so) $\wedge$ conformsTo(sa, so) $\wedge$ refersTo(sn, so))))
SN02	An agent cannot simultaneously play the roles of service provider and target customer in the same service negotiation.
	$\forall sp, tc, sn$ ((Agent(sp) $\wedge$ Agent(tc) $\wedge$ ServiceNegotiation(sn) $\wedge$ participatesIn(sp, sn) $\wedge$ participatesIn(tc, sn)) $\rightarrow$ ($sp \neq tc$))
SN03	The service provider that participates in a service negotiation provides the service offering to which the negotiation refers.
	$\forall sp, sn$ ((ServiceProvider(sp) $\wedge$ ServiceNegotiation(sn) $\wedge$ participatesIn(sp, sn)) $\rightarrow$ ($\exists so$ (ServiceOffering(so) $\wedge$ provides(sp, so) $\wedge$ refersTo(sn, so))))
SN04	Every target customer that participates in a service negotiation is a member of the target customer community to which the service offering is offered.
	$\forall tc, sn$ ((TargetCustomer(tc) $\wedge$ ServiceNegotiation(sn) $\wedge$ participantesIn(tc, sn)) $\rightarrow$ ($\exists tcc, so$ (TargetCustomerCommunity(tcc) $\wedge$ ServiceOffering(so) $\wedge$ memberOf(tc, tcc) $\wedge$ offeredTo(so, tcc))))
SN05	The agents that are bound to a service agreement as hired service provider and service customer, have acted, respectively, as service provider and target customer in the service negotiation that resulted in this agreement.
	$\forall sc, hsp, sa$ ((ServiceCustomer(sc) $\wedge$ HiredServiceProvider(hsp) $\wedge$ ServiceAgreement(sa) $\wedge$ isBoundTo(sc, sa) $\wedge$ isBoundTo(hsp, sa)) $\rightarrow$ ($\exists sn$ (ServiceNegotiation(sn) $\wedge$ resultsIn(sn, sa) $\wedge$ participatesIn(sc, sn) $\wedge$ participatesIn(hsp, sn))))

3.2.3 Service Delivery

Service delivery concerns the execution of actions aimed at fulfilling the commitments established in the service agreement. 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.

Figure 20 shows an OntoUML class diagram presenting the main concepts and relations involved in service delivery according to UFO-S. *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 (*customer actions*), and actions performed by both in an 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 actions to a third-party. These actions are also part of the service delivery process, although they are not explicitly represented in Figure 20.

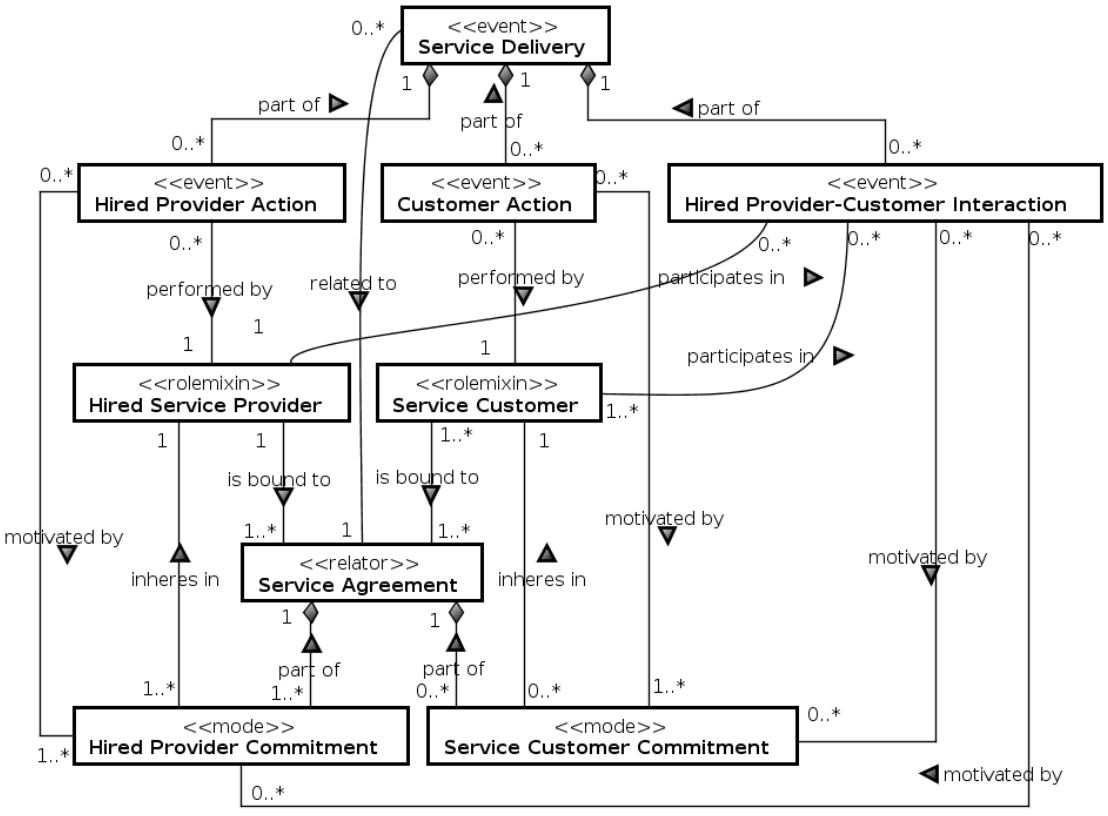


Figure 20 - Service Delivery model.

Table 8 presents the axioms that accompany the UFO-S Service Delivery model.

Table 8 - UFO-S Service Delivery model axioms.

ID	Description
SD01	Every service delivery has at least one part that is a hired provider action, a customer action, or a hired provider customer interaction.
	$\forall e$ (ServiceDelivery(e) → ($\exists e'$ (partOf(e, e') ∧ (HiredProviderAction(e') ∨ CustomerAction(e') ∨ HiredProviderCustomerInteraction(e')))))
SD02	The commitments that motivate a hired provider action inhere in the hired service provider that performs the action.
	$\forall ac, co$ (((HiredProviderAction(ac) ∧ HiredProviderCommitment(co) ∧ motivatedBy(ac, co)) → ($\exists hsp$ (HiredServiceProvider(hsp) ∧ inheresIn(co, hsp) ∧ performedBy(ac, hsp))))
SD03	The commitments that motivate customer action inhere in the service customer that performs the action.
	$\forall ac, co$ ((CustomerAction(ac) ∧ ServiceCustomerCommitment(co) ∧ motivatedBy(ac, co)) → ($\exists sc$ (ServiceCustomer(sc) ∧ inheresIn(co, sc) ∧ performedBy(ac, sc))))
SD04	Each hired provider-customer interaction is motivated by at least one commitment (a hired provider commitment or a service customer commitment).
	$\forall i$ (HiredProviderCustomerInteraction(i) → ($\exists co$ ((HiredProviderCommitment(co) ∨ ServiceCustomerCommitment(co)) ∧ motivatedBy(i, co))))
SD05	The hired provider commitments that motivate a hired provider-customer interaction inhere in the hired service provider that participates in the interaction.
	$\forall i, co$ ((HiredProviderCustomerInteraction(i) ∧ HiredProviderCommitment(co) ∧ motivatedBy(i, co)) → ($\exists hsp$ (HiredServiceProvider(hsp) ∧ inheresIn(co, hsp) ∧ participatesIn(hsp, i))))
SD06	The service customer commitments that motivate a hired provider-customer interaction inhere in a service customer that participates in the interaction.
	$\forall i, co$ ((HiredProviderCustomerInteraction(i) ∧ ServiceCustomerCommitment(co) ∧ motivatedBy(i, co)) → ($\exists sc$ (ServiceCustomer(sc)) ∧ inheresIn(co, sc) ∧ participatesIn(sc, i))))
SD07	Each hired provider action that is part of a service delivery related to a service agreement is performed by the hired service provider bound to that agreement.
	$\forall ac, sa, sd$ ((ServiceDelivery(sd) ∧ HiredProviderAction(ac) ∧ ServiceAgreement(sa) ∧ partOf(ac, sd) ∧ relatedTo(sd, sa)) → ($\exists hsp$ (HiredServiceProvider(hsp) ∧ performedBy(ac, hsp) ∧ isBoundTo(hsp, sa))))
SD08	Each customer action that is part of a service delivery related to a service agreement is performed by the service customer bound to that agreement.
	$\forall ac, sa, sd$ ((ServiceDelivery(sd) ∧ CustomerAction(ca) ∧ ServiceAgreement(sa) ∧ partOf(ac, sd) ∧ relatedTo(sd, sa)) → ($\exists sc$ (ServiceCustomer(sc) ∧ performedBy(ac, sc) ∧ isBoundTo(sc, sa))))
SD09	Each hired provider-customer interaction that is part of the service delivery related to a service

	agreement, has the participation of the hired service provider and some service customers bound to that agreement.
	∀*i*, *sd*, *sa* ((HiredProviderCustomerInteration(*i*) ∧ ServiceDelivery(*sd*) ∧ ServiceAgreement(*sa*) ∧ partOf(*i*, *sd*) ∧ relatedTo(*sd*, *sa*)) → (∀*ag* (participatesIn(*ag*, *i*) → ((HiredServiceProvider(*ag*) ∨ ServiceCustomer(*ag*)) ∧ isBoundTo(*ag*, *sa*)))))

3.3 A Complete Example: A Car Rental Service

In this section we present an example in the car rental service application domain. This example encompasses all the service life cycle phases (service offer, service negotiation/agreement, and service delivery) addressed by UFO-S.

We use a tabular approach that describes an instantiation of UFO-S concepts. This tabular approach is inspired by Alter's "service responsibility tables" (ALTER, 2008), and Ferrario and Guarino's adaptation of that idea (FERRARIO; GUARINO, 2008). The example reflects terms and conditions of car rental services found in contracts and in specialized websites available on the Internet. Also, it is organized in three tables, each of which concerns the different service life cycle phases: service offer (Table 9), service negotiation (Table 10) and service delivery (Table 11).

Table 9 concerns the service offer phase in which "Find a Car Inc." offers a car rental service towards its target community. In this example, the event of registration of the car rental service in a chamber of commerce is considered to create a service offering from "Find a Car Inc.". The content of this service offering is described in registration documents on the chamber of commerce (and may also be referred to in marketing folders and other kinds of publicity).

Besides the description of the target community's profile (the criteria for being a member of the community), the content of the service offering also includes the service offering commitments that "Find a Car Inc." (as a service provider) establishes towards the target community. Thus, "Find a Car Inc." is then committed to provide this service for all the member of the community. "Jack", "John", "Mary", and "XYZ Bookstore Inc." are examples of members of this community (target service customer) by fitting the defined target community's profile.

In terms of UFO-S, in the service offer phase, only the service provider is committed to the target community (by means of service offering commitments). The target community has no commitments towards the provider. Despite that, when

making an offering, the service provider usually makes reference to conditions that he/she expects to be fulfilled in the case of a future service agreement. These conditions will become commitments from service customer towards the hired service provider in the case of a successful service negotiation.

Since service claims are just counter parts of the service commitments, for sake of simplicity they were not represented on the tables.

Table 9 – Service offer phase: "Find a Car Inc. offers a car rental service".

Concepts	Instantiation(s) in the Example	Relationship(s)
Service Offer	Registration of the car rental service by "Find a Car Inc." in the chamber of commerce.	**creates** the car rental service offering
Service Provider	"Find a Car Inc." (an Agent that plays the role of Service Provider)	**provides** the car rental service offering
Target Customer Community	The community of people or enterprises that are able to rent a car from "Find a Car Inc.", including "Jack", "John", "Mary", "XYZ Bookstore Inc." etc.	
Target Customer	"Jack", "John", "Mary", "XYZ Bookstore Inc." etc.	is **member of** the car rental service target customer community
Service Offering	The car rental service offering made by "Find a Car Inc." (towards the target customer community)	is **offered to** the car rental service target customer community
Service Offering Description	Registration documents in the chamber of commerce (but also marketing folders, and/or publicity material).	**describes** the car rental service offering made by "Find a Car Inc."
Service Offering Commitment	In a particular service agreement, "Find a Car Inc.", will: - provide a clean and ready-to-use car to its service customers (from the to be agreed category and in the to be agreed date). - replace the rented car in case of failure As long as service customer commits to: - pay the rental fee according to the table of "vehicle categories and prices" - pay fines due to delays according to the table of "vehicle categories and prices" - pay for damages in the car which do not result from normal use	is **part of** the car rental service offering **inheres in** "Find a Car Inc." is **externally dependent on** the car rental service target customer community

Table 10 presents a service negotiation between "Find a Car Inc." (as a service provider) and "Jack" (as a target customer) that resulted in a service agreement between them. This specific service negotiation results in a service agreement, which conforms to the service offering by "Find a Car Inc.". From now on, "Jack" and "Find a Car Inc." play, respectively, the service customer and the hired service provider roles. As such, they are bound to a car rental service agreement.

The content of this agreement is described in a car rental service contract (service agreement description). Thus, the contract includes the "Find a Car Inc." commitments (hired service commitments) and the Jack's commitments (service customer commitment), since both parties are mutually committed in this agreement.

The commitments in a service agreement usually refer to the specific terms and conditions discussed in the negotiation. For example, whereas the service offering commitment does not refer to a specific value to be payed, the service costumer commitment defines a specific value ("$ 1000,00") for the car rental (regular) period. Also, we can notice that some service customer commitments are directly derived from conditions/expected situations indicated in the service offering commitments.

For example, the service customer commitment refers to "*Pay US$ 100,00 per day of delay*". This is related to what is referred by the service offering commitment as "*As long as service customer commits to:[…] pay fines due to delays according to the table of 'vehicle categories and prices'*". Thus, besides returning the rented car, the service customer is also committed to pay fines for any delay. In fact, there is an interesting relation between service offerings and service agreements. The former present a kind of schema, more general, that can accommodate a number of variations in a certain space of negotiation. In the latter, therefore, this schema is defined by means of values and conditions within this (allowed) space of negotiation.

Table 10 - Service negotiation phase: "Find a Car Inc." and "Jack" enter into a service agreement.

Concepts	Instantiation(s) in the Example	Relationship(s)
Service Negotiation	A negotiation event (interaction) between "Find a Car Inc." (as a service provider) and "Jack" (as a target customer).	**results in** the car rental service agreement between "Find a Car Inc." and "Jack". **refers to** the car rental service offering by "Find a Car

		Inc.”
Service Provider	“Find a Car Inc.” (an Agent playing the role of Service Provider)	**participates in** the car rental service negotiation with “Jack”.
Target Customer	“Jack” (an Agent playing the role of Target Customer)	**participates in** the car rental service negotiation with “Find a Car Inc.”
Hired Service Provider	“Find a Car Inc.” (an Agent and Service Provider now playing the role of Hired Service Provider)	**is bound to** the car rental service agreement with “Jack”
Service Customer	“Jack” (an Agent and Target Customer now playing the role of Service Customer)	**is bound to** the car rental service agreement with “Find a Car Inc.”
Service Agreement	A service agreement between “Find a Car Inc.” (as hired service provider) and “Jack” (as service customer).	**conforms to** the car rental service offering by “Find a Car Inc.”
Service Agreement Description	The car rental service contract between “Jack” and “Find Car Inc.”.	**describes** the car rental service agreement between “Jack” and “Find Car Inc.”.
Hired Provider Commitment	In the agreement established between "Jack" and "Find a Car Inc." in the date of 21/10/2014, “Find a Car Inc.” is committed to: - provide a clean and ready-to-use <<economy car>> from 21/10/2014 to “Jack” - replace the rented car in case of failure	is **part of** the car rental service agreement between “Find a Car Inc.” and “Jack” **inheres in** “Find a Car Inc.” is **externally dependent on** “Jack”
Service Customer Commitment	In the agreement established between "Jack" and "Find a Car Inc." in the date of 21/10/2014, “Jack” is committed to: - pay $ 1000,00 - pay US$ 100,00 per day of delay - pay for damages in the car which to not result from normal use	is **part of** the **car rental service agreement** between “Find a Car Inc.” and “Jack” **inheres in “**Jack**”** is **externally dependent on** “Find a Car Inc.”

Table 11 presents the actions performed by “Find a Car Inc.” and by “Jack” during service delivery. In this example, service delivery is a complex event spanning from the provision of a car by “Find a Car Inc.” to the return of this car by “Jack”. This event is composed by actions performed by “Find a Car Inc.” (e.g., “*Clean car”*), actions performed by “Jack” (e.g., “*Pay $1000*”), and interactions performed by both (e.g., *“Deliver the car*”, and “*Return the car*”). These (inter)actions are motivated by the service customer commitments and hired provider commitments established in the

service agreement. Thus, in terms of UFO-S, the service delivery event is related to the service agreement whose commitments motivate (inter)actions that compose this event.

Table 11 - Service delivery phase: "Find a Car Inc." and "Jack" act in the service delivery.

Concepts	Instantiation(s) in the Example	Relationship(s)
Service Delivery	The (complex) event regarding the delivery of what was agreed between "Find a Car Inc." (as a hired service provider) and "Jack" (as service a customer).	**related to** the car rental service agreement between "Find a Car Inc." and "Jack".
Hired Provider Action(s)	- Clean and prepare the car.	**part of** the car rental service delivery agreed between "Find a Car Inc." and "Jack". **performed by** "Find a Car Inc." **motivated by** the hired provider commitment of "Find Car Inc."
Customer Action(s)	- Pay $1000. (no fine or damages to be payed)	**part of** the car rental service delivery agreed between "Find a Car Inc." and "Jack". **performed** by "Jack". **motivated by** the Jack's service customer commitment
Hired Provider-Customer Interaction(s)	- Deliver the car. - Return the car.	**part of** the car rental service delivery agreed between "Find a Car Inc." and "Jack". "Find a Car Inc." and "Jack" **participates in** the "deliver the car" and "return the car" interactions. **motivated by** the hired provider commitment of "Find Car Inc.", and by the Jack's service customer commitment

3.4 Applying UFO-S to Various Perspectives on Services

In this section, UFO-S is assessed by showing how it explicates and harmonizes some service perspectives. In the terminology for design science research (HEVNER; CHATTERJEE, 2010) (HEVNER et al., 2004), this amounts to a "descriptive evaluation" of UFO-S as a design artifact.

We consider four service perspectives, taking as basis important service characterizations found in literature (see Section 2.2). Table 12 presents the service perspectives and the corresponding service characterizations considered in this thesis. Although we do not aim at stressing all possible service perspectives and characterizations, the ones enumerated in Table 12 constitute an important and useful baseline for the following analysis.

Table 12 – Service perspectives and corresponding service characterizations.

Service Perspective	Service Characterization
Service as value co-creation	Service as value co-creation
Service as Capability and Application of Competences	Service as capability
	Service as application of competences
Service as Behavior	Service as (production) process
	Service as activity/functionality
	Service as interaction
Computational Service	Service as software

3.4.1 Service as Value Co-Creation

The literature on services often identifies the creation of value as the "raison d'être" for services, i.e., services exist for service participants to benefit or to extract value from their participation. Maglio and colleagues (MAGLIO; SPOHRER, 2008), for example, have characterized service systems as dynamic configurations of resources capable of providing benefit to other service systems, forming dynamic network structures "(1) capable of improving the state of another system through sharing or applying its resources [...] and (2) capable of improving its own state by acquiring external resources" (MAGLIO et al., 2009). Vargo and Lusch have pushed this notion to the extreme, characterizing services as the fundamental basis of value creation through exchange ("all economies are service economies") (VARGO; LUSCH, 2004). In

(MAGLIO et al., 2009), the authors have explained that “service systems engage in three main activities in order to co-create value: (1) proposing value, (2) accepting a proposal, and (3) realizing the proposal”.

In UFO-S, agents become service providers and service customers by participating in intentional actions (service offer and service negotiation). According to UFO-C, all actions are motivated by agents’ goals and beliefs, even if the result of the actions does not match these goals. Thus, entering into service commitments is motivated by the goals of service providers and service customers, and the beliefs they hold towards service commitments, e.g., that performing a service offer or establishing a service agreement will lead to benefits. However, entering into such commitments cannot be said to guarantee the accomplishment of the motivating goals, e.g., because agents may fail to fulfill their commitments. Even in case agents fulfill their commitments, they may not achieve the goals that led them to enter into these commitments yet, unless in the trivial case in which the satisfaction of the goals is entailed by the fulfillment of commitments.

Whether or not value is produced in the service life cycle is, in fact, a subjective notion, which depends on how the service participants assess their participations, i.e., whether they ascribe to the experience in the service life cycle a positive assessment. Regarding this, we agree with Vargo and Lusch when they discuss that “value is always uniquely and phenomenologically determined by the beneficiary” and that “value is idiosyncratic, experiential, contextual, and meaning laden” (STEPHEN L. VARGO; AKAKA, 2009). As such, value cannot be (directly) transferred or exchanged. Thus, we refrain from using terminology that would suggest otherwise such as “transfers of value” and “service value exchange”. This terminology was used initially by Ferrario and Guarino in (FERRARIO; GUARINO, 2008), but then abandoned it in (FERRARIO; GUARINO, 2012), when they say that “it is service, not value that is exchanged, because value is subjective”. This is not to say that there are no objective outcomes or effects of the actions performed in order to fulfill service commitments. However, the value ascribed to these actions and the situations that are brought about by these actions are subjective.

3.4.2 Service as Capability and Application of Competences

Many authors have characterized services by focusing on the *capability* of providers to produce benefits to customers (e.g., (OASIS, 2006)(RUOKOLAINEN, 2013)) or on the *application of such capabilities (competences)* of one party in benefit of another party (VARGO; LUSCH, 2004).

This is accounted for in UFO-S by means of the notions of "dispositions" and their "manifestations" (through events) provided by UFO. We regard a capability or competence as a disposition of an agent, be it human or organizational, which under certain conditions is manifested in actions, such as those in the service life cycle. By combining this explanation with the notion of commitment, UFO-S reveals an important distinction, namely that between: (i) possessing a capability to perform certain actions or to produce certain outcome, i.e., bearing a certain disposition, and (ii) employing capabilities in order to fulfill social commitments, i.e., manifesting the disposition motivated by social commitments. The former is not sufficient for services, since the capability of an organization to wash cars (cf. (i)) does not automatically make it a car wash service provider. In fact, an agent as a service provider must be committed to apply systematically its capabilities, according to some terms and conditions, benefit of a service customer. Also, even an organization that is not capable, by itself, of "washing cars" may still offer a car washing service, delegating the actual car washing to a third party that is capable of doing it. Thus, the capability manifested by the provider is not that of "car washing", but that of "delegating it to a capable party" (GUIZZARDI; GUIZZARDI, 2010), and ultimately, of "delivering car washing service". In any case, the picture is only complete by considering commitments that influence the manifestation of dispositions (cf. (ii)).

Usually in service agreements not only providers but also customers commit themselves to manifesting capabilities under specific conditions. For example, while an online shop commits itself to manifest its capability of shipping goods, the customer commits himself to manifest his capability of paying for the purchased goods, providing accurate information for delivery, ensuring that someone is present at the delivery address to receive the goods during delivery hours, and so on. This view emphasizes the aspect of co-production of services that was discussed in the original

Service-Dominant logic article (VARGO; LUSCH, 2004), and further shows that the asymmetry in the service provider/service customer relation cannot be explained solely by the application of competences of one party on the behalf of another, because the customer also employs its competences to the benefit of the provider. In order to account for the asymmetry, we need to consider the life cycle of (meta-) commitments (service offering and service agreement) as discussed in Section 3.2.

Finally, the notion of capabilities/competences manifested in service relations is also related to the notion of resources applied in the service provision. A resource can be understood as a role an individual (agent or object) plays when employed in the scope of the efforts to achieve goals (AZEVEDO et al., 2013). For example, the specific soap "X" used in a car washing company is a resource applied for cleaning cars. This soap has the capability (or disposition in terms of UFO) of removing smudges. "John", in turn, is a human resource that acts cleaning cars in the same car washing company. "John" has the capability of cleaning cars. Thus, the car washing company, by counting on its resources, has the capabilities necessary for providing the service of cleaning cars, and then, can fulfill the established service commitments.

3.4.3 Service as Behavior

The notion of service is also characterized by behavioral aspects that arise from the interaction between service provider and service customers. As such, the notion of service has been associated with concepts, such as interaction, process, and functionality/function. In this section, the term "behavior" encompasses all of these concepts.

In (QUARTEL et al., 2007), Quartel et al. propose, at a high-level of abstraction, that a service can be considered as a single interaction between a "service user" and a "provider". This interaction represents an (atomic) activity in which the involved participants produce some common result in cooperation. At this level of abstraction, the focus is on what is produced and not on how it is done. Further, at a lower level of abstraction, a service can be regarded "as multiple related interactions between a service user and provider" (QUARTEL et al., 2007). Thus, a service as an interaction can be successively refined from the higher abstraction level (atomic activity) to the lower one (multiple related interactions).

In the context of the Unified Service Theory (SAMPSON, 2010b), Sampson defines the concept of service as a "production process" for which the customers provides significant inputs. In essence, service processes differ from other production processes, because the former obtains inputs from customers (e.g., information). Thus, "service processes" are distinguished from non-service process (manufacturing or extractive processes) only by the presence of customer inputs (and implications thereof). In non-service processes, the participation of customers is limited, e.g., to select and consume outputs, not contributing with inputs necessary for the production process (SAMPSON; FROEHLE, 2006). According to Sampson, input refers specifically to components (resources) used in production, and not, e.g., payments after production or ideas about processes or outcomes (feedback). Sampson also admits co-production (kind of interaction), mainly in the case of what is called "customer-self inputs", i.e., when the customer employs her labor in the service process.

ArchiMate is an enterprise architecture modeling framework (THE OPEN GROUP, 2012) in which the concept of service is based on the notion of "unit of functionality", which is applied as a basic structuring element through the enterprise architecture layers ("Business", "Application", and "Infrastructure" layers). Thus, business services and computational (application and infrastructural) services are characterized as behavioral elements (a kind of "function") that can be "used by" service customers. Besides being considered a behavioral element in ArchiMate, a service is "realized by" other behavioral elements such as processes, functions, and interactions, which reinforces the behavioral characterization of service in this framework.

In (TERLOUW; ALBANI, 2013), Terlouw and Albani propose a definition for service that is based on the idea of transaction. However, in the case of service relations, the focus of the transaction is more on executor-side (service provider in terms of UFO-S) than on initiator-side (service customer in terms of UFO-S). This notion is applied for specifying what is called "human services" (services implemented by human beings) and "IT services" (services implemented by IT systems). Terlouw and Albani highlight the importance of a comprehensive service specification approach, and focus on the analysis of "what" should be specified, instead of on "how". Similarly to UFO-S, Terlouw and Albani use a theoretical basis (the ψ-Theory) for grounding the

characterization of service. According to this theoretical basis, the notion of service is based on two types of acts that are performed by actors involved in transactions: coordination acts and production acts. By production acts, actors contribute to bring about the actual function of the organization, i.e., they deal with delivering material or immaterial goods. By coordination acts (request, quit, reject and accept), actors enter into and comply with commitments regarding production acts, i.e., they coordinate the execution of production acts. These acts are taken as part of a transaction, which encompasses three phases: order phase, execution phase, and result phase. The order phase is quite similar to service negotiation and agreement in terms of UFO-S, for example, when coordination acts are performed to establish commitments. The execution phase is related to the delivery phase in UFO-S, when actions are performed in order to fulfill commitments. In the result phase, coordination acts are also performed in order to evaluate and define if what was performed is in conformance to what was committed in the service negotiation.

The aforementioned works illustrate that “service as behavior” is an important perspective that has been applied for characterizing the notion of service. Nevertheless, as we have discussed in the example of the insurance service, it is possible that there is no action during service delivery and still the service is provided, due to the existence of the service agreement. Further, service delivery includes all actions caused by the intention to fulfill a service agreement, including those referred to in the content of the service agreement, in the case of closed delegation. In this case, the service agreement can refer to the planned actions (type of actions) that may be performed (instantiated) in case of a trigger event (e.g., an accident). In terms of UFO-S, depending on the particular business service model, service agreements may refer to types of customer-side actions, provider-side actions, interactions between provider and customer, or even third-party participations. For example, in the case of the car wash service, the service agreement may include that the car should be vacuum cleaned, specifying thus a type of action that the provider is responsible to perform during service delivery.

Finally, in light of (GUARINO, 2013), we can say that, by considering social commitments, we bring the notion of service at a new level (so-called “mesoscopic”), in which the service relations are analyzed at a coarser-grained granularity, so that

these relations are business activities that involve more than just service delivery actions/interactions. Thus, while the view defended in UFO-S encompasses that of "service as behavior", we conclude that services should not be reduced only to interactions, and that a broad account must also include the notion of commitments. Moreover, UFO-S considers that interactions occur in other phases of the service life cycle, e.g., when a service agreement is negotiated.

3.4.4 Computational Services

In computer science, the notion of service has been used and defended as a software design paradigm for over three decades. Regarding to this perspective, services are, generally speaking, described/specified in terms of Inputs, Outputs, Pre-conditions, and Effects (hence the acronym IOPE) forming together a kind of "contract". In fact, many of the current service-oriented software specification approaches are influenced by the "design by contract" paradigm (MEYER, 1992), which was initially applied in object-oriented software engineering for building reliable (i.e., correct and robust) software components. As such, 'clients' and 'suppliers' have 'obligations' and 'benefits' (translated in terms of inputs, outputs, pre-conditions, and post-conditions) described by means of contracts (software specifications), which drive the tasks and interactions among software components.

In the context of data communication protocols, for example, service is characterized as "observable behavior" (VISSERS; LOGRIPPO, 1986). In that view, a service specification does not reveal the service provider's internal structure, but it just defines the provider's behavior as it can be observed from outside (QUARTEL et al., 2007)(VISSERS; LOGRIPPO, 1986). This notion of *observable behavior* can be accounted for in UFO-S, since it is possible to define a particular kind of service whose service agreement does not refer to how the commitments are fulfilled, by using open delegation. For example, the provider's commitments towards the service customer can just refer to what is committed to be produced (in terms of outputs and effects) when the expected inputs are received under the appropriate pre-conditions. In contrast, the customer may claim the fulfillment of these commitments when accessing the service as specified.

In a computational service-oriented architecture (such as that discussed in (W3C, 2004a)), what counts as a service offer is typically the publication or registration of a service description, or the definition of a *contract* (in the sense of the "design by contract" approach (MEYER, 1992)). In this case, the service offering description (in UFO-S) is often reduced to descriptions of operations (functions) that are typically characterized by a pair of "interaction types and their constraints" (possibly relating other operations). These service descriptions can be specified in many fashions, such as, by means of WSDL documents or API (Application Programming Interface) descriptions in natural language.

In UFO-S, such operations can be considered as units of service delivery. So, an operation invocation can count as an implicit and trivial service negotiation, which presupposes an agreement on a pre-defined kind of service offer. In any case, whether service negotiation is implicit, explicit, online or offline, the notion of commitment is instrumental in explaining both the semantics of service description publications and the establishment of service agreements, insofar it characterizes the service relations established between intentional agents (customers and providers) in the context of such offers and negotiations.

Despite the particularities of computational services, we can say that the notion of service commitment establishes a link between the business and computational views. This is because commitments established between organizational and human agents affect aspects existing at the computational level. The agent that provides a computational service (i.e., the provider) has to establish all IT infrastructure necessary and "guarantee" that it works as offered/agreed. By offering an interface through which certain capabilities are leveraged, an operation or a software application are driven by a set of aspects (such as response time, semantics of data, and (possibly) the steps followed by the operation / application) in order to produce the expected outcome. The agent (i.e., the customer) that accesses the operation / application, in turn, has to respect all of these aspects (a set of constraints) in order to get the expected result. These aspects, therefore, can be described in terms of (mutual) commitments, and can be established at business level, constraining the implementations of services in operations or in applications. Therefore, the notion of service commitments and claims offers an important mindset towards establishing a

unified view on Business and Information Technology (IT), since it allows one to characterize business level services as well as computational level services by means of the same fundamental concepts.

3.4.5 UFO-S and Service Perspectives

Figure 21 presents a schema that summarizes how UFO-S (by considering the "service as commitment" perspective) relates/harmonizes the other service perspectives. In summary, we advocate that the various service perspectives are related at some level, mainly through the notion of service commitments.

For example, during the interactions between service provider and service customer in a service delivery ("service as behavior"), these agents can apply their capabilities/resources in benefit of each other ("value co-creation"). However, in order to characterize these interactions and applications of capabilities/resources in the context of a service provision, we should take into account the mutual service commitments and claims established between these service participants. The service commitments and claims act as a "glue" in service relations, and characterize these kind of relations even if no action is performed or any capability is applied.

Further, the notion of service commitment is related to the experience of value in service relations as agents enter into service commitments seeking to benefit from these commitments. The fulfillment of these commitments may "create value". Finally, we have shown that computational services are also characterized by commitments and claims, even in the cases in which these commitments and claims are not explicitly represented in computational artifacts.

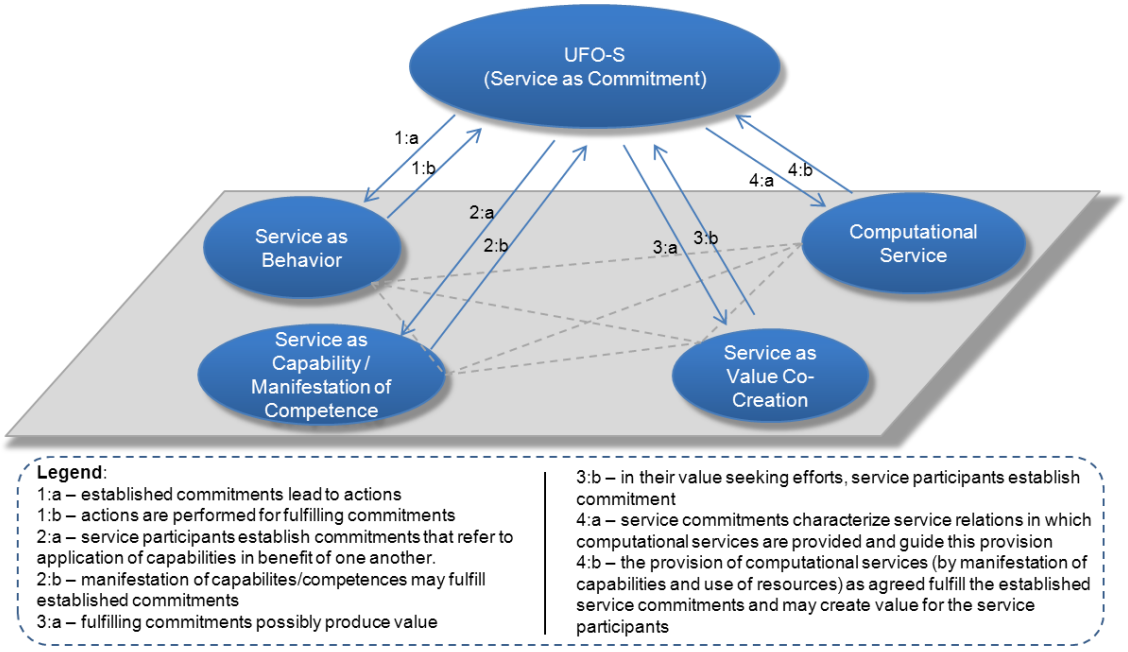


Figure 21 - UFO-S harmonizing service perspectives.

Table 13 presents correlations between UFO-S and the other service perspectives considering the most evident aspects between them. From these correlations, we can see how these aspects are mapped and addressed in UFO-S, which offers a panorama of the coverage of this service ontology.

Table 13 – Correlations between UFO-S and the other perspectives.

Service Perspectives	**UFO-S (Service as Commitment)**
Service as Capabilities and Application of Competences	
Capability/Competence	Disposition (from UFO-C)
Capability/Competence application	Manifestation of disposition
Focuses on provider-side capabilities /competences (customer as beneficiary)	Considers both provider-side and customer-side capabilities in service relations
Focuses on offering access to capabilities	Advocates that only by means of service commitments it is possible to guarantee systematic access to (or manifestation of) capabilities
Lacks a clear distinction between capability/competence and resources	Resources are substantials (that play a certain role in a given service delivery, e.g., "the soap used in a car clean service as a cleaning product"). Dispositions are intrinsic moments that inhere in substantials (e.g., "the disposition of removing dirt").

Service as Behavior	
Behavioral aspects - Service process description	Action universals can be referred to in service offering and service agreement descriptions, describing how the service delivery will be executed.
Behavioral aspects - Service process execution	Service delivery is a (complex) event (which may be an instance of an action universal).
Service description is focused on process specification	Service (offering and agreement) description is taken from a broader notion, addressing not only "how to perform some behavior", but, also the motivations (social commitments). Able to account for services which cannot be reduced to behavior (e.g., insurance services).
Does not account for commitments/motivation for behavior execution	
Service process is mainly characterized in terms of inputs, outputs, effects and pre-conditions	Accounts for the service commitments about the necessary input and pre-conditions, and the expected outputs and effects.
Service as Value Co-Creation	
Value Co-creation	Intentional moments (intention/goal, desire, belief from UFO-C) offer the basis that accounts for: (i) what is expected in a service relation, and; (ii) what is experienced as value, as a consequence of service relations (and possibly service delivery);
Does not make finer-grained distinctions concerning "value co-creation", "service commitments" and "service delivery".	In their value-seeking behavior, service participants establish and fulfill service commitments. Discusses about objective outcomes or effects of the actions performed in order to fulfill service commitments and the subjective value ascribed to these actions and the situations that are brought about by these actions.
Does not establish a clear distinction between provider and customer in terms of responsibilities (both are service relation's parties that create value)	Establishes a clear distinction between customer and provider in terms of their commitments along the service life cycle.
Computational Services	
Often collapses service negotiation and service agreement	Service negotiation and agreement are defined as two different well-defined ontological entities
Often reduces service description in terms of operation specifications	Service description is able to express not only technological aspects, but also social aspects between provider and customer
Often ignores intentional agents behind services, and focuses on technical resources ("server" and	Only intentional agents are service providers and customers. They apply resources/capabilities towards fulfilling established service

"client")	commitments.
Often neglects the role of service commitments (as a social aspect) and focuses on constraints (as a technical aspect)	Constraints are analyzed in terms of the service commitments that have to be fulfilled for guaranteeing, at a certain level, the expected execution

3.5 UFO-S and Related Work

In this section, we compare UFO-S with a number of ontologies and conceptual models of service found in the literature, and discuss how these works are related to UFO-S. These works are briefly presented in Section 2.3.3, and range from ontologies for implementation purposes to ontologies applied as technical reference models, as well as ontologies and conceptual models of general purpose.

OWL-S (W3C, 2004b) and WSMO (W3C, 2006) are two Semantic Web service ontologies that focus mainly on technological aspects and are usually applied for automating tasks such as service discovery and composition (OBERLE et al., 2009). These ontologies are not based on foundational ontologies and none of them addresses explicitly the notion of commitments. Further, both are focused on the *description* of computational services, while UFO-S aims instead at explicating service phenomena in order to support (offline) meaning negotiation. Finally, we should note that OWL-S and WSMO are built on Semantic Web languages that give precedence to computational tractability over expressiveness. As a consequence, these ontologies, as *operational ontologies* (FALBO et al., 2013b), are less suitable for meaning negotiation and consensus establishment between human beings, while UFO-S, as a *reference ontology*, favors these aspects.

In the Service-Oriented Architecture Ontology by The Open Group (THE OPEN GROUP, 2009), the concept of "service" is defined as a logical representation of a repeatable activity that has a specified outcome. As we have discussed earlier, this view fails to address the commitment aspects of services. Although the notion of service contract is addressed in this ontology, it is considered optional, and the content of contracts is not considered in enough detail. No distinction between service offer and service agreement is made. Finally, the Open Group Service-Oriented Architecture Ontology avoids defining concepts such as consumer and provider as core concepts

(THE OPEN GROUP, 2009), although it mentions that these concepts may be used in service contracts. This is a consequence of their view on services that cannot account for the asymmetry involved in service provider-customer relations.

As a framework for defining service-oriented architectures, the Reference Ontology for Semantic Service Oriented Architectures developed by OASIS (OASIS, 2008) focuses on structural aspects and defines service as "a mechanism to enable access to one or more capabilities…". The terms of this access are defined by a number of constraints and policies, which can be described in service descriptions. We believe that "a mechanism to enable access" is too narrow a notion for characterizing the concept of service, even in case of computational services. In UFO-S, in turn, a service relation is characterized by the set of commitments and claims between a service provider and a service customer, which can reference the access to the capabilities of the service provider. In the case of computational services, these set of commitments and claims could be understood as the constraints and policies that define the access to the functionality and that are usually described in service specifications, e.g., WSDL, and WADL. Regarding the rigor, this ontology does not explicitly use a well-defined theoretical foundational to ground its conceptualization. This limitation may lead to misunderstandings regarding the use of concepts and relationships. For example, in (OASIS, 2008) the concept of capability is used in two ways: (i) as "some functionality", and (ii) as something that "represents a functionality".

The Healthcare SOA Ontology (MILOSEVIC et al., 2013) is an ontology of service in the domain of eHealth services. This ontology counts on a number of "core" concepts (e.g., service, service description, service user, service provider, contract, object) that are refined in the "enterprise" and "computational" viewpoints. In this ontology, the concept of service is defined as a "behavior element" that can be specified, e.g., by means of business processes, in case of business services, or by RPC interactions in case of computational services. The ontology also proposes service agreements (possibly represented in a contract) as a key element for service phenomena. Differently from UFO-S, however, it does not distinguish explicitly service offerings and service agreements. The proposal is grounded on concepts for RM-ODP (such as that of community) which have been analyzed successfully with UFO in the past (ALMEIDA; GUIZZARDI, 2012). A similar effort for the Healthcare SOA Ontology is

planned using UFO-S as a reference ontology, which should provide a sound foundation for this standard. We believe the commitment-based account is particularly useful in the Healthcare domain as commitments in providing services (e.g., "managing patient records") have important consequences, and failing to fulfill them can bring grave consequences and serious sanctions.

The Service Ontology proposed by Oberle and colleagues (OBERLE et al., 2009) is structured in modules that span several application domains (e.g., healthcare, and automotive). This ontology is grounded by the upper level model, which consists of a foundational ontology (DOLCE (MASOLO et al., 2003)). As such, we consider it a core reference ontology. The Core Service Description module is one of the most important modules, which presents two central notions: service and service description. Oberle et al remark that this distinction is important, because in scenarios such as service marketplace, the service descriptions are managed instead of the service itself, since a service is defined as an event (in terms of DOLCE). The service descriptions would contain the terms regarding the service provision, such as, the commitments between providers and customer. Thus, the notion of commitment/claims as presented in UFO-S (as social relators that can be described in service descriptions, including service offering descriptions and service agreement descriptions) may be useful to refine the notion of service description in the Service Ontology.

The Goal-Based Service Ontology (GSO) (SANTOS et al., 2009) is a core reference ontology, also grounded in UFO. Thus, we can say that both GSO and UFO-S share the same grounding. However, GSO focuses on the concept of goal in order to define the notion of service. Thus, in GSO, the concept of service is characterized by the commitment of a service provider to perform a task on behalf of a service customer so that the outcome of this task satisfies a goal of that customer (SANTOS et al., 2009). The notion of commitments addressed in GSO lacks a more detailed description. For example, GSO does not consider the kinds of commitments and how these kinds of commitments influence the definition of the agents' roles along the service life cycle. As a consequence, in GSO, it is not possible to discuss the notion of target service customer, and hired service provider, for example. Further, in the service definition of GSO, only the provider is committed to achieve the goal. However,

service relations are usually characterized by mutual commitments, since the service customer is also committed.

Onto-ServSys (MORA et al., 2011) is an ontology designed for the domain of service system (and for other kinds of systems) in which the concept of "service" is characterized by three facets: (i) service interactions, (ii) service measures, and (iii) service outcomes. Onto-ServSys does not address explicitly the notion of service commitments and claims. Thus, the conceptualization of UFO-S can be useful for representing the service commitments and claims regarding the service interaction and the measures and outcomes to be produced from that. For example, the service interaction facet in Onto-ServSys can be analyzed, in terms of UFO-S, as being related to the service delivery (the execution). The service interaction as a plan (i.e., a planned sequence of actions to be performed by the provider and customers in tandem) can be analyzed as a set of service commitments established between provider and customers and that drive the service delivery. Therefore, a service interaction, as a flow of actions in execution, regards to the actions performed to fulfill the set of established commitments. Further, the understanding about service outcomes and service measures can benefit if analyzed in light of creation of value in the context of service relations. Thus, service measures and service outcomes concern the creation of value insofar the commitments established between providers and customers are fulfilled as expected. Finally, besides using a kind of ontological foundation based on a transcendental realistic ontology (BHASKAR, 1975), the limited set of concepts incorporated to Onto-ServSys does not guarantee a well-defined ontological foundation.

As discussed in Section 2.3.3, the model of service proposed by Bergholtz and colleagues (BERGHOLTZ; JOHANNESSON; ANDERSON, 2011) is based on three perspectives: "service as means for co-creation of value", "service as means for abstraction", and "service as means for providing restricted access to resources". Similar to our work, the authors present a multi perspective approach for addressing the diversity of service views, instead of proposing a single service definition. In the "service as means for co-creation of value" perspective, a service is seen as a process in which providers and customers supply resources (inputs) and together co-create value. In the "service as means for abstraction" perspective, the service process is

specified by means of the effects produced by the resources used in this process instead of the resource themselves. In the "service as means for providing restricted access to resources" perspective, the notion of commitments/claims is discussed in the context of offerings and contracts, which make reference to how the resources can be used/accessed in benefit of the customers. Despite addressing the notion of commitments and claims in this latter perspective, unlike UFO-S, the notion is not used to unify the three perspectives. For example, what they call service process is not explicitly related to the commitments that motivate this process (and the events that are part of it). Further, the notion of resource is a central concept in the approach. The notion is rather abstract and subsumes entities of different ontological natures, including claims, goods, information and what they call "service resources". While this is interesting to show that these elements can be transacted between agents in events, this presents a challenge from the point of view of semantic clarity. Finally, the model of services proposed by Bergholtz and colleagues has its theoretical foundation in REA (Resource-Event-Agent) ontology (MCCARTHY, 1982) and Hohfeld's classification of rights (HOHFELD, 1978). Being based on REA, this model differs from UFO-S with respect to the ontological foundations employed. The relation between REA and UFO is discussed in (GUIZZARDI; WAGNER, 2004).

Ferrario and Guarino (FERRARIO; GUARINO, 2008) (FERRARIO; GUARINO, 2012) present an ontological model of service systems that is also based on the notion of commitments. However, by adopting a different foundational ontology (UFO instead of DOLCE), we could address aspects not explicitly evidentiated/considered in works of Ferrario and Guarino. We could then count on the social and intentional distinctions underlying UFO-C, which offered the basis for better characterizing the service relations as social phenomena as well as for harmonizing the different service perspectives. Also, besides offering a hierarchy of individuals, UFO (in contrast to DOLCE) also offers a hierarchy of universals, which contributed, among other things, to the definition of types required in our account (e.g., role mixins, and relator universals). Moreover, the notion of "relator" was adopted as an important ontological entity useful for characterizing material relations between service participants (providers and customers) in service relations. From the notion of "relator" we could better characterize aspects of service relations (e.g., in service offerings and service

agreements) that the notion of event adopted by Ferrario and Guarino does not properly accounted for. Briefly, from evidentiating social relators in service relations, we could account for the fact that agents participate in events (e.g., service negotiation, and service delivery) according to/due to relators previously established. In terms of UFO, we can say that such agents can participate in such events insofar some "dispositions" (e.g., the disposition of a provider to deliver a service to a specific customer) are created from the establishment of social relators (e.g., after service agreements establishment). Moreover, we should also remark the adoption of OntoUML ontology language, which offers well-founded modeling capabilities that are associated to a number of tools (e.g., model verification and simulation (BENEVIDES et al., 2011) and generation of OWL implementations (ZAMBORLINI; GUIZZARDI, 2010)), which were used in this work for guaranteeing a desirable degree of rigor in UFO-S. Finally, by understanding that the term "service" is laden with different meanings, we have refrained from settling on a specific definition for "service", but we establish what we consider as the *core meaning* of "service" concept, inspired by *systematic polysemy* notions (see Section 3.6).

In summary, UFO-S was not designed to be an alternative service ontology that is based on a particular service perspective. As a core reference ontology, UFO-S establishes (besides, e.g., behavior, capabilities and resources, and co-creation of value aspects) the basis for the service phenomena along the service life cycle considering the notion of service commitments as foundationally necessary. As a result, UFO-S aims to be useful for the existing service ontologies insofar it offers a detailing of service relations around service commitments, offering also a means through which different service ontologies can be aligned in a commitment-based reference point. As follows, we highlight the main contributions of UFO-S in contrast with related work on service ontologies:

- It makes a clear distinction between service offer, service offering, service negotiation and service agreement concepts, which are, as a whole, often neglected in current approaches.
- It reinforces the importance of what "contract" and "policy" elements represent in service relations, since these elements are used to

communicate commitment-related aspects. These elements are commonly used in service-oriented architectures.

- It establishes the asymmetry between providers and customers regarding service commitments, and clearly defines the roles of target customer, service customer, service provider, and hired service provider, which are important for understanding the dynamics of service relations.
- It incorporates the notion of commitments into dynamics of behavior (relating it to actions and interactions) in service provisioning.
- It associates the notion of commitments to value co-creation, insofar for co-creating value, providers and customers establish service commitments and act, in the context of the service relation, for fulfilling them.
- By counting on UFO-C, it offers means to explicitly account for the notion of (provider and customer) "goals" in service relations. Especially by considering that commitments are "paired" with corresponding claims and that such commitments are established in mutual relations, UFO-S offers supports to discuss, e.g., that the fulfillment of customer commitments may lead to the achievement of provider's goals.
- Taking UFO as a basis, UFO-S incorporates a clear distinction between capabilities (and called competences), application of capabilities, and resources. Such concepts are clarified, respectively, in terms of dispositions (as intrinsic moments), manifestation of dispositions, and individuals that bear such dispositions.
- It establishes that the application of capabilities is not, in isolation, enough for characterizing service provisioning. The establishment of service commitments is indeed a foundational notion that guarantees (at certain level) such systematic application in service relations.
- It offers means for characterizing service specifications (especially when referring to constraints) in terms of service commitments (as a social aspect), which is often neglected in computational approaches.

Table 14 summarizes four important design aspects of UFO-S and of the other service ontologies and conceptual models discussed in this section, such as: (i) the

characterization of service advocated for each ontology, (ii) the primary purpose of application (general purpose, technical reference model, or implementation), (iii) the language used to represent the ontology, and (iv) the adopted ontological foundation.

Table 14 - Summary of the four design aspects of UFO-S and related service ontologies/models.

Ontology / Conceptual Model	Service Characterization	Application Purpose	Representation Language	Ontological Foundation
UFO-S	Based on the notion of "service relations" characterized by service commitments and claims	General	OntoUML + many-sorted logic	UFO (GUIZZARDI, 2005a) (GUIZZARDI; FALBO; GUIZZARDI, 2008)
OWL-S (W3C, 2004b)	Based on the notion of dynamic web sites (performing of actions)	Implementation	Graphical notation and specification in OWL	---
WSMO (W3C, 2006)	"Web service" as computational entity "Service" is based on the notion of the value provided by the invocation of a "web service"	Implementation	UML and specification in Web Service Modeling Language (WSML)	---
The SOA Ontology by The Open Group (THE OPEN GROUP, 2009)	Based on the notion of repeatable activity	Technical Reference Model	UML and specification in OWL	---
The Reference Ontology for Semantic SOA (OASIS, 2008)	Based on access to capabilities (as functionality)	Technical Reference Model	Concept Maps, UML, and specification in WSML	---
Healthcare SOA Ontology (MILOSEVIC et al., 2013)	Based on the notion of behavior and contracts	Technical Reference Model with focus on eHealth	UML	---
The Service Ontology/ Core Service Description (OBERLE et al., 2009)	Based on the notion of temporal entity (event) and service commitments/claims	General	Graphical notation and specification in OWL-DL	DOLCE (MASOLO et al., 2003)
Goal-Based Service Ontology (GSO) (SANTOS et al., 2009)	Based on the notion of temporal entity and satisfaction of customer's goal	General	UML	UFO (GUIZZARDI, 2005a) (GUIZZARDI; FALBO; GUIZZARDI,

				2008)
The Onto-ServSys (MORA et al., 2011)	Based on three facets: (flow of) interaction, (objective) measures and (subjective) outcomes	General	A notation adapted from Common KADS Methodology	Transcendental realistic ontology (BHASKAR, 1975)
Ferrario and Guarino's service ontological foundation (FERRARIO; GUARINO, 2012)(FERRARIO; GUARINO, 2008)	Based on the notion of temporal entity (event) and service commitments/claims	General	UML	DOLCE (MASOLO et al., 2003)
The model of services of Bergholtz and colleagues (BERGHOLTZ; JOHANNESSON; ANDERSON, 2011)	Multi perspectives of service: service as means for co-creation of value, service as means for abstraction, and service as means for providing restricted access to resources.	General	UML	REA ontology (MCCARTHY, 1982), and Hohfeld's classification of rights (HOHFELD, 1978)

3.6 What is a service after all?

We have shown that UFO-S is able to account for a number of perspectives on services, including those that emphasize (i) "services as value co-creation", (ii) "services as capabilities and application of competences", (iii) "services as behaviors", and (iv) "computational services".

In order to relate the various perspectives, we have refrained so far from proposing a specific definition for the term "service", understanding that the term is laden with different meanings. Indeed, in such cases of heavy semantic overloading, we strongly believe that, before attempting any terminological standardization, what is most important is to describe the different interconnected phenomena underlying services, providing a foundation that can be used to articulate the intended semantics of the related terms.

The term "service" is a case of *systematic polysemy*, in which the same nominal is used to denote different –*although related*– notions. This is a well-documented phenomenon in linguistics, which is explained with the semantic notion of "complex types" or "dot objects" (cf. Pustejovsky *apud* (RAVIN; LEACOCK, 2002)). The idea is that

the term assumes different senses depending on the context in which it is used, but all the senses are more or less implicitly present, so that in some cases a single occurrence of the word in a sentence carries more than one meaning (this is called *co-predication*).

An instructive example of this phenomenon is the word 'book', which may refer to the physical object (a copy of the book) or to the abstract information object (the text or content) that is carried by the physical object. An example of co-predication is "The book weighs one kilogram but is easy to understand". "Weighing one kilogram" is predicated of the physical copy and not of the text, while "easy to understand" predicates over the abstract information object and not over the physical copy. Thus, if one builds an ontology about books and demands a single ontological notion as the referent for the term "book", one would be forced to choose one of the two meanings above. Of course, either option would be inadequate when both perspectives are relevant. An alternative is to replace the polysemous term with a set of unambiguous terms, each denoting a particular sense of the original term, while maintaining (and possibly explaining) the relation between them.

Thus, an ontology about books would have two distinct, unambiguous terms to account for the two senses above (e.g., "physical copy" and "book text"), but would not settle on a single referent for the term "book". Making use of a richer terminology would enable us to explain the relation between a "book text" and a number of "physical copies" (in the sense that the text is encoded in the physical copies).

The case of services is not much different from that of books. Both are examples of systematic polysemy. Consider the following case of co-predication involving the term service: "Dr. Smith's dental service is expensive but unreliable". "Expensive" is a property ascribed to Dr. Smith's service offering, while "unreliable" is a property ascribed to the expected (or previously-experienced) service delivery.

For the "service" term, one would have several alternatives, including service offering, service offering type, service agreement, and service delivery. The aforementioned sentence could be disambiguated by paraphrasing it as "Dr. Smith's dental *service offering* is expensive but the *service delivery* is unreliable." These are much less ambiguous terms, whose intended semantics has been carefully characterized in this thesis. Not using these specific terms –relying instead on the

generic term "service"– may result in serious problems: for instance, ontologies attempting at providing a notion of "service description" may end up confusing what is to be described (leaving too much room for interpretation), sometimes describing a service offering type (when no one is committed), sometimes describing a service offering (this problem in the context of the SOA Healthcare Ontology has been identified by analyzing it with UFO-S (MILOSEVIC; ALMEIDA; NARDI, 2014)). Similar confusion in terminology arising from the polysemy of the term "service" also appears in technical glossaries[7].

Considering that our intent is to establish a reference ontology for meaning negotiation, we have chosen to use a set of non-ambiguous concepts (e.g., service offering, service negotiation/agreement, and service delivery) all related to the generic notion of "service" (instead of proposing a regimented terminological definition, as attempted in some previous works, e.g., (FERRARIO; GUARINO, 2008) (FERRARIO; GUARINO, 2012)). Thus, when using the term "service", it is important to determine pragmatically (i.e., based on the context) which of these concepts are being referred.

We stress that various possible senses of the term "service" do not form a flat list: systematic polysemy means that there is an internal structure within a sense cluster, based on a relation of *ontological dependence* between the different senses. In our case, the concepts of service offering, service negotiation/agreement and service delivery such as they are organized in the service life cycle model, fit in a (ontological) structure of senses around the term "service". Thus, a service delivery depends on a service negotiation, which in turn depends on a service offering. This justifies our suggestion that, after all, the notion of service offering (which in turn builds on a pattern of commitments and claims) is the *core meaning* of the commonly used "service" concept (even if this core is not explicitly referred to). This means that when attempting to define what "service" means, some reference to this core must be taken in to account.

[7] For an interesting example of the confusion between "service" and "service type" in the scope of a large service-based company, consider this definition, taken from the UPS glossary: "*Service: The UPS service type for a shipment. For more information on service types, refer to the UPS Rate and Service Guide.*" http://www.ups.com/content/us/en/resources/ship/glossary/

3.7 Final Considerations

This chapter presented a core reference ontology for services called UFO-S. UFO-S is grounded in a foundational ontology (UFO) that includes social and intentional concepts that form the basis for our account of the social relations established between service participants throughout the service life cycle. UFO-S accounts for the agent's intentionality with respect to the actions they perform by entering into and aiming to fulfill their social commitments.

As a kind of "analysis theory" (GREGOR, 2006), UFO-S establishes the basic concepts and relationships around the notion of service with the purpose of being general enough to harmonize different perspectives of service. Thus, besides contributing to the body of knowledge regarding service, we have argued that the theoretical foundation of service provided by UFO-S can span the business and computational perspectives, with the potential of promoting a much-needed conceptual integration of Business and IT views. In fact, results of the application of UFO-S in service-oriented enterprise architectures can be found in the following chapters.

Finally, "rigor" (HEVNER; CHATTERJEE, 2010) (HEVNER et al., 2004) in the design of UFO-S was achieved by: (i) grounding UFO-S in the Unified Foundational Ontology (UFO), and (ii) by defining an axiomatization to ensure "precision" (BORGO et al., 2002) avoiding unintended model instantiations. With respect to "relevance" (HEVNER; CHATTERJEE, 2010) (HEVNER et al., 2004), we discussed, by means of a "descriptive evaluation" (HEVNER; CHATTERJEE, 2010) (HEVNER et al., 2004), the improvements that UFO-S brings to other service ontologies and conceptual models, as well as how UFO-S can harmonize various service perspectives found in literature.

Chapter 4. Revealing Service Commitments in Service-Oriented Enterprise Architecture

In this chapter we analyze the structuring principles underlying Service-oriented Enterprise Architecture (SoEA) in light of UFO-S. UFO-S is applied as a kind of "theory" to support the analysis of SoEA structuring techniques and thereby for revealing social aspects inherent to the service phenomena in SoEA (e.g., commitments/claims, and delegations) that remain underexplored due to the current prevailing "capability-based SoEA view". From that, we advocate for a "commitment-based SoEA view", which can be harmonized to the capability-based SoEA view in order to establish richer SoEA structuring principles. Implications of our analysis are discussed taking as basis widely adopted service-oriented approaches, such as, SOA-RM by OASIS, ITIL, and ArchiMate.

4.1 Introduction

By counting on resources, enterprises can count on the capabilities inherent to them. According to (AZEVEDO et al., 2013), capabilities can be taken as intrinsic properties that inhere in individuals (e.g., people, enterprises, and devices). By controlling resources (e.g., a Database Management System - DBMS), an enterprise can count on the capabilities inherent to these resources (e.g., the "Data access" capability of the DBMS). Thus, in an enterprise architecture, resources (and their capabilities) can be combined within and through architectural layers for supporting business operation.

With the service orientation paradigm a vision of world in which enterprise resources are cleanly partitioned and consistently represented in terms of services has arisen (SCHEKKERMAN, 2014)(BRAUN; WINTER, 2007). In Service-oriented Enterprise Architectures (SoEA), services are often seen as a means of accessing the capabilities of Business and IT resources. In this thesis, we call this view the *capability-based SoEA* view.

This view can be found in important frameworks, such as ITIL (ITSMF, 2007), the Reference Model for SOA (SOA-RM) by OASIS (OASIS, 2006), and ArchiMate (THE OPEN GROUP, 2012). In ITIL, the management of capabilities is an important aspect for guaranteeing the provision of IT services (ITSMF, 2007). In SOA-RM, a service is defined as "a mechanism to enable access to one or more capabilities" (OASIS, 2006). In

ArchiMate, the concept of service is characterized as “unit of functionality”, which can be seen as realized/provided by application of enterprise resources (i.e., by manifestation of their capabilities) (THE OPEN GROUP, 2012). Despite offering support to represent service provision, ArchiMate is inherently focused on the capability-based SoEA view within and through its three architectural layers (Business, Application, and Technology).

In fact, the wide applicability and acceptance of these frameworks show that the capability-based SoEA view is important and useful in SoEA structuring and practice. However, despite that, this view fails to account for social aspects inherent to service relations, such as service commitments and claims established between service participants (service providers and service customers), which we argue essential for a full account of service phenomena. Thus, by using UFO-S as a service commitment-based theoretical foundation capable of harmonizing different service perspectives (including “service as capability”), we believe it is also possible to harmonize the capability-based SoEA view with a *commitment-based SoEA* view towards enriching the understanding about service phenomena in SoEA. For doing this, along this chapter we take ArchiMate as an archetypal framework embodying the capability-based SoEA view, and we use this framework for supporting our discussion.

In this chapter we show how the broad account of services that underpins UFO-S can clarify the structuring principles of SoEAs. We intend to present the limitations of adopting a strict capability-based SoEA view, and to show that, by introducing the notion of service commitments and claims, one is able to reveal important business service relations that are not present in such view. Further, the discussion we put forward is also applicable to IT services, being thus able to account for application and infrastructure as a service scenarios. The consequence of revealing service commitments throughout the SoEA leads to an additional structuring principle, here termed “commitment-based SoEA view”. We advocate that this view can be harmonized and combined with the prevailing capability-based SoEA view, offering a broader and richer view for SoEA structuring.

We believe that this richer SoEA view has implications for a number of SoEA-related academia and industrial initiatives, contributing to the structuring of SoEAs in

general, and, more specifically, to Business-IT alignment efforts, to integration of service management and EA, and to modeling/representation of SoEA.

This chapter is further organized as follows: Section 4.2 presents the analysis of SoEA in light of UFO-S; Section 4.3 discusses the implication of our ideas in current service-oriented approaches; and, finally, Section 4.4 presents the final considerations of this chapter.

4.2 Analysis of SoEA in light of Service Commitments

In this section we analyze a number of service provisions in SoEAs in light of UFO-S. For supporting our analysis, we use a hypothetical scenario of online book selling, which is modeled in ArchiMate as shown in Figure 22.

The analysis intends to show that the distinctions supported by a richer service commitment-based foundation (harmonized to the notion of resource/capability) allow us to reveal nuances in the capability-based SoEA view that, at first glance, remain hidden due to the emphasis on resources/capabilities in SoEA. Thus, a number of questions is used to guide our analysis, e.g.: (i) “who is responsible to honor SLAs (i.e., who is committed in service provisioning)?”, (ii) “what are the service commitments/claims that drive the actions towards applying resources/capabilities for provisioning services?”, and (iii) “what guarantees the establishment of a network of resources/capabilities (at different enterprise layers and from different business partners) for provisioning service?”.

In the proposed scenario, the “@Books Inc.” bookstore sells books through the Internet. The bookstore provides two business services for its market customers: “Make purchase order” and “Monitor purchase order”. Both services are completely automated by the “@Books’ ERP” and can be accessed through a website. The “Monitor purchase order” offers the customer the facility of having online information about purchase orders made previously (including shipping information). Besides these services, the bookstore offers a “Complaint” business service. The market customers can have access to this service through phone calls (24h). In order to realize this service, the bookstore defines the “Handling complaint” business process that is conducted by people (human resources) playing the “Attendant” business role. The attendants, along this business process, can use the “Record complaint” application

service realized by the “Complaint system”. The ERP and the “Complaint system” use the “Data access” infrastructure service realized by the bookstore’s database server.

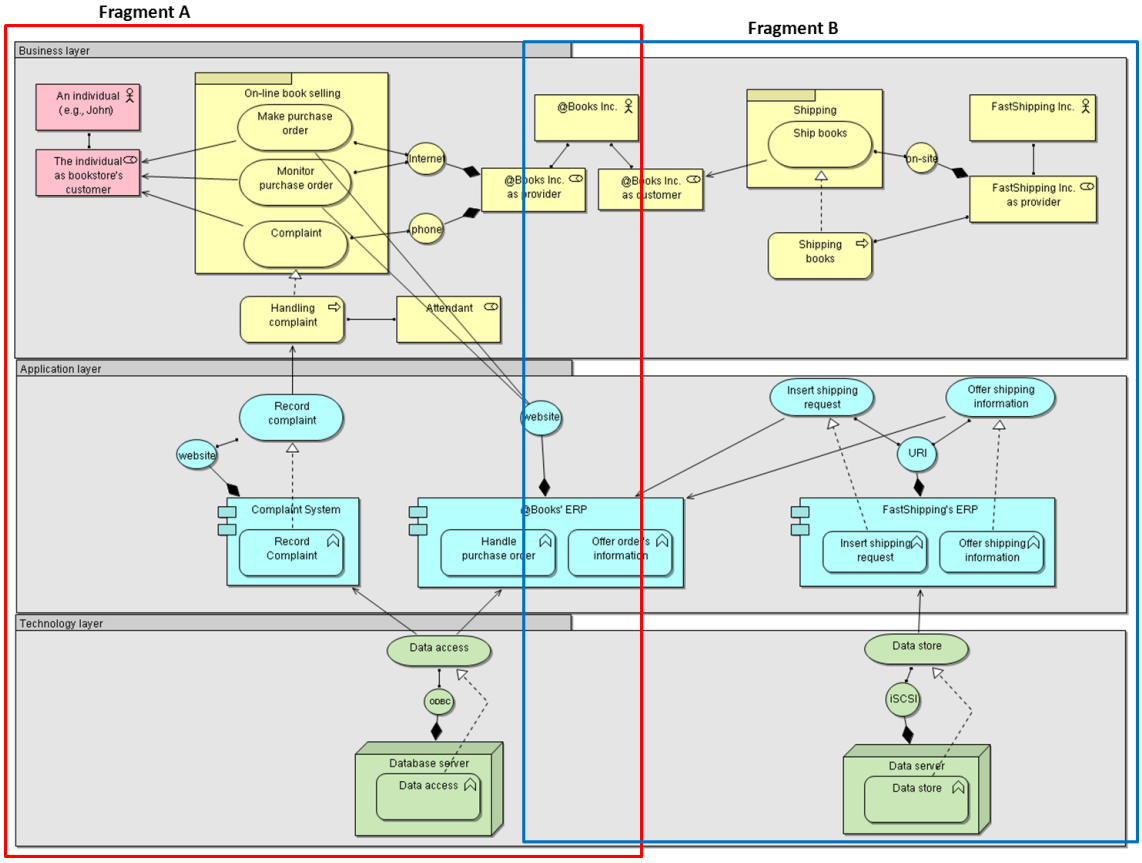


Figure 22 - Online book selling scenario.

For delivering the purchase orders, the bookstore has entered in a service relation with “FastShipping Inc.” (a company specialized in delivering goods). In this service relation, “FastShipping Inc.” also provides the “Insert shipping request” and the “Offer shipping information” application services to the bookstore. These application services are realized by the “FastShipping’s ERP”, and are available through RESTful technology. This ERP uses the “Data store” infrastructure service realized by the “Data server”. By means of these application services, the ERPs of these two companies can be integrated and exchange information. Due to the service relation with “FastShipping Inc.”, the bookstore is capable of shipping ordered books and also offer to its customers information about package tracking.

4.2.1 Analysis of "intra-enterprise service provisioning"

Consider the Fragment A in the left-hand side portion of Figure 22. By means of this fragment we can analyze service provisioning internal to the same enterprise (through enterprise layers).

At the Technology layer, we have the "Data access" infrastructure service. We can say that, by owning the "Database server" (as an IT resource), the bookstore can count on the "Data access" capability. This capability, represented by an *infrastructure function* element in ArchiMate, is put internally available to the enterprise by means of that infrastructure service. This service, in turn, is used for supporting the operation of the "Complaint system" and the "@Books' ERP". The capabilities of the "Complaint system" can be accessed by an application service in a website available in the intranet, whereas capabilities of the ERP are available by direct access to this system through a website in the Internet. Thus, resources (and their capabilities) at the IT layers (Application and Technology) are used by resources at the Business layer for supporting business operations.

Since, in terms of UFO-S, service relations are only established between intentional agents, we can say that it is not the "Database server", or even the "@Books' ERP" (as IT resources), that "provide" these IT services (application and infrastructure services). In terms of UFO-S, the resources (or the manifestation of their capabilities) are used (as agreed between service participants) as a means for delivering (Business or IT) services. This notion of service leads us to reveal the (intentional) agents involved in service relations, in such a way that we understand service provisions not only as mere application of resources/capabilities, but as a wide and organizational view that also considers the commitments between organizational actors towards guaranteeing the agreed application of resources/capabilities. Thus, in this fragment, there should be an IT department (or other organization actor not represented in the model) that would be committed to provide (by means of application of IT resources/capabilities) the aforementioned IT services. Note that not only the service provider is not identified explicitly, but also the service customers (which could be the, e.g., a marketing department, or even, the bookstore as a whole).

Revealing the actors that provide the "Record complaint" service allows us to consider not only application service provisioning from an internal point of view (i.e., an internal IT department establishing a service relation with the enterprise or with other departments), but also from an external point of view. In this latter case, the enterprise becomes a customer of another enterprise offering an IT solution of processing complaints (in a software-as-a-service business model). There would thus be a number of service commitments and claims between business partners that would drive the application of all resources/capabilities (from IT to Business resources/capabilities) necessary to provide this service. Emphasizing only the capability-based view hides the actors playing the roles of service customer and service provider, showing only the resources employed in service delivery. This prevents us from distinguishing the cases in which a piece of software is employed under no service management practice from those cases in which software is part of a genuine software-as-a-service model (either provided by internal or external actors).

In contrast to the capability-based view, the commitment-based view transcends the application of a resource's capability. For example, the "Record complaint" application service should not be thought of as being provided by the "Complaint system" because there are number of other capabilities that are required for providing this service (e.g., electricity, and security aspects) but that are not guaranteed by the "Complaint system" (as an IT resource). It is necessary, therefore, the "presence" of an intentional agent (e.g., the IT department) committed to guarantee the operation of the "Complaint system" and of all other resources/capabilities necessary for the provision of this application service.

As the commitment-based view emphasizes the opportunities for delegation, it can also be seen as a means to deal with the complexity of an organization's goals. In our example, the bookstore is committed to its target customers to sell books through the Internet. If the bookstore is acting honestly, this social commitment will be internalized into a goal ("to fulfill the established commitments towards its customers"). This general goal could be addressed by a number of strategies, some of which may involve the delegation of specific goals to internal organizational actors through service relations (e.g., such as those related "to guarantee provision of IT services" which can be delegated to the IT department.) As a consequence, the IT

department will act (e.g., applying the IT resources and capabilities under its responsibility) towards creating means for fulfilling its commitments and, ultimately, contribute for achieving the overarching organizational goals. In this process, the IT department has the freedom to fulfill its commitments in different ways, as long as the commitments are fulfilled. This allows the enterprise architect to consider an alignment of the goals that arise from the need to fulfill commitments with other goals the actor intends to pursue (e.g., cost reduction in the IT department.) This analysis reveals a "separation of concerns" established by means of delegations in service relations. By delegating a goal/plan the customer can deals with the service provisioning at a high level abstraction (focusing on service commitments fulfillment perspective) and let other more specific aspects (e.g., usage/maintenance of resources/capabilities) under provider's responsibility. This contributes for the design of SoEA in a true modular fashion, including the alignment of goals of the various organizational actors as well as trade-off analysis.

Finally, there may be a number of service relation arrangements in a service-oriented enterprise. Here, we discussed some of them in order to show how social aspects (mainly based on service commitments/claims, delegation, and goals/intentions) can be useful for better understanding SoEA. The organizational structure and the autonomy of the departments and organizational units have direct influence on it. Despite these various possible arrangements, we believe that, beyond providing access to resources/capabilities by means of services, it is also important to analyze the relations between the intentional agents responsible for providing the services (service providers) and the beneficiary agents (service customers). Thus, it is possible to go from a mere application of resources/capabilities towards a more complete organizational view, in which organizational actors act as participants in service relations for fulfilling service commitments and achieving organizational goals.

4.2.2 Analysis of "inter-enterprise service provisioning"

We now analyze Fragment B in the right-hand side portion of Figure 22. This fragment offers support for discussing service provisioning between enterprises.

Consider, initially, the "Offer shipping information" application service, which is realized by the "FastShipping's ERP" application. By using this service, the "@Books'

ERP" application can have access to the information about the books' shipping status and thereby "Offer order's information". In terms of UFO-S, we can say that there is a set of mutual service commitments between the bookstore and the "FastShipping Inc." that characterizes the service relation between these two enterprises. Through this service relation, the bookstore delegates to "FastShipping Inc." the task of shipping books and, therefore, can count with the application of FastShipping's resources/capabilities which are necessary for this task. In this context, we can say that besides all service commitments regarding the tasks involved in transporting a purchase orders to a customer's address, one of these service commitments concerns providing online information about tracking status of each package shipped. Thus, we can say that there is a service commitment established at business level that states that "FastShipping Inc." is responsible for providing the "Offer shipping information" application service at application level. The provision of this application service, in turn, is characterized by a number of other service commitments concerning to technical aspects, such as communication protocol to be used, input and output parameters required, response time, etc.

This analysis, therefore, shows a relation between the application of IT resources/capabilities (besides other kinds of resources/capabilities) from one enterprise in benefit to another due to service commitments established between them at business level. Thus, the service commitments that guarantee (at a certain level) the provision of the "Offer shipping information" application service (and consequent application of the resources/capabilities) is one of the service commitments established in the context of the service relation between the bookstore and the "FastShipping Inc.". This network of Business- and IT-layer resources/capabilities of different enterprises established and driven by a parallel network of mutual service commitments between these enterprises for delivering service is not evident or even clearly discussed in various service-oriented frameworks. ArchiMate, e.g., lacks a clear way to represent these aspects.

In addition to the "Offer shipping information" application service, the "Insert shipping request" service is also part of the commitments of "FastShipping Inc." towards "@Books Inc.". This service is used by the "@Books' ERP" to insert, in the "FastShipping's ERP", a request of a new purchase order shipping. In other words,

when a purchase order is made, this application service is a way the bookstore has to request a new purchase order shipping for the “FastShipping Inc.”. We can analyze the use of the “Insert shipping request” application service taking as basis the dynamics of the service commitments and claims in the service life cycle phases (service offer, service negotiation/agreement and service delivery). For that, consider that the bookstore and the “FastShipping Inc.” have established a business service model in which there is a permanent agreement regarding the service of shipping books. By this permanent service agreement, a simple shipping request (through the use of the “Insert shipping request” application service) is enough for triggering the “Shipping books” process, since all service provisioning terms (e.g., costs, delivery data, and transportation availability) where already agreed. In this case, therefore, the call to this application service acts as just an event that will trigger other service delivery actions (encompassing the execution of the actions and the application of resources/capabilities necessary for it).

As we can see, the service relation between the bookstore and the “FastShipping Inc.” encompasses a number of enterprise resources/capabilities of both enterprises (e.g., money, human resources, transport infrastructure, and information systems). The application of these resources/capabilities is guaranteed (at a certain level) by the mutual service commitments established between these service participants. In this sense, the enterprises may have the necessity to integrate/combine their resources/capabilities as a way of fulfilling their commitments. Thus, we can say that, for fulfilling the mutual service commitments established between the bookstore and the “FastShipping Inc.”, they have integrated their ERPs (as a kind of inter-enterprise application integration initiative). This integration was established by means of a technological service solution (e.g., RESTful services). Thus, the “Offer shipping information” and “Insert shipping request” application services can be seen, in this scenario, as a service technological solution by means of what IT resources/capabilities (e.g., the ERPs of both enterprises) were integrated for fulfilling the service commitments established between these enterprises at the business level. Therefore, the way in which IT resources/capabilities are integrated/combined at IT layers and how these resources/capabilities interact (in

software application integration initiatives, for example) can be regulated/driven by the service commitments established between the service business partners.

Finally, let us suppose that the “FastShipping Inc.” decides to outsource all infrastructure of data storage. As such, the provision of a data storage service will be hired as an infrastructure-as-a-service (IaaS) business model. From this outsourcing, we could say that the “FastShipping Inc.” will count on the resources/capabilities necessary for storing data of another company, the “DataCompany Inc”. So, the “FastShipping’s ERP” will have access to the data storage infrastructure of the “DataCompany Inc.” by means of a “Data store” infrastructure service. At the business layer, the “FastCompany Inc.” participates in a service relation with the “DataCompany Inc.” for having the provision of the data storage service. By that, the “FastCompany Inc.” can count on the DataCompany’s “Data server” (as an IT resource) for storing data processed by its ERP. In this service relation, therefore, the “FastCompany Inc.” (as service customer) and “DataCompany Inc.” (as service provider) establish a set of mutual service commitments and claims that concern to the application of resources/capabilities towards the provision of the data storage service. An important aspect is that the analysis of this service provision can not be limited to the application of the infrastructural resources/capabilities (e.g., data servers, and electricity), but also other kinds of resources/capabilities for the management of infrastructure as a service, such as those one at Application layer (e.g., software applications for device management) or at Business layer (e.g., human resources, and SLAs management business process). As we have advocated, the application of all these kinds of resources/capabilities is guaranteed (at a certain level) by the service commitments and claims established between service provider and service customers at business level. The capability-based view, however, lacks a wider perspective of service relations that unifies the application of Business-layer and IT-layer resources/capabilities by the establishment of service commitments and claims through enterprise layers and between business partners.

In conclusion, it is important to reveal that there is a network of service commitments established between service participants that act as a “glue” that leads to the application of the resources/capabilities of these service participants as a way of fulfilling their commitments. As an example, the bookstore has entered in a service

relation (i.e., has established service commitments) with the “FastShipping Inc.” for being capable (or in other words, for counting on the resources/capabilities) of fulfilling her service commitments towards its customers. This network of service commitments is based on the notion of delegation of the service provisioning from the service customers towards the service providers. In the service provisioning, resources/capabilities of both parties (customers and providers) are applied towards fulfilling their mutual commitments.

4.3 Implications to Service-Oriented Approaches

In this section, we discuss the implications of the commitment-based view to three widely adopted service-oriented approaches: the Reference Model for SOA by OASIS (SOA-RM) (OASIS, 2006), ITIL (ITSMF, 2007), and ArchiMate (THE OPEN GROUP, 2012). Since these approaches are predominantly based on the capability view, we believe they can be enriched with the commitment-based view underlying UFO-S.

With respect to the OASIS SOA-RM (OASIS, 2006), its focus is on the application of IT resources/capabilities in the provision of services. In terms of SOA-RM, by means of services it is possible to access the capabilities (OASIS, 2006), which are means to realize one or more real-world effects (OASIS, 2006). The access to capabilities is, in SOA-RM, governed by the concepts such as “policy” and “contract” (OASIS, 2006). However, although SOA-RM offers these concepts to drive the application/access to capabilities, we believe that this reference model can benefit from the notion of service commitments and claims, as a means for detailing and relating the content of “policies”, “service descriptions”, and “business contracts” along service life cycle phases. Thus, the dynamics of service commitments and claims along the service life cycle (from service offer, passing through service negotiation/agreement until service delivery) can enrich the understanding about the dynamics of the responsibilities (in terms of SOA-RM) of the service providers and service customers (as intentional agents) in tasks such as service registration/publication (e.g., in UDDI registries), service negotiation/agreement (manually or automatically), and service execution/usage (e.g., by function calls). The service commitments and claims established between service participants (target customer, service provider, service

customer, and hired service provider) along all service life cycle phases are related and drive, ultimately, the application of capabilities as way of fulfilling the commitments.

Another important initiative that supports service orientation is ITIL (IT Infrastructure Library) (ITSMF, 2007). ITIL provides a framework of best practice guidance for IT Service Management (ITSM). In ITIL, service management concerns organizational capabilities (e.g., process, functions, and roles) for providing value to customers in the form of services (ITSMF, 2007). Since the perspective of "management" is essential in ITIL, many of the aspects discussed here are directly applicable to ITIL (e.g., intentional agents as service providers and customers, service relations in a wider view encompassing Business- and IT-layer resources/capabilities, and IT services required by the service provider to deliver customer-facing services in a wide service relation). Thus, the ideas discussed in this chapter has the following implications to ITIL: (i) the ontological foundation (offered by UFO-S) can support ITSM practices with a broad conceptual basis, and (ii) by discussing these aspects/concepts in light of SoEAs, we offer some basis for ITSM practices (embodied in ITIL) to be related to SoEA. If (Service-oriented)EA does not include the commitment-based view, then it would not be able to represent the important notions underlying ITSM.

Finally, ArchiMate (THE OPEN GROUP, 2012) adopts the perspective of "service as unit of functionality" within and through its three enterprise layers (Business, Application, and Technology). This perspective offers an important but particular perspective of service, and should be complemented with the commitment-based view in order to account for services more completely. Consider, e.g., the insurance service that is provided by an insurance company towards its market customers. In the end of the insurance service contract, even if no accident had occurred and no action/functionality had been performed, the customer could say that the insurance service was successfully provided. In this case, the service is not characterized only by an action/activity/unit of functionality (or by all resources/capabilities applied in service delivery), but also by the service commitments (the promise) of the insurance company to act (and apply the necessary resources/capabilities) as agreed in case of any accident. This example can be extended to the provision of application and infrastructure services, in which the usage/manifestation of IT resources/capabilities is guaranteed (even if they are not applied) by means of service commitments

established between service participants. In fact, the service perspective of “unit of functionality” adopted by ArchiMate is too focused on the capability-based SoEA view, and is not sufficiently expressive for representing the social aspects concerning the application of resources/capabilities in service delivery. Due to that, ArchiMate also lacks suitable modeling facilities (e.g., without ambiguity) for representing, e.g., the nuances of inter-layer service relations (e.g., between Business and Application layers) that regard the application of resources/capabilities of lower layers for supporting the higher ones. For example, consider the case in which there is an application service being realized by an application component (e.g., a software system) and used by a business process. In ArchiMate, it is not possible to properly represent who is the service provider (the intentional agent) committed to the provision of this service, since the resources themselves are considered as service providers (through the assignment relation). We believe that these and other limitations could be minimized if the notion of service commitments and claims (and all the related aspects, e.g., delegation) were harmonized to the current capability-based view as a way of addressing semantic limitations and increasing the modeling language expressiveness. In fact, by means of an ontological analysis of service modeling fragments in ArchiMate (taking as basis UFO-S), we have shown limitations of the language with respect to semantic clarity and expressiveness of business service relations. This is the subject of Chapter 5.

4.4 Final Considerations

In this chapter, we have analyzed SoEAs in light of UFO-S. In terms of “design science” research initiatives (HEVNER; CHATTERJEE, 2010), UFO-S was applied as a theory to support the analysis of SoEA structuring techniques (that is seen as a kind of artifact, in a general sense).

This analysis enabled us to reveal and relate a number of aspects in SoEA that remains underexplored due to the prevailing capability-based SoEA view. Some of the revealed aspects can be summarized as follows:

- Identification of the intentional agents (service providers and service customers) that are committed to act and apply their

resources/capabilities for fulfilling their commitments towards delivering services as agreed.

- The characterization of a network of service commitments established between internal organizational agents as well as external business partners, which (at certain level) is responsible for guaranteeing the operation of a parallel network of enterprise resources/capabilities.
- Discussion about how enterprise resources/capabilities (e.g., software applications, and hardware devices) are used and integrated to fulfill service commitments.
- The separation of concerns established due to delegations of goals/plans in service relations within an enterprise (e.g., between departments, or between a department and the enterprise as a whole) and among different business partners.

These revealed aspects contribute for the definition of a *commitment-based SoEA* view, which is not contrary to the prevailing *capability-based SoEA* view, but complementary. So, we believe that these two views can be harmonized towards establishing richer SoEA structuring principles.

Chapter 5. An Ontological Analysis of Service Modeling at ArchiMate's Business Layer

Defining Service Commitment-Based Modeling Patterns

ArchiMate is a widely-adopted enterprise architecture language based on the service-oriented paradigm. Despite that, ArchiMate presents problems. In particular, the predominance of the capability-based SoEA view (based on 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 chapter we discuss an ontological analysis of service modeling fragments of ArchiMate's Business layer taking as basis UFO-S and considering the service commitment-based SoEA view discussed in the Chapter 4. As a result, we provide real-world semantics to service modeling fragments in ArchiMate based on the notion of service commitments/claims, and offer recommendations in the form of modeling patterns to ensure expressiveness and to clarify the semantics of service elements.

5.1 Introduction

In the previous chapter we discussed the importance of a new view, so-called service commitment-based SoEA view, which focuses in social aspects inherent to SoEA. Complementary to the prevailing capability-based SoEA view, which focuses on usage/application of resources (and their capabilities), the commitment-based view aims at revealing the relations between intentional agents that drive the usage/application of resources/capabilities.

As discussed in Chapter 4. , the service commitment-based SoEA view has implications in a number of widely adopted service-oriented approaches/frameworks, such as, the Reference Model for SOA by OASIS (SOA-RM) (OASIS, 2006), ITIL (ITSMF, 2007), and ArchiMate (THE OPEN GROUP, 2012), which have been based on the capability-based SoEA view.

In this chapter, we focus on one of these approaches/frameworks, ArchiMate, for deepening our discussion in the context of service modeling. Our choice by ArchiMate relies on the belief that, since this framework provides a service-oriented architecture modeling language, we could directly incorporate the commitment-based SoEA view in the way modelers and stakeholders design and communicate decisions

about SoEA. Moreover, our choice was reinforced by the fact that, 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 still presents problems. We have observed that some of these problems are rooted in the dominance of a conceptualization of service as "unit of functionality" (i.e., "service as capability") 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 broad foundations for service science in the last decade (FISK; GROVE, 2010) (FERRARIO; GUARINO, 2012).

Our objective in this chapter is to examine ArchiMate's service modeling from a broad service-orientation perspective and contribute to the improvement of the language's expressiveness and semantic clarity in the representation of SoEA. Despite the ideas advocated in this work (based on a broad notion of service offered by UFO-S, and on the commitment-based SoEA view) apply in technical as well as in business SoEA layers, in this chapter we focus on ArchiMate's Business layer. This layer is especially characterized by social aspects, since the service relations in this layer are explicitly 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 UFO-S (and aligned with the commitment-based SoEA view), and propose recommendations in the form of modeling patterns, in order to overcome the identified limitations of the language. Thus, the contributions of this chapter 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 three modeling patterns to improve 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 chapter is organized as follows: Section 5.2 presents the running example used for supporting our discussion along this chapter; Section 5.3 analyzes ArchiMate service modeling fragments in light of UFO-S, identifying limitations of the language

with respect to semantic clarity and expressiveness of service relations; Section 5.4 presents recommendations for the language in the form of three modeling patterns (service offering type modeling pattern, service offering modeling pattern, and service agreement modeling pattern); Section 5.5 revisits the running example of Section 5.2 by applying the proposed modeling patterns; Section 5.6 discusses related work; and Section 5.7 presents our final considerations.

5.2 The Running Example

Figure 23 shows an ArchiMate service model in the car insurance domain, which is used for supporting our discussion along this chapter. The model describes a scenario in which two different car insurance companies ("ArchInsurance" and "XInsurance"), as "Insurers", provide two *services* ("Car Insurance" and "Roadside Assistance") that take part in a *product* ("Special Car Insurance"). The terms and conditions related to the product are described in *contracts* ("Car Insurance Contract 1", and "Car Insurance Contract 2". "John" and "Mary", as "Insurants", are service customers.

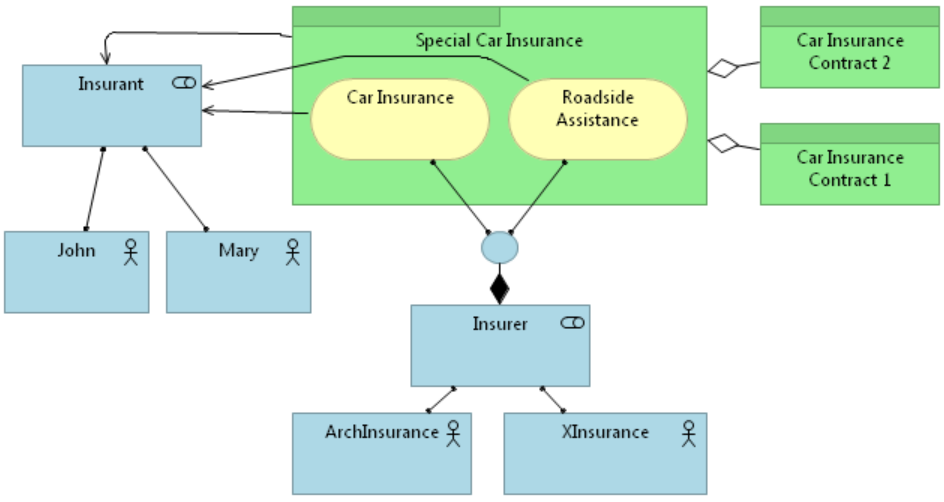


Figure 23 - The running example: "Car Insurance".

This model was built taking as basis strictly the ArchiMate Specification 2.0 (THE OPEN GROUP, 2012). However, as we shall see, this model leaves a number of questions unanswered, e.g.: (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 5.3, we analyze fragments of this model in light of UFO-S, and in Section 5.4, we present recommendations in form of modeling patterns for addressing such limitations.

5.3 Ontological Analysis and Interpretations

In this section, we analyze the semantics of some service model fragments in ArchiMate, taking as basis UFO-S. We start the analysis with small fragments of the running example model (Section 5.2) and increase their complexity progressively. Limitations of ArchiMate for service modeling are identified and labeled (as "L#").

5.3.1 Service and Structural Elements

Initially, we analyze the model fragment of Figure 24, 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 (ALMEIDA; GUIZZARDI, 2008), 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).

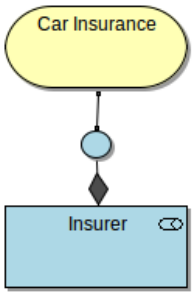


Figure 24 - Service offering type.

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 25-A augments the previous fragment with the "ArchInsurance" *business actor assigned to* the "Insurer" *role*. Following (ALMEIDA; GUIZZARDI, 2008), 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 25-B[8] 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 24).

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")[9]. This lack of expressiveness limits detailing service offerings that instantiate the same service offering type.

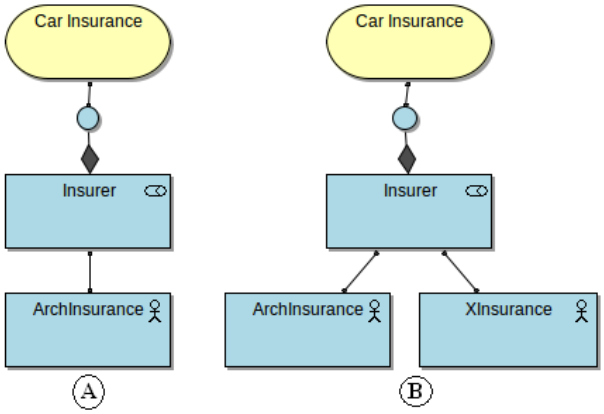


Figure 25 - Service offerings.

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

[9] The *contract* element could be used to differentiate service offerings. But, it cannot be used directly with *services*, only by means of *products*. Section 5.3.2 discusses this in details.

The fragment of Figure 26-A enriches the fragment of Figure 25-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").

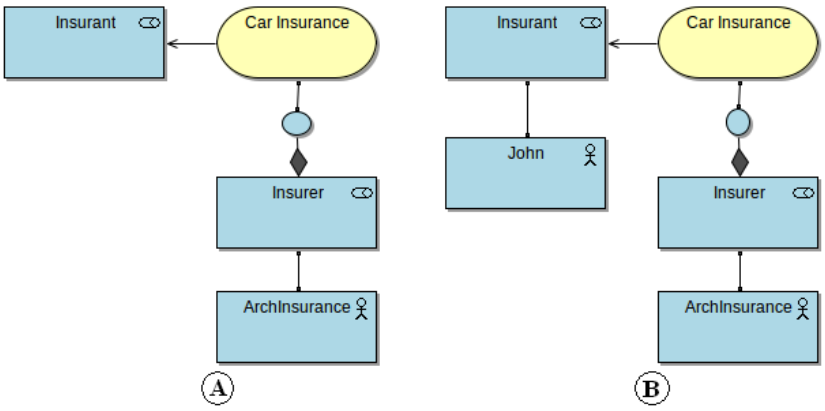


Figure 26 - "*Used by*" relationship.

Consider, further, the model fragment of Figure 26-B, which extends the fragment of Figure 26-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 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 26-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 26-B is augmented, as presented in Figure 27, 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").

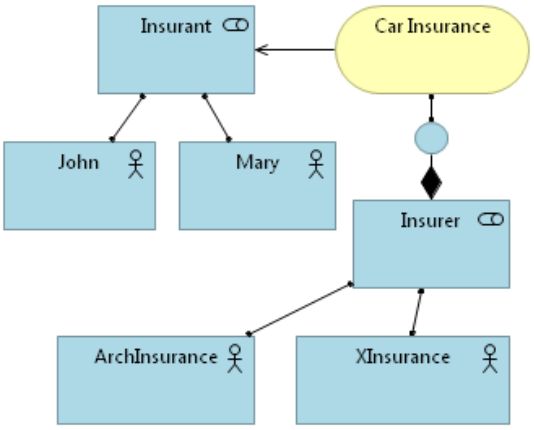


Figure 27 - Service agreements.

5.3.2 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" (THE OPEN GROUP, 2012). A *contract*, in turn, is "a formal or informal specification of agreement that specifies the rights and obligations associated with a product" (THE OPEN GROUP, 2012). 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 28. 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 24 ("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 28 an interpretation similar to the one of Figure 24, 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.

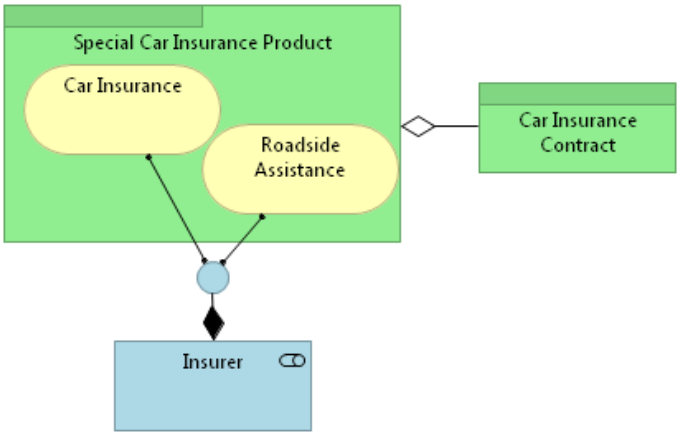


Figure 28 - Service offerings and contract.

Consider the model fragment of Figure 29. Analogously to interpretation of Figure 25-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 30. Let us suppose that this fragment represents agreements between "John", "Mary", "ArchInsurance", and "XInsurance".

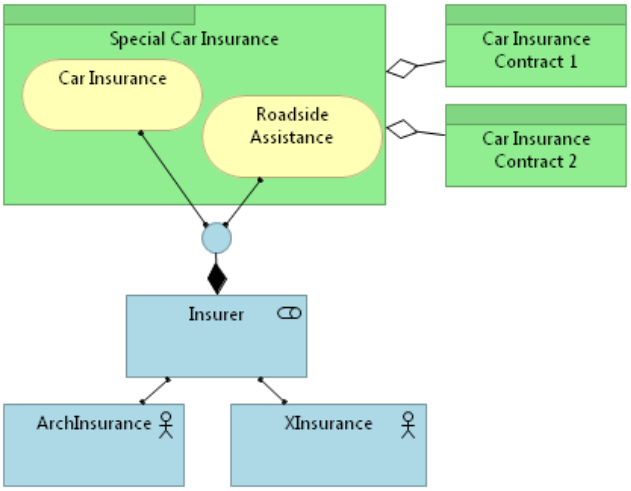


Figure 29 - Different service offerings and contracts.

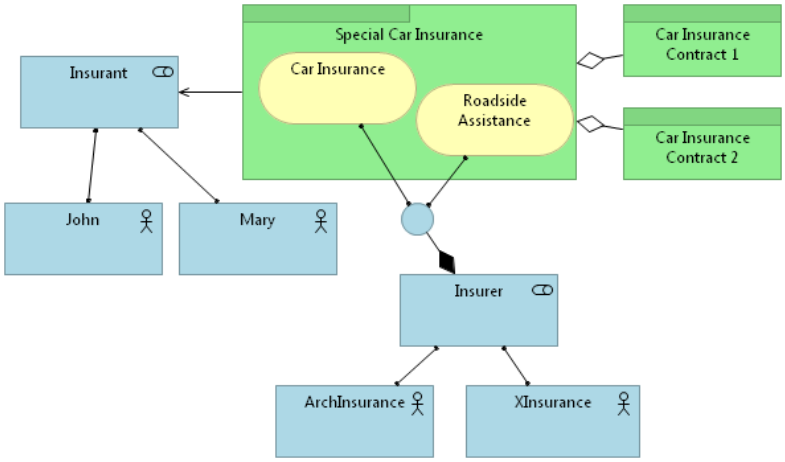


Figure 30 - Product agreements and contracts.

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 27. 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 5.3.2.

5.4 Service Modeling Patterns

The ontological analysis performed in the previous section points out some limitations of ArchiMate, which are summarized in Table 15. 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.

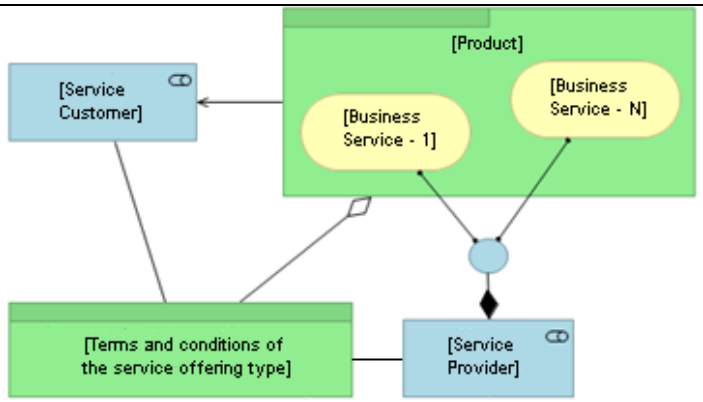
Table 15 - Summary of limitations.

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 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).

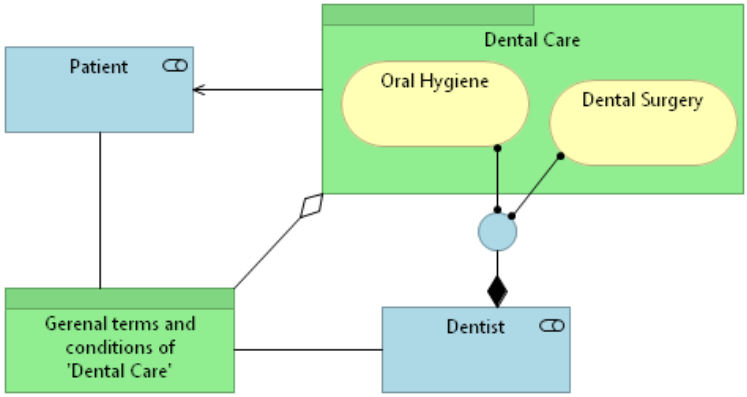
In order to address these limitations without changing ArchiMate's metamodel, we propose a pattern-based solution, which comprises three service modeling patterns: service offering type modeling pattern, service offering modeling pattern, and service agreement modeling pattern. The patterns are based on the existing ArchiMate elements, namely *service, product, business actor, business role* and *contract*, as well as on the *association* relationship. The *association* relationship, in ArchiMate, is a general purpose relationship, defined as "a relationship between objects that is not covered by another, more specific one" (THE OPEN GROUP, 2012).

Each pattern is composed basically by four groups of elements: (i) *products*[10] 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 service providers and to service customers. Thus, *contracts* are in the center of each modeling pattern. Details of each pattern are described as follows. The description template of such patterns is inspired by Design Patterns works by Gamma and colleagues (GAMMA et al., 1995).

Service Offering Type Modeling Pattern

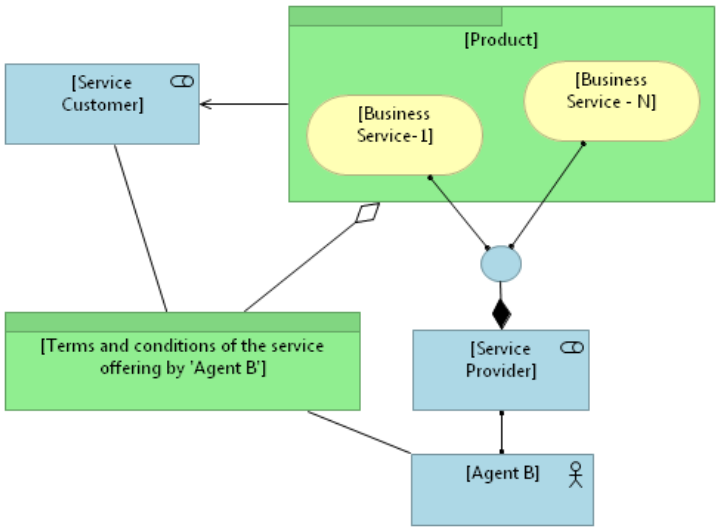
Intent	Representing Service Offering Types at ArchiMate's Business Layer.
Motivation	ArchiMate is ambiguous for expressing service offering type (Limitation 'L1').
Applicability	Use this pattern for representing a service offering type (e.g., a general 'Dental Care' offering type) from a service provider type (e.g., 'Dentist').
Structure	
Constituent Elements	**[Product]**: groups business services. In the context of this pattern, services are offered by a type of service provider. **[Service Customer]**: represents the role, i.e., the type of individual that will act as service customer, i.e., the one that will have the right of using the service(s) due to an establishment of a (future) service agreement. **[Service Provider]**: represents the role (type) of the individuals that are service providers, i.e., those one that provides services. **[Terms and conditions of the service offering type]:** represents a service offering type description. It describes general terms and conditions (e.g., price, and quality requirements) about the provision/use of the service(s) being offered. Such terms and conditions are not dependent on a specific service provider individual. **Obs.**: Target customer and target customer community concepts are not explicitly represented in this pattern. However, if necessary, they can be referred in the description of the terms and conditions.

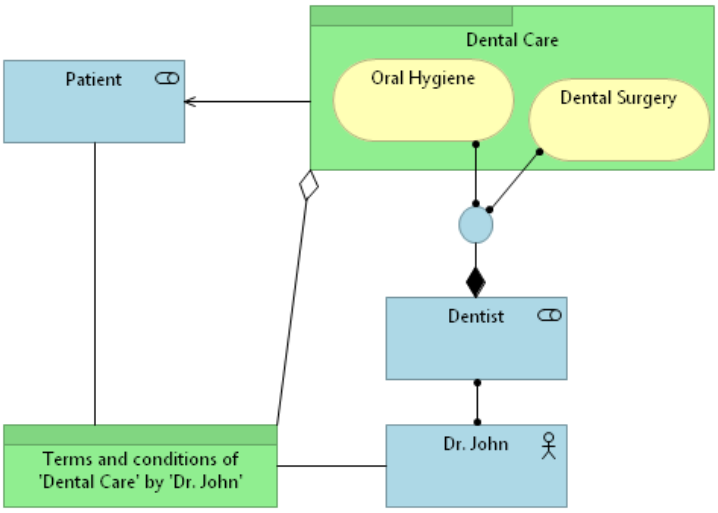
[10] The *product* element is used as a way to aggregate the *contract* element in the representation of service relations. According to ArchiMate, a contract must be aggregated by a product. Thus, even if only one service is modeled, the patterns establish the use of the *product* element.

Dynamics	For each service offering type, only one service provider role is represented. For each service offering type, only one service customer role is represented. The contract "[Terms and conditions of the service offering type]" is related to the product/service(s) to which it refers, to the business role that represents the service customer type (i.e., the type of the individual that will use, as a result of a service agreement, the product/service(s)), and to the service provider role, which represents the type of individual that provides the service.
Usage Example	 The example illustrates a service offering type, the 'Dental Care', which includes the 'Oral Hygiene', and the 'Dental Surgery' business services. The 'Dentist' role represents the type of service provider related to this offering type. The terms and conditions of such offering type are described in the 'General terms and conditions of 'Dental Care'' element. The 'Patient' element represents the service customer role.
Consequences	With this pattern, it is possible to model a service offering type, in which business services are offered by a type of service provider. The terms and conditions of such offering type (which describe the commitments and claims to be established and fulfilled in an actual service provision) are described in a "contract" element, which relates both the service provider role and the service customer role. Thus, a service offering type is mainly characterized by the fact that a "contract" element is only associated with roles (types), i.e., service provider role and service customer role.
Related Patterns	Service Offering Modeling Pattern

Service Offering Modeling Pattern

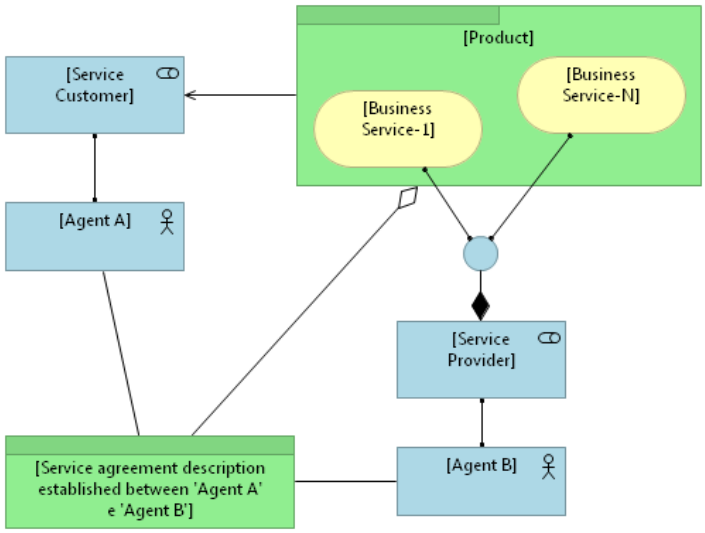
Intent	Representing Service Offerings at ArchiMate's Business Layer.
Motivation (Limitations)	ArchiMate is ambiguous for expressing service offerings (Limitations 'L1', and 'L3'). Differences between service offerings that instantiate the same service offering type cannot be properly represented (Limitation 'L2').
Applicability	Use this pattern for representing a service offering from a specific service provider individual (e.g., 'Dental Care by Dr. John').

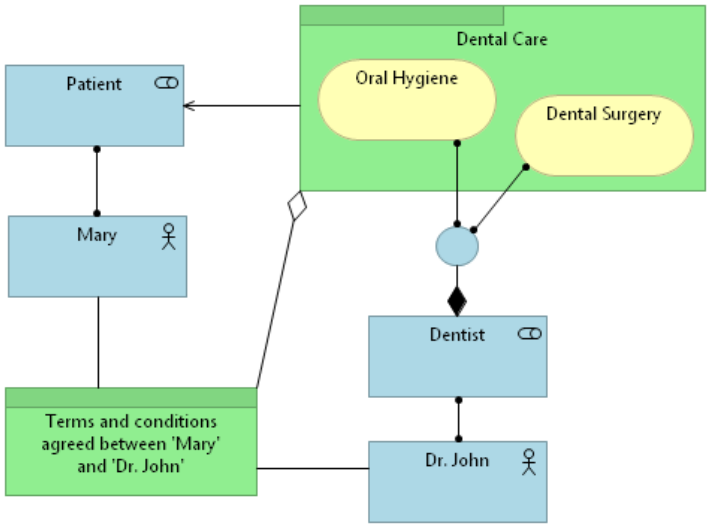
Structure	
Constituent Elements	**[Product]**: groups business services. In the context of this pattern, the services are offered by a specific individual ('Agent B') acting as service provider (and thus instantiating the service provider type). **[Service Customer]**: represents the role, i.e., the type of individual that will act as service customer, i.e., the one that will have the right of using the service(s) due to an establishment of a (future) service agreement. **[Service Provider]**: represents the role (type) of the individuals that are service providers, i.e., those one that provides services. **[Agent B]**: represents an individual playing (instantiating) the role of service provider and that, consequently, is responsible for the service offering. **[Terms and conditions of the service offering by 'Agent B']:** represents a service offering description, which describes the terms and conditions (e.g., price, and quality requirements) about the provision/use of the service(s) being offered. Such terms and conditions are specified by the specific service provider individual 'Agent B', and apply only to her offering. **Obs.**: Target customer and target customer community concepts are not explicitly represented in the pattern. However, if necessary, they can be referred to in the service offering description.
Dynamics	For each individual (e.g., 'Agent B') that instantiates the service provider role, there is a service offering. Each service offering has only one individual that acts as service provider. For each service offering, only one service customer role is represented. The contract "[Terms and conditions of the service offering by 'Agent B']" (representing a description of the service offering by 'Agent B') is related to the product/service(s) to which it refers, to the business role that represents the service customer type (i.e., the type of the individual that will use, as a result of a service agreement, the product/service(s)), and to the specific individual ('Agent B') that instantiates the service provider role, which is committed to what is described in the service offering.

Usage Example	 The example illustrates the 'Dental Care' service offering by 'Dr. John'. Since he instantiates the 'Dentist' service provider role, we say that he is responsible for such offering. The terms and conditions of this offering are described in the "Terms and conditions of 'Dental Care' by 'Dr. John'" element. The "Patient" element represents the service customer role.
Consequences	With this pattern, it is possible to model a service offering from a specific service provider individual. The terms and conditions of such service offering are described in a "contract" element, which relates the service provider individual to the service customer role. It means that the service provider individual is committed to provide the offered services to any individual that plays the service customer role (i.e., as result of a service agreement establishment). Two service offerings that instantiate the same service offering type can be unambiguously identified. Each service offering will have a service provider individual associated with a unique "contract" element, which describes the terms and conditions of the correspondent service offering.
Related Patterns	Service Offering Type Modeling Pattern Service Agreement Modeling Pattern

Service Agreement Modeling Pattern

Intent	Representing Service Agreements at ArchiMate's Business Layer.
Motivation (Limitations)	ArchiMate is ambiguous to represent service agreements (Limitation 'L3'). ArchiMate lacks a sound way to represent which individuals are involved in each service agreement (Limitation 'L4').
Applicability	Use this pattern for representing a service agreement that is established between a specific individual acting as hired service provider and one or more individuals acting as service customer.

Structure	
Constituent Elements	**[Product]**: groups the business services. In the context of this pattern, these services are the "object of agreement" among specific individuals (e.g., 'Agent A', and 'Agent B') that act as service customer and service provider. **[Service Customer]**: represents the service customer role (type). This role represents the type of the individuals that have the right of using the service(s) (as a result of having established a service agreement). **[Service Provider]**: represents the role (type) of the individuals that are service providers, i.e., those one that provides services. **[Agent B]**: represents an individual that plays (instantiates) the service provider role. By being related to a "contract" element that represents a service agreement description, this individual also plays the hired service provider role. **[Agent A]**: represents an individual playing (instantiating) the service customer role. An individual that plays the service customer role must, necessarily, be associated with a "contract" element that represents a service agreement description. This indicates that this individual has established a service agreement (i.e., she hired service(s)). **[Service agreement description established between 'Agent A' and 'Agent B']**: represents a service agreement description, since it relates the (hired) service provider individual and the service customer individual(s). Such description contains specific terms and conditions related to the service agreement established between provider and customers agents (e.g., 'Agent A' and 'Agent B'). These terms and conditions can be a result of a service negotiation, and they must be in conformance with the terms and conditions of the corresponding service offering.
Dynamics	In a service agreement pattern, all the agents (represented as actors) involved in an agreement (customers and providers) must be represented. There must be only one hired service provider individual associated with a service agreement description. All the individuals involved in a service agreement (hired service provider and service customers) must be associated with the "contract" element that describes the terms and conditions of this agreement. The contract "[Service agreement description established between 'Agent A' and 'Agent B']" is related to the corresponding product/service(s), to the individual(s) that plays the service customer role, and to the individual that acts as hired service provider.

Usage Example	 The example illustrates a service agreement between 'Dr. John' and 'Mary' regarding the 'Dental Care' product (and the correspondent business services). Since 'Dr. John' instantiates the 'Dentist' service provider role and is associated with the service agreement description, we say that he is the hired service provider. Since 'Mary' instantiates the 'Patient' service customer role, being also related to the service agreement description, we say that she is the actual service customer. The terms and conditions of this agreement (e.g., price, and payment conditions) are described in the "Terms and conditions agreed between 'Mary' and 'Dr. John'" element.
Consequences	With this pattern, it is possible to model a service agreement between a hired service provider and one or more service customers. The terms and conditions of the service agreement are described in a "contract" element (service agreement description), which relates the service provider individual to the service customer individuals. It means that the service provider and the service customers are mutually committed as a result of the establishment of a service agreement. By adopting this pattern, the individuals involved in a service agreement can be unambiguously identified, since the "contract" element that describes a service agreement links all individuals involved in such agreement.
Related Patterns	Service Offering Modeling Pattern

The service modeling patterns can be used together with the purpose of representing, in the same diagram, service offering types, service offerings, and service agreements. When used in tandem, it may be useful to indicate conformance relationships from a service offering towards the corresponding service offering type, and from a service agreement towards the corresponding service offering. It means that the terms and conditions of such service relations are in conformance. This conformance can be represented by means of an association relationship stereotyped as <<conformance>>. Such association must be established between the "contract" elements that represent the service offering type description, the service offering

description, and the service agreement description. Figure 31 presents a composition of these three patterns with explicit usage of conformance relationship between them.

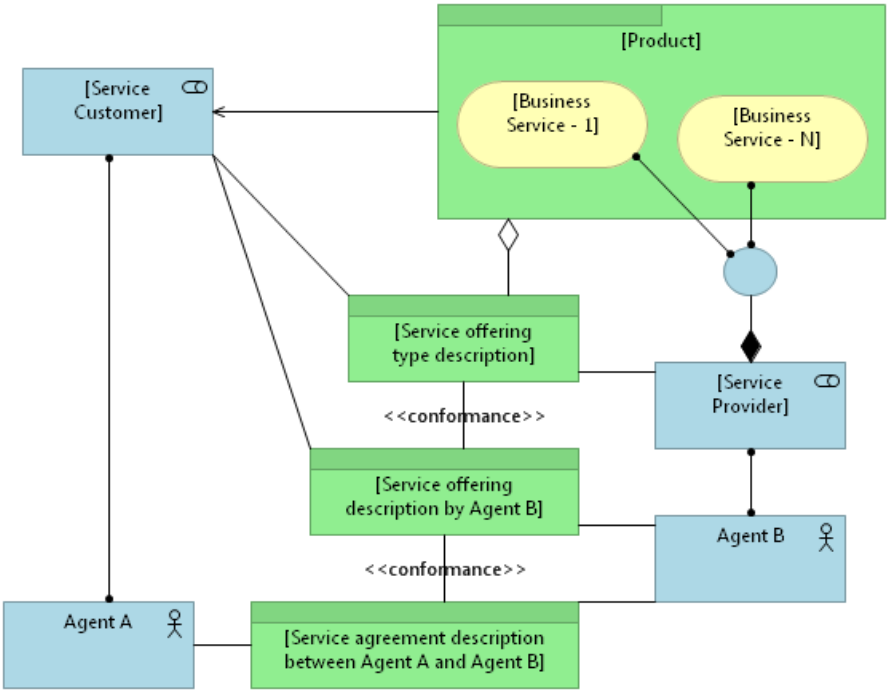


Figure 31 - Composition of modeling patterns and usage of conformance relationship.

5.5 Revisiting the Running Example

For exemplifying the use and the applicability of the patterns towards addressing the limitations, we applied them over the running example model of Figure 23. The resulting model is presented and discussed in three fragments corresponding, respectively, to the application of the service offering type pattern (Figure 32), service offering pattern (Figure 33), and service agreement pattern (Figure 34).

The model fragment of Figure 32 illustrates the use of the service offering type pattern in the context of general "Car Insurance" and "Roadside Assistance" services, which are grouped in the "Special Car Insurance" product element. "Insurer" and "Insurant" represent, respectively, the service provider role and the service customer role associated with such offering type. The terms and conditions of this offering type (service offering type description) are described in the "Insurance General Terms and Conditions" contract element. This service offering type may be instantiated in specific service offerings, as Figure 33 shows.

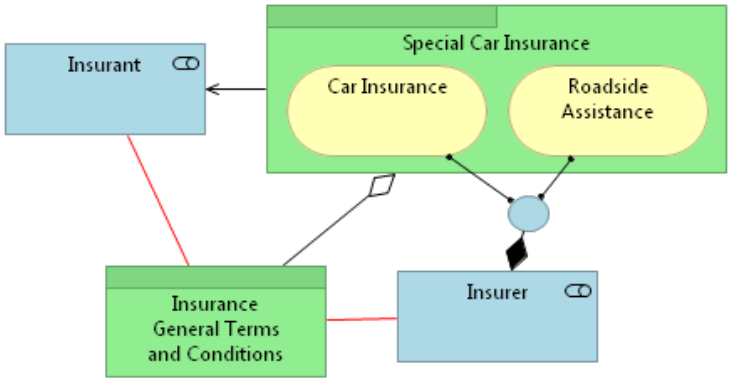


Figure 32 - The use of service offering type pattern.

Figure 33 illustrates the use of the service offering pattern twice: one for "ArchInsurance" and other for "XInsurance". Thus, 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 offering, and "XInsurance" service offering, respectively.

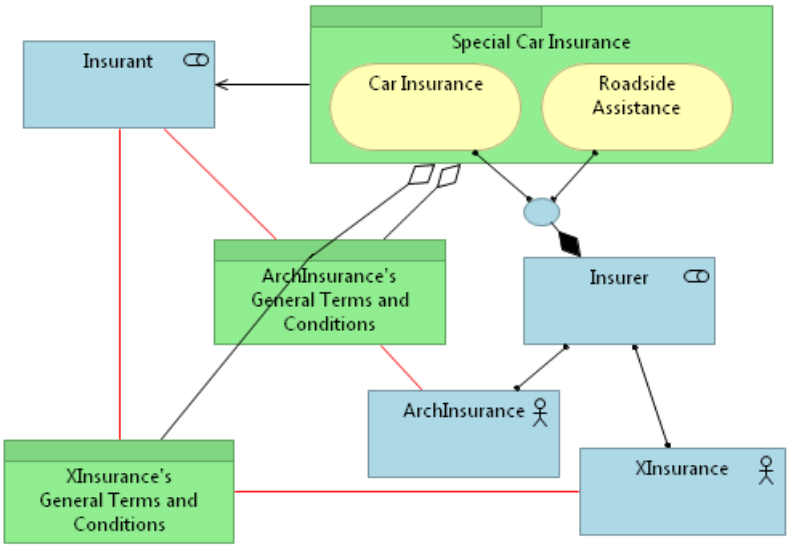


Figure 33 - The use of service offering pattern.

These service offerings are uniquely described by their respective service offering *contracts*, i.e., "ArchInsurance's General Terms and Conditions" and "XInsurance's General Terms and Conditions", respectively. These service offering *contracts* may specify in more details the terms and conditions of the service offering type ("Insurance General Terms and Conditions", see Figure 32). Thus, each service offering *contract* represents a set of commitments (and the related claims) that "ArchInsurance" and "XInsurance", as service providers, establish towards the community of target customers (not represented in the pattern). These service

offerings, in turn, may result in service agreements between specific agents, as illustrated in Figure 34.

Figure 34 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 represents the set of commitments and claims established between the service participants as a result of a successful service negotiation. Thus, 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. As a result, we can establish who hires and who is hired in each service agreement.

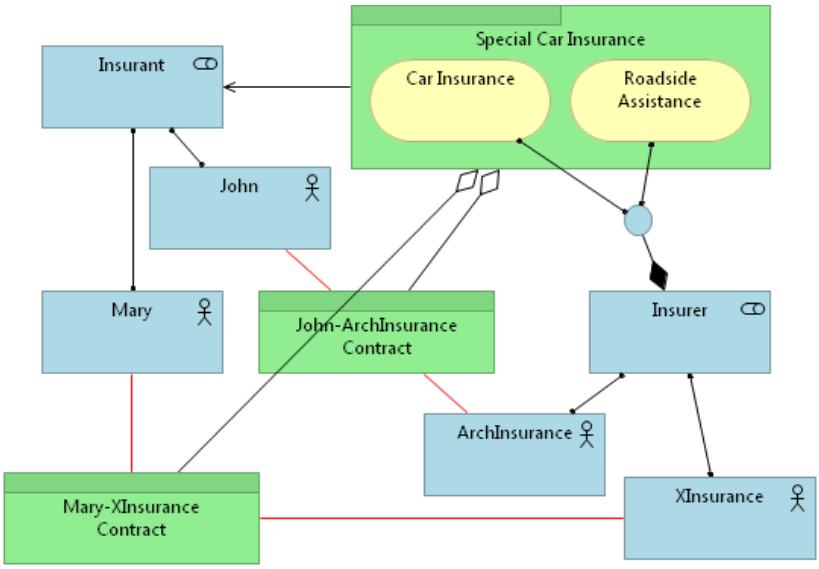


Figure 34 - The use of service agreement pattern.

Figure 35 presents a fragment that exemplifies the three modeling patterns applied in tandem (in a situation in which all the three aspects of the service life cycle 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 conformance relationships between service offering type, service offering, and service agreements are represented by associations with the <<conformance>> stereotype.

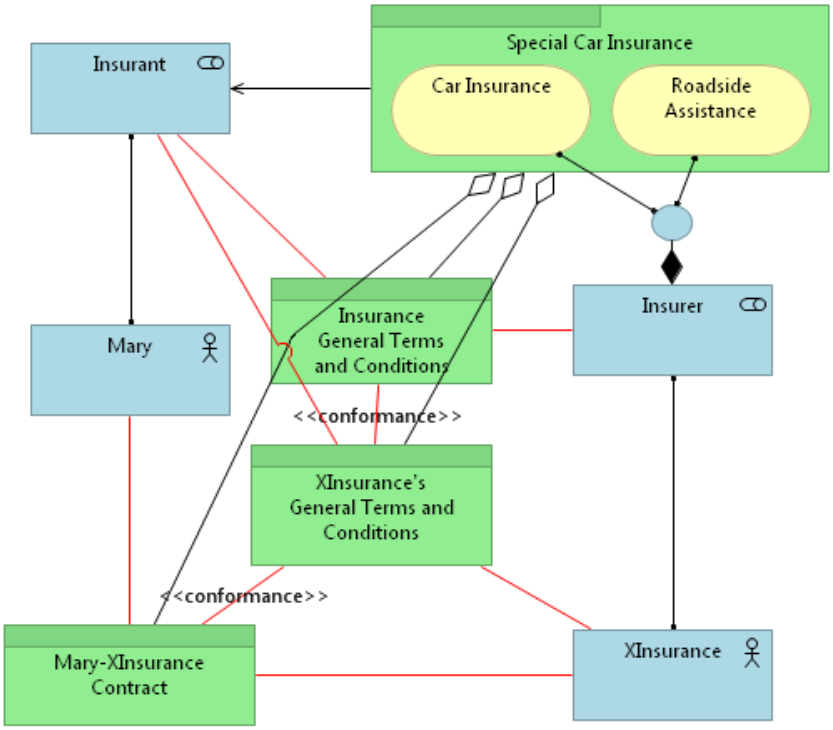


Figure 35 - The use of the three modeling patterns in tandem.

5.6 Related Work

As pointed out by Umapathy and Purao (UMAPATHY; PURAO, 2007), 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 thesis, 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.

In the case of business process and business rule modeling, Letsholo et al. (LETSHOLO; CHIOASCA; ZHAO, 2012) 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 (PREZEL; GAŠEVIĆ; MILANOVIĆ, 2010) and (RECKER et al., 2010), 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 improving enterprise modeling languages.

Despite not focusing on service modeling, some other efforts have performed detailed ontological analysis of ArchiMate's fragments. In (ALMEIDA; GUIZZARDI, 2008), Almeida and Guizzardi have performed a semantic analysis of the concept of "role" in a number of enterprise modeling languages, including ArchiMate. In (AZEVEDO et al., 2013), the concepts of "capability" and "resource" in ArchiMate are also ontologically analyzed. In (AZEVEDO et al., 2011), 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.

5.7 Final Considerations

This chapter presented a semantic analysis of service modeling fragments in ArchiMate taking as basis UFO-S and also considering the service commitment-based SoEA view. We have focused especially on model fragments representing service offerings (and types thereof), and service agreements. By this, we aim at clarifying the semantics of service modeling in ArchiMate in such a way that these models are understandable and faithful to the phenomena they represent.

In fact, as discussed in Chapter 3. , 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, or a service agreement) by different modelers. Consequently, the ambiguity obscures service life cycle 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 and service agreement) in the same model. Further, modelers may believe that the language is serving their purpose (defining conventions for effective communication) while this is not really the case (resulting in what is called “false agreement” (GUIZZARDI, 2005a) (GUARINO, 1998), a miscommunication problem that is hard to detect). So, we believe that 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 shortcomings. A benefit of this approach is that no modification of ArchiMate’s metamodel is required, and that modelers can adopt the proposed patterns, directly obtaining benefits of expressiveness and clarity. 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. Thus, we have explored the opportunity of a lightweight extension based on patterns. The patterns proposed here could be reflected in an appendix of the ArchiMate Specification (THE OPEN GROUP, 2012).

Finally, taking as basis previous work that remark significant empirical evidence that ontological deficiencies affect the usefulness and ease of use of conceptual modeling languages (RECKER et al., 2011), we conducted an empirical evaluation (empirical study) to gather explicit evidence for the suitability and usability of the proposed patterns. This evaluation is described in the following chapter.

Chapter 6. An Empirical Evaluation of the Service Modeling Patterns

This chapter presents an empirical evaluation of the service modeling patterns proposed in Chapter 5. This evaluation was conducted with a sample of 24 participants. It aims at ratifying the ontological analysis described in Section 5.3, and assesses the benefits in adopting the proposed modeling patterns. In the context of this evaluation, the results of the ontological analysis were confirmed, and the usage of the proposed patterns was positively evaluated by the participants (i.e., minimizing ambiguity and increasing expressiveness in service modeling).

6.1 Introduction

In Chapter 5. , three modeling patterns (Service Offering Type, Service Offering, and Service Agreement) were proposed as a way of clarifying semantics of service modeling in ArchiMate and incorporating some social aspects inherent to the service phenomena, especially those one used for representing service offerings (and types thereof) and service agreements. These modeling patterns were designed for addressing the limitations ("L1", "L2", "L3", and "L4") identified during the ontological analysis conducted in light of UFO-S. As such, the patterns incorporate some concepts and relationships of UFO-S and, by means of these patterns, the *commitment-based view* discussed in Chapter 4. could be explored in service modeling initiatives.

The relationship between ontologies and modeling languages has been discussed in many works, such as (WAND; STOREY; WEBER, 1999) (GUARINO, 2009) (TEIXEIRA; FALBO; GUIZZARDI, 2013) and (CARVALHO; ALMEIDA; GUIZZARDI, 2014). In this context, discussions about a certain level of correlation between modeling languages (and consequently their meta-models) and ontologies, used as reference models of "real-world semantics", remarks. The proposed modeling patterns, therefore, were designed in such way of having a certain level of correlation with UFO-S. Thus, we can say that, by using these patterns, the conceptualization of UFO-S is, indirectly, put in practice.

Among the ontology evaluation techniques found in literature, one of them, so-called "application-based evaluation", concerns to evaluation of ontologies when they are put in practice (BRANK; GROBELNIK; MLADENIC, 2005). According to this technique, outputs of the application of an ontology (its performance) on a given task

can offer means for evaluating if the ontology brings benefits when supporting the execution of such task (BRANK; GROBELNIK; MLADENIC, 2005).

Inspired by this ontology evaluation technique and also taking into account the correlation between UFO-S and the proposed modeling patterns, we designed an empirical evaluation. This evaluation aims, by means of a study of service modeling in ArchiMate and of the use of the proposed modeling patterns, at indicating the benefits of UFO-S, as a reference ontology, in tasks of (i) ontological analysis of service modeling languages, and (ii) (re)design of such languages towards representing service phenomena consistently.

The evaluation was organized in two parts - Part 1 and Part 2 -, which were conducted in sequence. Figure 36 illustrates the evaluation strategy. In Part 1, the participants analyzed a service model in ArchiMate strictly constructed based on the ArchiMate Specification 2.0 (THE OPEN GROUP, 2012), and answered a set of questions that inquires participants about general aspects regarding services being offered and services being hired. The set of questions was designed to be as neutral as possible from UFO-S' conceptualization. In Part 2, the participants also analyzed a service model, but this model was built taking as basis the proposed modeling patterns[11]. The same set of questions applied to Part 1 was also used in Part 2, which offers a baseline for comparison. From the results of Part 1 and Part 2, two main analyses are conducted:

- *Do the results of Part 1 confirm the limitations (L2, L3, and L4) of service modeling in ArchiMate identified by the ontological analysis described in Section* 5.3*?* Considering that the results of Part 1 were achieved through participants' interpretations, we have here a possibility to compare these interpretations to those one conducted by us in the ontological analysis of Section 5.3. Our hypothesis is that the participants' interpretations will ratify the results of our ontological analysis (limitations "L2", "L3", and "L4").

[11] Only the Service Offering and Service Agreement modeling patterns were used in the evaluation. It is due to the fact that the Service Offering Type pattern deals with types (of concepts), which does not have direct relation to UFO-S concepts and relationships (since this ontology does not deal with types). As a consequence, we analyze the benefits of these patterns in addressing only the limitations L2, L3, and L4 (since L1 refers to types).

- *Does the usage of patterns address limitations ("L2", "L3, and "L4") identified by the participants in Part 1?* With this analysis we intend to analyze, from the point of view of the participants, if the use of the proposed modeling patterns (Service offering pattern and Service agreement pattern) brings benefits for the task of service modeling in ArchiMate. By that, we expect indirectly to verify if UFO-S (as a reference ontology used in the design of the patterns) contributes for consensus establishment (minimizing ambiguities) and communication in service modeling. Our hypothesis is that the usage of these patterns brings the expected benefits (i.e., decrease ambiguity and increase expressiveness) and, as a consequence, it attests the usefulness of UFO-S as a service reference model.

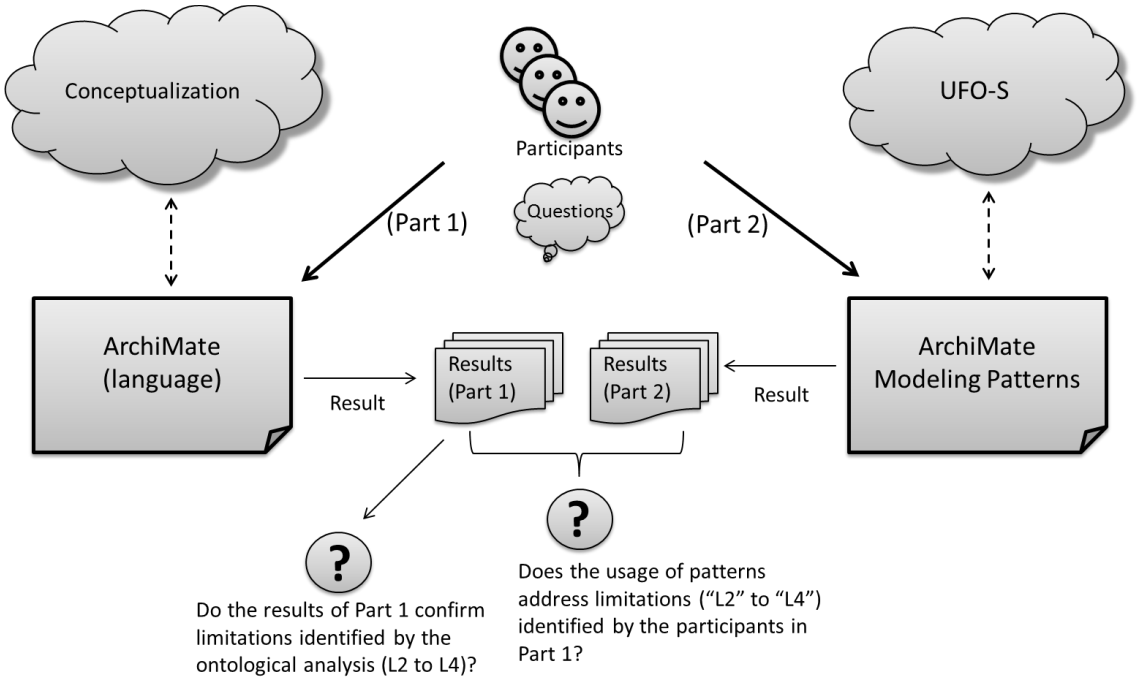


Figure 36 - Evaluation strategy.

This chapter is structured as follows: Section 6.2 presents in details the design of the evaluation; Section 6.3 presents the profile of the participants of the evaluation; Section 6.4 and Section 6.5 present data analysis and discussion of, respectively, Part 1 and Part 2 of the evaluation; Section 6.6 discusses possible limitations of the evaluation; and Section 6.7 presents the final considerations of this chapter.

6.2 Design of the Evaluation

For conducting the evaluation in a systematic way, it is important to define a consistent design. In the previous section, the evaluation strategy was presented, providing general aspects concerning the evaluation process. In this section, we present details concerning the evaluation protocol (summarized in Table 16), which includes object of study, goals, hypothesis, summary of the questionnaires, etc. The evaluation protocol was defined taking as basis the guidelines presented in (TEIXEIRA; FALBO; GUIZZARDI, 2013) and (JURISTO; MORENO, 2001).

Table 16 – Summary of the evaluation protocol.

<table>
<tr><th></th><th>Part 1</th><th>Part 2</th></tr>
<tr><td>Object of Study</td><td>Service models built taking only the ArchiMate Specification 2.0 into account.</td><td>Service models built based on the proposed modeling patterns (Service offering and Service agreement)</td></tr>
<tr><td>General Goal</td><td colspan="2">This evaluation aims, by means of an empirical study of service modeling in ArchiMate and of the use of the proposed modeling patterns, at indicating the benefits of UFO-S, as a reference ontology, in tasks of: (i) ontological analysis of service modeling languages, and (ii) (re)design of such languages towards representing service phenomena consistently.</td></tr>
<tr><td rowspan="2">Goal by Part</td><td rowspan="2">Main goal. Verify if the participants' interpretations (third-party interpretations) about service models in ArchiMate ratify the limitations ("L2, "L3", and "L4") identified in the ontological analysis of Section 5.3.</td><td>Main goal. Identify if the usage of the "Service offering" and "Service agreement" modeling patterns brings benefits in decreasing ambiguity (clarifying semantics) and increasing expressiveness of service modeling in ArchiMate.</td></tr>
<tr><td>Secondary goal. Identify if the usage of UFO-S, as a reference model, brings benefits in consensus establishment and communication in service modeling.</td></tr>
<tr><td>General hypothesis</td><td colspan="2">UFO-S, as a reference ontology, brings benefits in tasks of: (i) ontological analysis of service modeling languages, and (ii) (re)design of such languages towards representing service phenomena consistently.</td></tr>
<tr><td>Hypothesis by Part</td><td>The participants' interpretations ratify the results of the ontological analysis.</td><td>The usage of "service offering" and "service agreement" modeling patterns, based on UFO-S, brings benefits in clarifying semantics and increasing expressiveness of service modeling in ArchiMate. As a consequence, UFO-S brings benefits for consensus establishment and communication tasks, in service modeling.</td></tr>
<tr><td>Participants</td><td colspan="2">(under-graduate or post graduate) Students or professionals of Computer Science area, which have basic knowledge in conceptual modeling.</td></tr>
<tr><td>Analyzed Aspects</td><td colspan="2">Ambiguity and Expressiveness in ArchiMate service models.</td></tr>
</table>

	"Decrease of ambiguity" is given by the decrease of the number of (variety of) participants' interpretations when identifying service offerings and service hirings (and related concepts/relationships) after using the modeling patterns. "Increase of expressiveness" is given by the capacity of expressing, after using the modeling patterns, concepts and relationships (necessary to represent service offering and service hiring) that were not possible to express before. This capacity is analyzed by considering if the participants can identify, after having access to the patterns, new concepts in the service models.	
Data Analysis	The data analysis is conducted taking as basis the answers of the participants to each question about the interpreted models. The content of the answers is categorized and a counting of the occurrences of each category is done. Finally, charts and tables are created for representing the analyzed data. Despite using some *quantitative* apparatus for characterizing the (content of the) answers, the data analysis is mainly *qualitative*. As such, answers about the models are taken in account and compared among them towards offering information to verify our hypothesis.	
Data Collection	In order to facilitate data collection, a website was developed. The website contained the models to be analyzed, the corresponding questions, and a link to the instructional material. The participants answered the questions of Part 1 and Part 2 directly in the website. Although we have used a website, the evaluation was conducted in a lab (informatics laboratory of Federal University of Espírito Santo), in order to ensure a stable Internet connection and to avoid distractions to participants, thereby reducing threats to the evaluation. The participants were invited by email and/or personally. Only pre-confirmed participants could participate of data collection. Participants that were not present at the scheduled date-time could have controlled access to the material used in the evaluation through the Internet ("at distance").	
Instructional material (Appendix A)	Overview of service modeling constructs in ArchiMate Specification 2.0.	- General description of UFO-S conceptualization. - Description of "Service offering" and "Service agreement" modeling patterns.
Summary of Questionnaires (Full version in Appendix A)	- Questionnaire of Part 1 -	- Questionnaire of Part 2 -
	Q1P1 – Identification of service offering and related elements (e.g., who offers, and for whom service is offered).	*Q1P2* – Idem.
	Q2P1 – Identification of service hiring and related elements (e.g., who hires, and who is hired for providing services).	*Q2P2* – Idem.
	Q3P1 – Identification of what each "contract" element represents (e.g., "terms and conditions of an offering", "terms and conditions of a hiring", others, etc.).	*Q3P2* – Idem.
	Q4P1 – Identification of participants related to each "contract" element, and the role played by these participants in the context of each "contract" element.	*Q4P2* – Idem.

	--	*Q5P2* and *Q6P2* – Investigate the benefits in using the modeling patterns.
	--	*Q7P2* – Investigate what needs to be improved in the modeling patterns.

Regarding group organization, the participants were divided (randomly) in two groups - Group A and Group B – and both groups participated in Part 1 and Part 2 of the evaluation. We did not use "control group". As presented by Table 17, this group organization allowed that Group A and Group B could exchange the two adopted application domains ("Car Insurance" and "Online Book Selling") from Part 1 to Part 2 of the evaluation. Thus, whereas in Part 1 Group A analyzed an ArchiMate service model about the "Car Insurance" domain, the Group B analyzed an ArchiMate service model about the "Online Book Selling" domain. In Part 2, whereas Group A analyzed a modeling patterns-based model about the "Online Book Selling" domain, Group B analyzed a modeling patterns-based model about the "Car Insurance" domain.

Table 17 – Exchanging application domains from Part 1 to Part2.

	Part 1	**Part 2**
Group A	ArchiMate service model AND "Car Insurance" application domain	Service model based on the modeling patterns AND "Online Book Selling" application domain
Group B	ArchiMate service model AND "Online Book Selling" application domain	Service model based on the modeling patterns AND "Car Insurance" application domain

"Car Insurance" and "Online Book Selling" application domains were chosen, because we consider that these domains are familiar for a number of people, and allow us to build models relatively equivalents between them (considering the nuances of service relations we aim at exploring). This group organization based on exchange of application domains was used as a way of minimizing the impact that could be caused by using the same application domain, when the learning about the application domains from Part 1 to Part 2 could lead to some biases. Also, the usage of two different application domains may minimize the fact that previous knowledge of the

participants and/or any difficult inherent to an application domain could interfere in the evluation.

In this chapter, for sake of brevity, we will present the data analysis and discussion taking as basis the perspective of the participants allocated to Group A, i.e.: in Part 1, these participants interpret a service model about the "Car Insurance" application domain, built without using the modeling patterns (which is shown in Figure 37), and in Part 2, they interpreted a service model about the "Online Book Selling" application domain built by the adoption of modeling patterns (as presented in Figure 38). The service models used by Group B, in Part 1 and Part 2 of this evaluation, can be found in Appendix A.

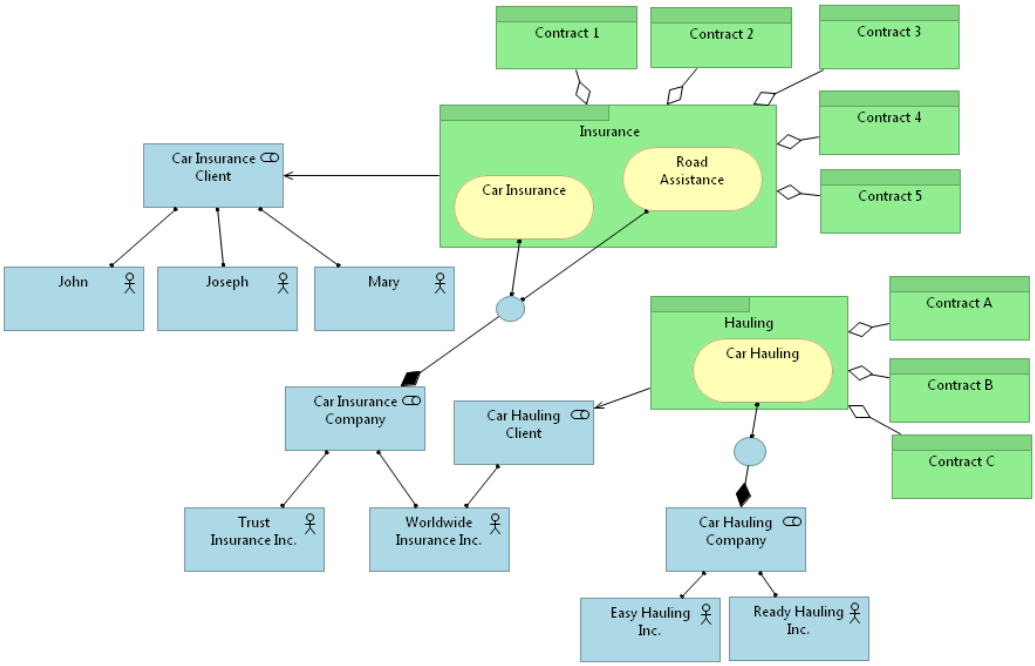


Figure 37 – Service model used in Part 1 of the evaluation (perspective of participants of Group A).

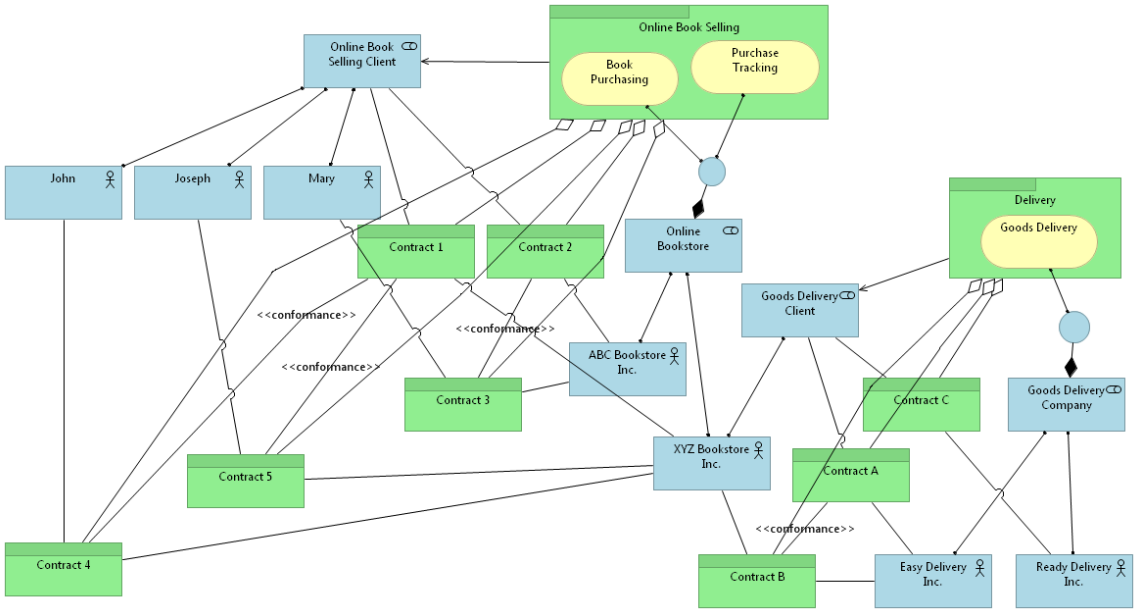


Figure 38 - Service model used in Part 2 of the evaluation (perspective of participants of Group A).

6.3 Participants' Profile

24 people participated in the evaluation. Before starting the evaluation, each participant answered a profile questionnaire. This questionnaire considers three aspects: (i) education background, (ii) experience in conceptual modeling, and (iii) experience in ArchiMate. Based on these aspects, it was possible to raise the participants' profile. The profile questionnaire can be found in Appendix A.

Despite the participants had been organized in two groups (Group A and Group B), in this section, the participants' profile will be discussed as a whole, i.e., without making difference between the participants of each group. This can be justified by two reasons: first, due to the design of the evaluation (with exchange of application domains, and without "control group"), possible differences between participants of Group A and Group B do not interfere considerably in the evaluation; second, after analysis, we could really notice that there was no significant difference between the participants of Group A when compared to the ones of Group B.

Education Background. The first aspect analyzed concerns to the education background of the participants. Figure 39 shows the percentage of participants per the highest academic degree of education. By the figure, we can notice that 50% of the participants are "PhD students" or professionals with "MSc degree". If we also consider "MSc students", the percentage achieves 88%, which characterizes a high

degree of specialization of the participants. These participants present education background in Computer Science, but also in related areas, such as, Information System, Mathematical and Computational Modeling.

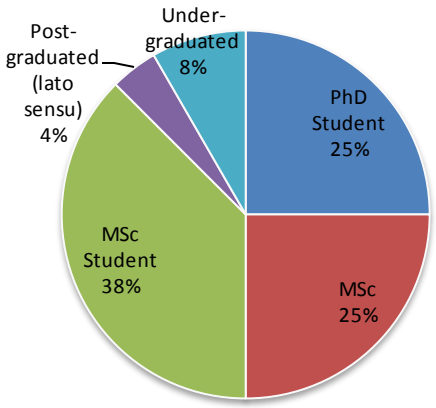


Figure 39 – Percentage of participants per the highest academic degree of education.

Experience in Conceptual Modeling. Together with education background on Computer Science, having basic experience in conceptual modeling is also a requirement for participating in the evaluation. Experience in conceptual modeling is important, because it favors model interpretation, and offers a background to support participants in evaluating/suggesting possible improvements in the usage of the proposed modeling patterns.

Figure 40 (a) presents data about years of experience in conceptual modeling. As this figure shows, 10 participants (42%) have "more than 5 years" of experience (the highest rate of experience). If we analyze the participants with more than 3 years of experience, the number achieves 15 participants (63%). Beyond that, 7 participants (29%) have "from 1 to 3 years" of experience, and only 2 participants (8%) have less than 1 year of experience in conceptual modeling. Based on these numbers, we can say that, considering the goals of this evaluation, the participants present a satisfactory level of experience in conceptual modeling.

Figure 40 (b) shows in which context ("Academic" and/or "Industry/Govern") the participants acquired their experience. By the chart, we can notice a relative equilibrium regarding the context of experience acquisition: whereas 11 participants (46%) have only experienced conceptual modeling in "Academy", 13 participants (54%) have also experienced conceptual modeling in "Industry/Govern". By that, we can say

that the sample of participants presents a good equivalence between theory and practice in using conceptual modeling.

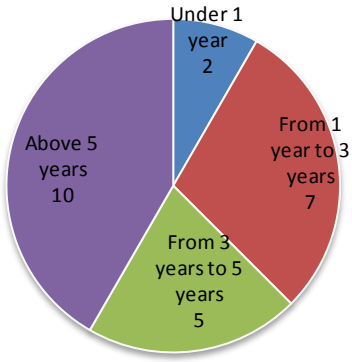


Figure 40 (a) - Years of experience.

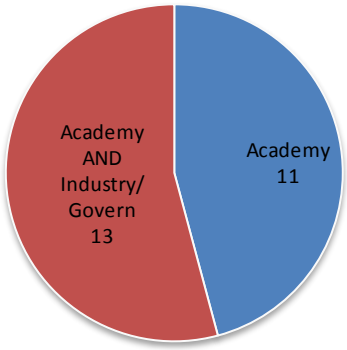


Figure 40 (b) – Context of experience acquisition.

Figure 40 - Experience on conceptual modeling.

Experience in ArchiMate. Despite of not being a requirement for participating in the evaluation, we analyzed participants' profile regarding their experience in ArchiMate. As we can see in Figure 41, 18 participants (75%) do not have any experience in ArchiMate, and 3 participants (16%) have less than 1 year of experience in this language. Thus, we can say that the experience of the participants in ArchiMate is low. However, this fact does not represent a limitation for the evaluation. Indeed, it can be a positive fact, since most participants had a first contact with both, ArchiMate Specification 2.0 and the proposed modeling patterns, during the evaluation. As a consequence, there may be an equilibrium regarding participants' background about ArchiMate Specification 2.0, and also about the proposed patterns.

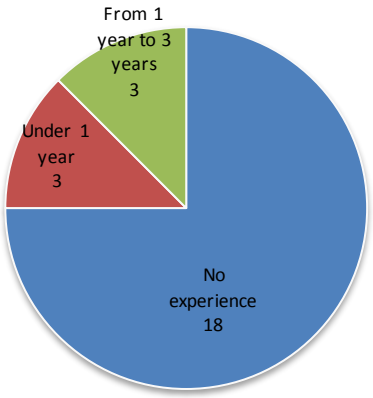


Figure 41 - Years of experience in ArchiMate.

Based on the aforementioned, we believe that the participants present a satisfactory profile for the intent of the evaluation. In summary, the profile of the sample is characterized by:

- High degree of education background: 50% of the participants are “PhD students” or professionals with “MSc degree”; if we consider the “MSc students”, the percentage achieves 88%.
- Satisfactory level of experience in conceptual modeling: 15 participants (63%) have more than 3 years of experience; among them, 10 participants (42%) having more than 5 years of experience.
- Low experience in ArchiMate: 18 participants (75%) do not have any experience in ArchiMate, and 3 participants (16%) have less than 1 year of experience in this language.

6.4 Evaluation Part 1

In this section we present data analysis and discussion of Part 1 of the evaluation, which are addressed, respectively, by Section 6.4.1 and Section 6.4.2.

6.4.1 Data Analysis of Part 1

In Part 1, we investigated, in general terms, how the participants interpret an ArchiMate service model considering aspects, such as: services being offered and services being hiring, and the elements involved in these service relations. These aspects were addressed by questions Q1P1 to Q4P1 presented in Table 16.

When asked if the analyzed model presents service offerings and service hirings, 23 participants (96%) considered that the model presents service offerings, and 20 participants (83%) considered that the model presents service hirings, as shown by Figure 42. A small number of participants considered that “it is not possible to identify” service offerings (1 participant – 4%) and service hirings (3 participants – 2%) in the model. At first glance, it seems that participants are able to identify offerings and hirings in the model. Let us continue, however, the data analysis for more information about it.

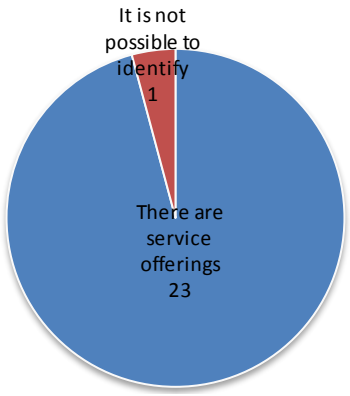


Figure 42 (a) – Identification of service offerings

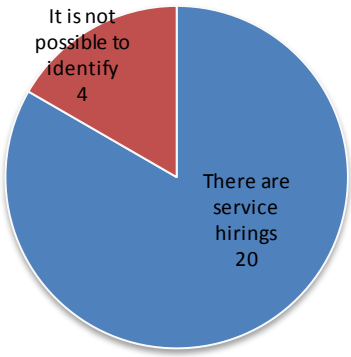


Figure 42 (b) – Identification of service hirings

Figure 42 - Identification of service offerings and service hirings.

Considering the possible existence of service offerings, we asked participants to identify "who offers the services" and for "whom the services are offered" to. As shown by Figure 43 (a), all participants (100%) that identified service offerings in the model, considered the business roles related to business interfaces ("Car Insurance Company", and "Car Hauling Company") or the business actors assigned to these roles ("Trust Insurance Inc.", "Worldwide Insurance Inc.", "Easy Hauling Inc.", and "Ready Hauling Inc.") as representing the ones "who offer the service".

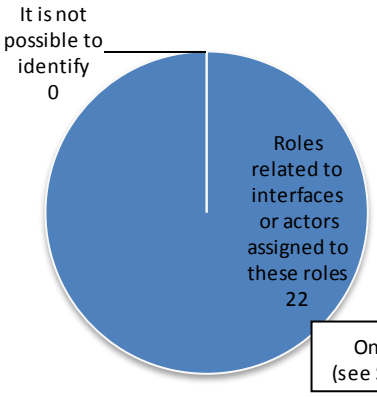


Figure 43 (a) – "Who offers services"

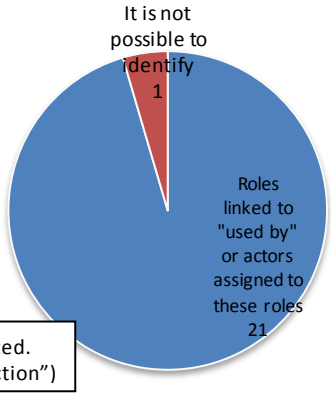


Figure 43 (b) – "For whom services are offered"

Figure 43 – Identification of "who offers services" and "for whom services are offered".

Moreover, according to Figure 43 (b), 21 of these participants (95%) considered that business roles linked to "used by" relationship ("Car Insurance Client", and "Car Hauling Client") or the business actors assigned to these roles ("John", "Mary", "Joseph", and "Worldwide Insurance Inc.") represent the ones "for whom services are offered". Here it is important to highlight that none participant has indicated "Trust Insurance Inc." as someone for whom "Car Hauling" service is offered. It seems to

indicate that, for the participants, if there is an individual in the model for whom a service is offered, this individual should be assigned to the business role that is linked to the corresponding service by means of a "used by" relationship.

Considering the possible existence of service hirings, we asked participants to identify "who is hired for providing services" and "who hires service provision". We expected to identify the ones involved in each service hiring. Thus, we focused on the answers of the participants that have identified service hirings in the model. According to Figure 44 (a), 12 (63%) of these participants considered the business roles related to the business interfaces ("Car Insurance Company", and "Car Hauling Company") or the business actors assigned to these roles ("Trust Insurance Inc.", "Worldwide Insurance Inc.", "Easy Hauling Inc.", and "Ready Hauling Inc.") as representing "who is hired for providing services". The other 7 participants (37%), however, considered that it is not possible to identify them. Regarding "who hires a service provision" (see Figure 44 (b)), 11 of 19 participants (58%) considered the business roles linked to "used by" relationship ("Car Insurance Client", and "Car Hauling Client") or the business actors assigned to these roles ("John", "Mary", "Joseph", and "Worldwide Insurance Inc.") as representing the ones "who hire service provision". Other 8 participants (42%) considered that it is not possible to identify "who hires a service provision".

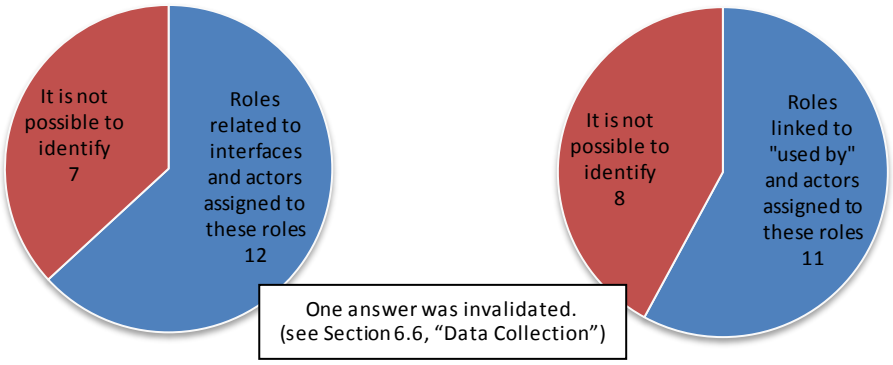


Figure 44 (a) – "Who is hired for providing services" Figure 44 (b) – "Who hires a service provision"

Figure 44 - Identification of "who is hired for" and "who hires" service provision.

Here, the number of participants that could not identify "who is hired for" (7 participants - 37%) or "who hires" (8 participants – 42%) a service provision became representative, if compared to the number of participants that did not identify "who offers" (0 participant) and "from whom services are offered" (1 participant - 5%), as

shown in Figure 43. Also, when we analyzed which model elements were identified by the participants as representing “who is hired” and “who hires” a service provision, we could notice that it is too similar to the identification of “who offers” and “for whom” services are offered, i.e.: role/actors related to business interfaces or linked to “used by” relationship. However, how can the roles/actors in service offerings be differentiated from those ones in service hirings, since they are interpreted in the same way? We believe that this similar interpretation may be due to the fact that there are no explicit constructs for differentiating these elements in the model. This conjecture is reinforced by the analysis of the interpretations about the “contract” element, as follows.

When asked about what each “contract” element represents in the model, 8 participants (33%) indicated that the contracts represent “Terms and conditions of service hirings”, 2 participants (8%) indicated contracts as “Terms and conditions of service offerings”, and 2 participant (8%) indicated as representing other elements (such as “privacy policy”, and “types of contracts”) (see Figure 45 (a)). A considerable number of 7 participants (29%) indicated that it is not possible to identify what each “contract” element represents. Moreover, 5 participants (21%) did not indicate a unique answer, i.e., for these participants some of the eight “contract” elements (“Contract 1” to “Contract 5”, and “Contract A” to “Contract C”) were classified as “Terms and conditions of service offerings”, whereas others were classified as “Terms and conditions of service hirings”, even not existing apparent elements that could justify, at first glance, these answers. Based on these different interpretations, we believe that it is not possible to properly represent/identify what each “contract” element represents in ArchiMate service models.

Finally, considering the analysis of the individuals/actors related by means of each “contract” element, we noticed that most of the participants (15 – 63%) indicated that “it is not possible to identify” which actors are related by means of each contract (see Figure 45 (b)). 8 participants (33%) indicated that each “contract” element links all the actors related to the product (set of services) to which the contract takes part. According to this interpretation, all “contract” elements of a product are related to all actors linked to this product. Moreover, only 1 participant (4%) indicated specific sets of actors linked to each contract, however, it seems not to exist a clear criteria for it.

From that, we consider that ArchiMate presents limitations in properly representing the individuals/actors related to each "contract" element.

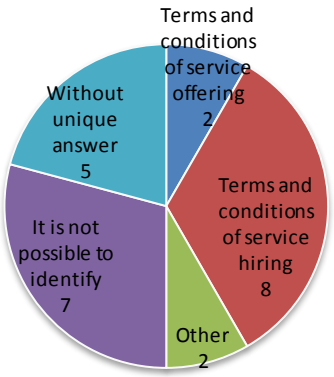


Figure 45 (a) – Identification of "contract" elements

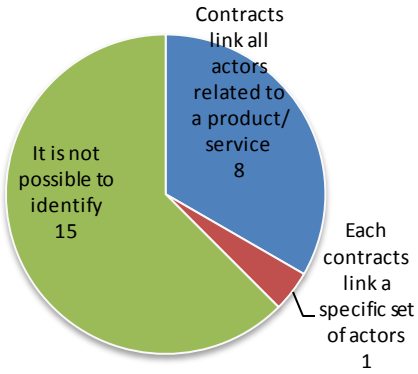


Figure 45 (b) – Actors involved in each contract

Figure 45 – Identification of "contract" elements and linked actors.

6.4.2 Discussion of Part 1

Considering that the goal related to the Part 1 of the evaluation regards *to verify if the participants' interpretations about service model in ArchiMate ratify the limitations identified in the ontological analysis of Section 5.3*, in this section, we discuss to what degree the data presented in the previous subsection ratify (or not) the limitations "L2", "L3" and "L4". Our discussion is driven by three topics:

- Lack of a clear way to describe specific terms and conditions (differences) of service offerings that offers the same set of services ("L2").
- Lack of a clear way to represent service offerings and service hirings (and parts thereof) ("L3").
- Lack of a sound way to represent actors involved in each service hiring ("L4").

Lack of a sound way to represent individuals involved in each service hiring ("L4"). According to the answers of the participants in questions related to the "contract" elements (see Figure 45 (b)), most of participants (15 – 63%) indicated that "it is not possible to identify" the actors linked to each contract. Also, 8 participants (33%) indicated that contracts link all the actors related to the product (set of services) to which the contract takes part, but without indicating the specific actors related to each contract. This set of 8 participants achieved this conclusion probably due to the fact that the "contract" elements were not directly related to specific actors. Thus, the model does not provide means to identify the specific actors related to specific

contracts. Also, if we consider the answers about “who is hired for service provision” and “who hires a service provision” (see Figure 44), we can notice that around 33% of the participants could not identify these individuals. Thus, the lack of a sound way to represent individuals involved in each service hiring is reinforced by two aspects: (i) participants had problems in identifying individuals related to each contract, and more than that, (ii) some of them had problems in identifying “who is hired” and “who hires” a service provision.

Lack of a clear way to represent specific terms and conditions (differences) of service offerings that offer the same set of services (“L2”). Service offerings from different individuals (e.g., “Trust Insurance Inc.” and “Worldwide Insurance Inc.”) but that encompasses the same set of services (e.g., “Car Insurance” and “Road Assistance”) can present different terms and conditions (e.g., prices, target customers, and availability), which use to be described in a kind of artifact (e.g., advertisements). Thus, a modeling element that can indicate where terms and conditions of each offering are described, can be useful towards uniquely characterizing a service offering. But, when participants were asked about what the “contract” elements represent, interpretations varied considerably (see Figure 45 (a)). Also, only 2 participants (8%) indicated that “contract” elements represent “Terms and conditions of service offerings”. Based on that, we believe there is a lack of an element for representing where specific terms and conditions of a service offering can be described. Moreover, based on collected data, we believe the analysis of this limitation can be extended to the representation of terms and conditions of service hirings.

Lack of a clear way to represent service offerings and service hirings (“L3”). This limitation is characterized by the fact that service modeling in ArchiMate is not expressive enough for representing, without ambiguity, service offerings and service hirings. Taking as basis data presented in Figure 42 (a) and Figure 42 (b), 23 participants (96%) considered that the analyzed model presents service offerings, and 20 participants (83%) considered that the model also presents service hirings. At first glance, we could say that participants properly identified service offerings and service hirings. However, by considering the other data about the analysis of service offerings and hirings (e.g., data about “who offers a service”, “for whom a service is offered”,

"who hired a service", and "who is hired for service provision"), we could notice that, despite considering the existence of offerings and hirings, participants could not clearly identify (i) which are the service offerings and which are the service hirings, (ii) who is related to each offering and each hiring, and (iii) which (contract) elements describe terms and conditions of offerings and hirings. Beyond these limitations, we could notice an overload in the use of the "used by" relationship. Thus, when asked for identifying the elements of service offerings, most participants considered that actors/roles related to services through interfaces were offering services to other actors/roles related to these services through "used by" relationship. However, when asked for identifying service hiring elements, most participants also considered that actors/roles related to services through interfaces were providing services to other actors/roles related to these services also through "used by" relationship. Moreover, around 42% of participants considered that it is not possible to identify "who hires" and "who is hired" for a service provision.

It is important to highlight that, along the analysis and discussion of Part 1, references to the "business actor" element (about 64%) and to the "business role" element (about 15%) in the participants' answers - when referring to "who offers services", "for whom services are offered", "who hires", and "who is hired" -, were analyzed in tandem (see Figure 43 and Figure 44). It is due to the fact that we concluded that the participants used roles (types) just as a general way of referring to actors (individuals). However, despite this seems to be a trend when referring to "who offers", "who is hired", and "who hires" services, in the case of the analysis of "for whom services are offered" (target customers) the numbers are different. We could notice an increase in the usage of "roles" (achieving 36% of the answers). Perhaps, this increase indicates that, in this specific case, the participants have used roles as an intensional criterion for referring to all individuals for whom services are offered (not only those one represented in the model as actors). This could be justified by the fact that a service offering, in the common-sense, is a relation between a specific individual towards a target community of individuals not necessarily identified. In contrast, in service hirings, the individuals involved in a service agreement (and consequently in service contracts) are identified, which could justify the higher usage of actors when referring, e.g., to "who hires" and "who is hired" for service provision. Anyway, for

supporting this hypothesis, new evaluations need to be conducted. For now, we should say that these different ways of interpreting ArchiMate service models (regarding the usage of actors and/or roles) may lead to misunderstandings, which requires some intervention in the language in such a way of clearly defining its semantics.

As a result, we can say that the participants' answers in Part 1 of evaluation ratified the limitations we got in ontological analysis, when we used UFO-S for supporting our analysis about service modeling in ArchiMate.

6.5 Evaluation Part 2

In this section, we present data analysis and discussion of Part 2 of this evaluation, which are respectively described in Section 6.5.1 and Section 6.5.2.

6.5.1 Data Analysis of Part 2

The questionnaire of Part 2 is composed of 7 questions (Q1P2 to Q7P2) that aim at investigating the benefits in using the Service Offering and Service Agreement modeling patterns. The first four questions (Q1P2 to Q4P2) of Part 2 are exactly the same questions answered by the participants in Part 1. With that, we expect to have a baseline for comparison between results of Part 1 and Part 2. The other three questions (Q5P2 to Q7P2) inquire participants about their opinion concerning possible benefits in using the patterns and/or necessary improvements to be incorporated.

When asked if the analyzed model presents service offerings and service hirings, all participants (100%) considered that service offerings as well as service hirings are represented in the model. Different from Part 1, when a little number of participants considered that it is not possible to identify service offerings (1 participant) and service hirings (4 participants), in Part 2 there was no doubt about it.

In the case of service offerings, when asked about "who offer a service", 22 participants (92%) correctly identified, according to the modeling patterns, the actors offering services (*service provider* in UFO-S), and only 2 participants (8%) did not correctly identify them. Whereas in Part 1 there was a certain misunderstanding about the one "who offers a service" (business actors and/or business roles), in Part 2 the huge majority of participants did not have doubt in indicating the correct actors ("ABC

Bookstore Inc.", "XYZ Bookstore Inc.", "Easy Delivery Inc." and "Ready Delivery Inc.") as representing "who offers a service", as Figure 46 (a) shows.

Although the proposed modeling patterns do not present specific constructs for representing "for whom a service is offered" (*target customer* in UFO-S), we kept a question about this in the questionnaire of Part 2. With that, we aimed at analyzing if, even if no construct for representing this concept had been defined, the same understanding about the model remains. In Part 1, 21 of 22 participants (95%) indicated actors and roles linked to the "used by" relationship as those one for whom services are offered, and only 1 participant (5%) indicated that "it is not possible to identify". In Part 2, the numbers were very similar, as can be seen in Figure 46 (b). Therefore, from Part 1 to Part 2, the model interpretations about "for whom a service is offered" kept basically the same. In fact, considering the modeling patterns, the expected answer (answer key) is "it is not possible to identify", since the modeling patterns do not offer any representation for this concept. However, we believe that the participants' answers may be explained by two reasons: (i) they did not understand that the modeling patterns do not offer any representation for this concept, and/or (ii) despite the fact that no new construct was offered for expressing the concept referent to "for whom a service is being offered", the participants tried to find a valid representation according to their own point of view.

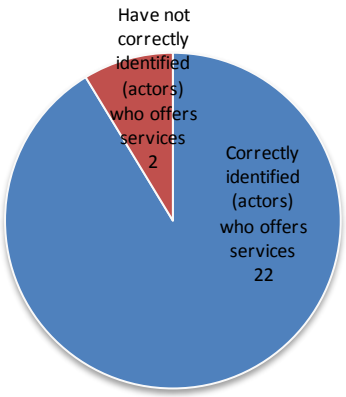


Figure 46 (a) – "Who offers a service" (*Service Provider* in UFO-S)

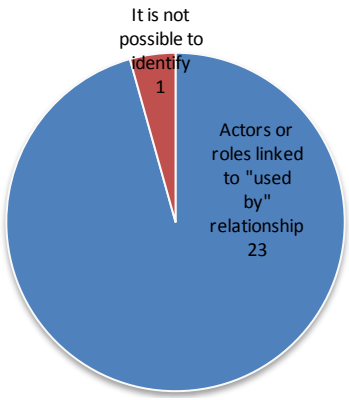


Figure 46 (b) – "For whom a services is offered" (*Target Customer* in UFO-S)

Figure 46 – Identification of "who offers" and "for whom" a service is offered.

Moreover, we analyzed the identification of "who is hired" (*hired service provider* in UFO-S) and "who hires" a service provision (*service customer* in UFO-S), as can be seen in Figure 47.

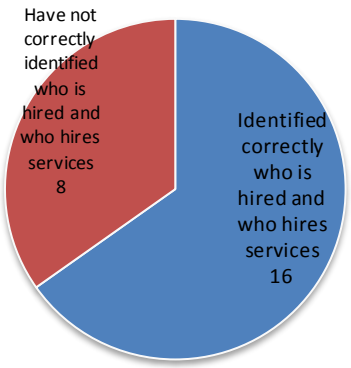


Figure 47 – Identification of who is hired and who hires a service provision.

Taking as basis the modeling patterns, 16 participants (67%) correctly indicated the individuals that are hired ("ABC Bookstore Inc.", "XYZ Bookstore Inc.", and "Easy Delivery Inc.") and the individuals that hires provisions of services ("John", "Joseph", "Mary", and "XYZ Bookstore Inc."), whereas 8 of these participants (33%) have not correctly identified these individuals. The main mistakes of these 8 participants are related to the fact that they could not identify between which individuals (including "who is hired" and "who hires" a service provision) the service hirings are established. However, we could notice an interesting phenomenon about that along the evaluation: the identification of "who hires" and of "who is hired for" a service provision got better insofar the participants proceed in the evaluation, as follows.

When asked for identifying the "contract" elements, as Figure 48 (a) shows, 21 participants (88%) correctly identified, according to semantics defined by the modeling patterns, what each "contract" element represents in the model (i.e., "Terms and conditions of service offering", or "Terms and conditions of service hiring"). Also, when asked about the individuals related to each "contract" element (acting as "who offers a service", "who hires the service", and "who is hired"), the rate of hit achieved 21 participants (88%) (see Figure 48 (b)).

Thus, whereas in Part 1 we had various interpretations about what the "contract" elements represented, in Part 2, the number of possible interpretations decreased considerably. Also, whereas in Part 1 many participants considered that it was not possible to identify the individuals related to each "contract" element (15 participants – 63%), in Part 2, we achieved a higher degree of agreement (21 participants – 88%) about who are the individuals and which roles these individuals

play in each “contract” element (and, consequently, in each offering and hiring described by the contract).

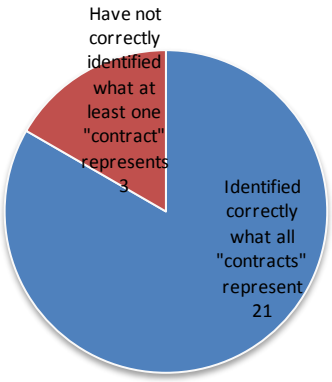


Figure 48 (a) – Identification of what each contract element represents

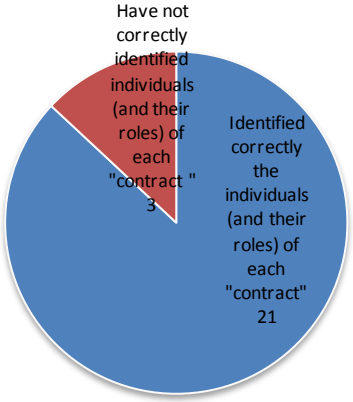


Figure 48 (b) – Identification of individuals (and their roles) in each contract element

Figure 48 – Identification of what each “contract” element represents and who is related to it

Considering that, according to the modeling patterns, each “contract” element indicates the existence of a service offering or of a service hiring, differently from Part 1, in Part 2 participants could properly identify that in the analyzed model there were various service relations (service offerings and service hirings), and that different participants were involved in each one of them (e.g., “Mary” hires “ABC Bookstore Inc.” in a service relation, and “Joseph” hires “XYZ Bookstore Inc.” in another service relation).

Finally, when asked for discussing the benefits in using the modeling patterns, 23 participants (96%) considered that the usage of the patterns brings benefits for service modeling in ArchiMate. These participants remarked as the main benefits, the followings (with highlight for the first one):

- It increases expressiveness and clarity (i.e., it improves the identification of individuals in each service offering and service hiring).
- It facilitates communication.
- It facilitates the understanding about the models for beginners.
- It drives model interpretation.
- Finally, some participants even believe that the usage of the modeling patterns may also facilitates tasks of service modeling.

Concerning necessary improvements, the participants remarked the followings:

- Difficulties in visualization. The way the modeling patterns were structured demands considerable overhead to identify the elements involved in each service relation, e.g., the elements involved in a service offering and a service hiring.
- Lack of a way of representing indirect service provision (in service provision chains). For example, in the model "Joseph" hires "XYZ Bookstore Inc." that hires "Easy Delivery Inc.". By the proposed patterns, it is not possible to say anything about "Joseph" (indirectly) hiring "Easy Delivery Inc.". As a consequence, more complex service relations encompassing a chain of delegations cannot be properly represented.
- Lack of representation of target customer. Some participants have claimed for an explicit representation for target customers in service offerings.

6.5.2 Discussion of Part 2

The main goal of Part 2 regards to *identify if the usage of the "Service offering" and "Service agreement" modeling patterns brings benefits in decreasing ambiguity (clarifying semantics) and increasing expressiveness of the service modeling in ArchiMate*. According to the evaluation strategy, these benefits are expected to be noticed insofar the results of Part 2 (when modeling patterns are used) are compared to the results of Part 1 (without patterns). In this section, we discuss three benefits identified from the participants' interpretations:

- Participants could identify what each "contract" element represents (terms and conditions of service offering or of service hiring).
- Participants could identify the individuals (and their roles) related to each contract.
- Participants could distinguish service offerings and service hirings (and parts thereof).

Participants could identify what each "contract" element represents. From that, participants could properly identify where specific terms and conditions of each service offering and service hiring are described. Thus, using the modeling patterns, 21 participants (88%) could correctly indicate what each "contract" element represents:

“Terms and conditions of a service offering” or “Terms and conditions of a service hiring”. Comparing to the results of Part 1, we can say that it was possible (i) to minimize the number of interpretations about what the “contract” elements represent (avoiding possible communication problems), and (ii) to offer a way of representing the description of terms and conditions of service offerings and service hirings. From that, different offerings and hirings that refer to the same set of services can have their own terms and conditions (e.g., price, and quality) represented by their corresponding “contract” element.

Participants could identify individuals (and their roles) related to each contract. 88% of the participants could identify the individuals (and their roles, i.e., “who offers”, “who hires” and “who is hired”) related to each “contract” element. This was possible because the modeling patterns were designed in such a way that the individuals (business actors) involved in each service relation (service offering / service hiring) are related directly to the contracts by means of “association” relationships. As such, the “contract” elements mediate the service relations (service offerings and service hirings) between the individuals. Whereas in Part 1 it was not possible to properly identify service relations established between specific individuals (e.g., service hirings between “Mary” and ABC Bookstore Inc.”, and between “Joseph” and “XYZ Bookstore Inc.”), in Part 2, by using the modeling patterns, it became possible, since participants could identify which individuals are related to the respective “contract” elements.

Participants could distinguish service offering and service hiring (and parts thereof). As aforementioned, from the usage of the modeling patterns, participants could identify what each “contract” element represents, as well as the individuals related to each contract, i.e., “who offers”, “who hires” or “who is hired”. Also, due to the fact that the modeling patterns have to be read as a whole, i.e., considering all their structural parts (the “contract” element, the business roles, the product and its services, and the business actors), we could minimize the construct overload associated to the “used by” relationship, as identified in Part 1. In Part 2, by adoption of the modeling patterns, the “used by” relationship is not interpreted in isolation, but as one of the structural parts of the modeling patterns. This favors the distinction of its usage in service offerings and service hirings. In summary, by analyzing the patterns as

a whole, the participants could better identify service offerings and service hirings, and their constituent elements.

Table 18 summarizes the general results of data analysis and discussion of Part 1 and Part 2 of the evaluation in three main aspects: (i) identification of what each "contract" element represents, (ii) identification of the individuals (and their roles) related to each contract, and (iii) representation of service offerings and service hirings as a whole.

Table 18 – Summarization of the results of Part 1 and Part 2.

Summarized Aspect	Results of Part 1	Results of Part 2
Identification of what each "contract" element represents	There were many interpretations: - "Terms and conditions of service hirings" (8 participants - 33%). - "It is not possible to identify" what each contract represents (7 participants – 29%). - Without a consistent answer (5 participants - 21%). - "Terms and conditions of service offerings" (2 participants - 8%). - Contracts as representing other elements (e.g., "policies") (2 participants – 8%). Lack of a way to represent terms and conditions of service offerings that offer the same set of services	Higher rate of consensus. 21 participants (88%) correctly identified what each "contract" element represents. As a result, the patterns offered a way to represent terms and conditions of service offerings (including those one that offer the same set of services).
Identification of the individuals (and their roles) related to each contract	Different interpretations about the individuals (and their roles): - "It is not possible to identify" (15 participants – 63%). - The contracts link all actors related to a "product" element (8 participants – 33%). - Each contract links a specific set of actors (1 participant – 4%).	Higher rate of consensus. 21 participants (88%) correctly identified the individuals (and their roles) related to each contract.
Representation of service offerings and service hirings (as a whole).	Lack of a clear way to represent the elements that take part in such service relations. The aforementioned results of Part 1 evidence such limitation.	It was possible to minimize such limitation. The aforementioned results of Part 2 evidence this.

Beyond the aforementioned benefits, the participants explicitly remarked that the usage of the modeling patterns contributed for increasing expressiveness and clarity, facilitating communication, modeling task, and understanding/interpretation of

the ArchiMate service models. However, they also highlighted some necessary improvements, such as difficulties in visualization, and lack of representation of "service provision chains" and of target service customers.

For addressing difficulties of visualization originated from complex models, we believe that modularization strategies could be useful. For facilitating the identification of what each element represents in the model, we could also use stereotypes. Thus, e.g., "contract" elements representing "terms and conditions of a service offering" or "terms and conditions of a service hiring" would have different stereotypes (beyond their specific relationships).

Our decision in not representing target service customers in the modeling patterns is due to modeling limitations we found in ArchiMate (such as the lack a sound way of representing types and instances thereof in the same model). It was not possible to properly represent both *service customer* and *target service customers* roles, and their instances, in the same service model. The solution for this modeling limitation would be related to structural changes in the ArchiMate metamodel, but we did not address it in the current version of the modeling patterns. In fact, we prioritized a lightweight pattern-based solution for favoring better user acceptance, and low barrier incorporation in ArchiMate. Finally, for addressing the lack of representation of "service provision chains", we should first extend UFO-S for better accommodating the influence of service commitments from a service relation towards others (considering all the aspects related, e.g., to open and close delegations inherent to these relations), building thus a notion of "chains of service commitments". From this, we could then improve the current modeling patterns for addressing the representation of "service provision chains". Anyway, despite being a natural improvement, incorporating the representation of target customers and of "service provision chains" in the current version of the patterns could increase their complexity, even before they be used in practice and have their application consolidated. As such, these improvements are considered as part of our future perspectives, as discussed in Chapter 7.

6.6 (Possible) Limitations of the Empirical Evaluation

Despite of using systematic guidelines (based on (TEIXEIRA; FALBO; GUIZZARDI, 2013) and (JURISTO; MORENO, 2001)) for designing the evaluation, some limitations[12] could be noticed during application of the evaluation. According to our analysis, these limitations do not invalidate the results, but they are described here for offering a complete report about the whole evaluation.

Number of participants. We could count on 24 participants that acted in Part 1 as well as in Part 2 of the evaluation. Despite offering satisfactory parameters for comparison, if the number of participants was bigger, we could use statistical analysis for better supporting our conclusions. As a consequence, the evaluation initiative (data analysis and discussion) was mainly characterized as a qualitative approach.

Data collection. Despite of using a guided set of questions, we could notice that some participants did not understand exactly how they should describe their answers. As a consequence, two answers were invalidated (1 in the analysis of service offerings (see Figure 43), and 1 in the analysis of service hirings (see Figure 44)), because the participants did not properly answered what was required by the question: the answers were too vague that we could not gather the necessary information. However, these two invalidated questions did not interfere (significantly) in the results. In fact, there is a trade-off to be considered when using "open-questions". When we use "open-questions", we can count on participants' answers without having a heavy interference in their answers. On the other hand, it is possible to have some answers invalidated. For minimizing this kind of limitation, the elaboration of the questions was conducted by two researchers, in a constant review effort. Also, we conducted a pilot-test in order to assess the questionnaire in practice.

Instructional design. In order to avoid some biases, during the trainning (when presenting ArchiMate Specification 2.0 in Part 1, and UFO-S and the modeling patterns in Part 2), we decide not to make an oral presentation. We offered to the participants a brief textual material about ArchiMate (in Part 1), and about UFO-S and the modeling patterns (in Part 2). This instructional material (see Appendix A) was carefully designed

[12] We use the term "limitation" in a broad sense, encompassing also what some works in literature call "threats" (SELTMAN, 2014).

and revised by two researchers. However, despite this effort, we could notice that the participants did not feel comfortable in reading all instructional material. Besides the fact we have tried to design an instructional material as summarized as possible, it seemed that some participants tried to answer the questions without having a good understanding about ArchiMate or even about UFO-S and the modeling patterns. We could notice some evidenced about it, mainly in Part 2, when the participants gave better (more accurate) answers insofar they proceed in the questionnaire. Maybe, an alternative towards avoiding this limitation would be the use of multimedia resources (e.g., videos) in order to improve the participants' training.

Data analysis and discussion. Some biases may have been introduced during the data analysis and discussion. For minimizing these possible biases, data analysis and discussion were conducted with the support of two other researchers (the supervisors) through textual review and periodic meetings.

6.7 Final Considerations

In this chapter, we described an evaluation initiative that was conducted by means of an evaluation (empirical study). The evaluation analyzed service modeling in ArchiMate without the adoption of the proposed modeling patterns (Part 1), and with the usage of such modeling patterns (Part 2).

From the results of Part 1, there are evidences that the limitations ("L2", "L3", and "L4") identified during ontological analysis (in Section 5.3) could be ratified. Thus, through participants' interpretations (a third-party analysis) we could evidentiate that, in the context of this evaluation, the analysis process conducted in the light of UFO-S seems to have been unbiased and have produced consistent results.

From Part 2, we get some evidences that the usage of the proposed modeling patterns seems to bring benefits towards minimizing ambiguity and increasing expressiveness, in comparison to Part 1. It was possible to minimize the number of model interpretations, and to allow the representation of new concepts and relationships (e.g., the use of the "contract" element for representing descriptions of terms and conditions of service offerings). As a result, we consider that, despite some necessary improvements identified by the participants, the modeling patterns were positively evaluated in the context of this evaluation.

Finally, the achieved evidences also seem to indicate that UFO-S had a positive assessment in the context of this evaluation. In Part 1, limitations previously identified in the ontological analysis conducted in light of UFO-S, as described in Chapter 5. , were ratified by third party analysis. In Part 2, the service modeling patterns designed based on UFO-S were positively evaluated (minimizing ambiguities and increasing expressiveness). From this, we believe to be possible to consider that UFO-S, as a reference model, brought benefits not only for supporting ontological analysis of a service modeling language, but also for the (re)design of such language towards representing the service phenomena consistently.

Chapter 7. Final Considerations

This chapter presents our final considerations. As such, it presents an overview about the thesis, remarks our research contributions, including a discussion about the impact of this thesis in other research works. Finally, the chapter describes future perspectives concerning improvements of ideas discussed in this thesis, and development of new research initiatives from the basis established by this work.

7.1 Introduction

As we have discussed in this thesis, the notion of service is far from be trivial. In order to deal with it, a number of service characterizations have been proposed by works from different economic sectors (e.g., Service, Manufacturing, and Extractive) and academic disciplines (e.g., Marketing, Business, and Computer Science). However, despite their importance, these various service characterizations reflect partial and non-harmonized service perspectives (such as "service as value co-creation", "service as behavior", "service as capability / manifestation of competences" and "computational service"). As a consequence, the establishment of an interoperable body of knowledge for services is hindered.

Besides the various non-harmonized perspectives of service, another important aspect relies on the polysemy associated with the usage of the term "service". In fact, the current initiatives that aim to characterize the concept of "service" (e.g., service ontologies, conceptual models, and theories) have established a terminological discussion that has not effectively contributed for disambiguation of the various possible usages of the term "service" along the service life cycle. As we discussed in Section 3.6, depending on the context, the term "service" can be used to refer to different concepts, such as service offering (or types thereof) and service delivery. Without a clear characterization about the service relations along the service life cycle, we cannot properly deal with the *referents*[13] associated with such polysemy. This indicates that the characterization of the notion of service does not rely necessarily in establishing a unique definition for the concept of "service".

In this thesis, we avoid inciting merely a terminological debate, i.e., we refrain from proposing yet another partial service definition. In contrast, we conducted an

[13] "*The object or idea to which a word or phrase refers*". (The Free Dictionary).

analysis of the service relations along service life cycle taking as basis the notion of service commitments and claims established between service participants (service provider and service customer).

As such, we have discussed the notions of service commitments and claims as social aspects that act as a "glue" in the characterization of *service offerings* and *service agreements*, and that drive the execution of actions/interactions in *service delivery*, guaranteeing (at certain level) that such behavior is executed. Also, the notion of service commitments and claims is essential for establishing a relation between the notion of service and other notions, such as: "capability", "manifestation of competences", and "usage/access to resources". Without service commitments, it is not possible to properly characterize the notion of service from each one of these previous notions. In fact, there must be commitments from the service provider towards service customers (and possibly from the customer towards the service provider) in applying her capabilities, in manifesting her competences, or in using her resources for providing services. Finally, the notion of service commitments and claims is also related to "value co-creation" in service relations. Service participants establish service commitments in their value seeking efforts. On the other hand, the fulfillment of the established service commitments may produce the expected values.

Based on the aforementioned, we proposed a broad theoretical foundation for service able to harmonize different service perspectives ("service as behavior", "service as capability / manifestation of competences", "service as value co-creation", and "computational services") and with focus on characterizing the service relations along service life cycle. Such theoretical foundation was specified in a well-founded core reference ontology for service (phenomena) called UFO-S.

As a *reference ontology* (GUIZZARDI, 2007), UFO-S was designed to support tasks of meaning negotiation and consensus establishment among human beings. As such, it contributes for enriching the (common) understanding about the notion of service, and, as a result, for the solution of problems in application areas. Thus, in the context of this thesis, UFO-S (and the underlying theoretical foundation) is considered a kind of "theory". In line with Gregor and Jones (GREGOR; JONES, 2007), we adopt a broad view of "theory", which encompasses what might be termed as conjectures, models, frameworks, or bodies of knowledge (GREGOR; JONES, 2007). More

specifically, according to the theory's classification by Gregor, UFO-S can be considered as an "analysis theory", which is a type of theory that "*[…] provides a description of the phenomena of interest, analysis of relationships among those constructs, the degree of generalizability in constructs and relationships and the boundaries within which relationships, and observations hold*" (GREGOR, 2006). This type of theory is primary characterized by classificatory, compositional, and/or associative relationships, without necessarily addressing causal relations.

As a *core ontology* (SCHERP et al., 2011), UFO-S was grounded in a foundational ontology, the Unified Foundational Ontology (UFO), which offered an important ontological support for developing the conceptualization behind UFO-S, and, together with OntoUML (and the associated ontology design tools) guaranteed a certain rigor in the design of UFO-S. By offering a sound support for addressing social aspects (e.g., social commitments/claims, delegation, dependence, and agents), UFO also established means for characterizing the dynamics of service relations as social phenomena. By being constructed with the primary goal of developing foundations for conceptual modeling, UFO also offered important features that were adopted in the design of UFO-S. Among them, we highlight the notion of "relator", from which we could better characterize the relationships between commitments/claims and service participants in the context of service relations (e.g., in service offerings, and in service agreements). Such characterization had not been established in previous works from which UFO-S was based on (specially works of Ferrario and Guarino (FERRARIO; GUARINO, 2008) (FERRARIO; GUARINO, 2012), which focus on the notion of "event" for characterizing service provision). Briefly, by evidentiating social relators in service relations, we could account for the fact that agents participate in events (e.g., service negotiation, and service delivery) according to/due to properties that they got from previous establishment of relators. For example, a car insurance company can enter in negotiation or deliver a car insurance service, since it had previously registered its service (i.e., had established a service offering) in a chamber of commerce. In terms of UFO, we can say that such agents can participate in such events insofar some properties (e.g., the right of the car insurance company in entering in a negotiation with a potential customer) are created from the establishment of social relators. Finally, regarding the adopted ontological engineering techniques, by using OntoUML

and the associated engineering tools in the design of UFO-S models (such as model verification and simulation approaches (BENEVIDES et al., 2011)), we could conduct the UFO-S formalization process in order to guarantee a certain rigor in the ontology.

Regarding its relevance, beyond its applicability in harmonizing different service perspectives, UFO-S brings a number of contributions in comparison to other service ontologies and conceptual models found in literature, as summarized in Section 3.5. Also, concerning the application of UFO-S in the solution of practical problems, in the context of this thesis, we focused on using UFO-S in the Enterprise Architecture application area, more specifically in Service-oriented Enterprise Architectures (SoEA). We took as a basis the theoretical foundation offered by UFO-S towards: (i) analyzing SoEA structuring principles under a unified view of services (able to harmonize the "capability-based SoEA view" with a "commitment-based SoEA view"), whose its impact was discussed in light of widely adopted service-oriented approaches (such as, SOA Reference Model by OASYS, ITIL, and ArchiMate); and (ii) improving service modeling in ArchiMate, by offering means of representing service offering types, service offerings, and service agreements in SoEA.

The results achieved along this research effort indicate that UFO-S, as a reference model, could contribute for enriching the body of knowledge about service, especially by harmonizing different service perspectives and by focusing on dynamics of service relations taking as basis the notion of service commitments and claims. Moreover, UFO-S showed to be useful in the analysis of structural principles of SoEA, mainly by revealing commitment-based aspects inherent to service relations, as well as in the ontological analysis of service modeling languages, especially ArchiMate. The empirical evaluation described in Chapter 6. showed that the proposed service modeling patterns, which were designed taking as basis UFO-S, could minimize semantic ambiguity and increase expressiveness in service modeling of SoEA. Moreover, the benefits of UFO-S were also highlighted in research works that are not part of this thesis, which reinforces the impact of such ontology. Such benefits are described in details in Section 7.3.

Finally, taking as basis the aforementioned, we consider that the research objectives were properly achieved and that the research hypothesis could be supported, insofar the proposed theoretical foundation based on the notion of service

commitments (and specified in UFO-S) could harmonize different perspectives of service, and contributed for improving a SoEA modeling language (ArchiMate) around a unified service commitment-based SoEA view between Business and IT.

7.2 Research Contributions

Considering the research strategy adopted in this work, the overall research contributions of this thesis are the proposal of a theoretical foundation for service (phenomena), and its application in the solution of practical problems in SoEA, especially those related to service modeling. More specifically, these contributions are:

- **The design of a well-founded core reference ontology for service (UFO-S)**. This ontology specifies the theoretical foundation proposed in this thesis. This foundation addresses the notion of service by considering the dynamics of service relations and taking as basis the service commitments and claims established between service participants along service life cycle (service offer, service negotiation, and service delivery). From that, UFO-S clearly establishes the service relations along such service life cycle, and contributes for minimizing misunderstandings related to the polysemy of the term "service".
- **The harmonization of different service perspectives** (such as "service as value co-creation", "service as capability / manifestation of competences", "service as behavior", and "computational services") around the notion of service commitments and claims towards establishing a certain level of interoperability between such service perspectives.
- **The analysis of SoEA structuring principles in terms of a "commitment-based SoEA view"** (harmonized with the prevailing "capability-based SoEA view"). From this, we briefly discussed the impact of this view in the definition of service-oriented architectures, service management, and service modeling, by analyzing widely adopted service-oriented approaches, namely: SOA Reference Model by OASIS, ITIL, and ArchiMate.
- **An ontological analysis of service modeling at ArchiMate's Business layer**. The ontological analysis conducted in light of UFO-S revealed limitations in service modeling at ArchiMate's Business layer. These limitations are especially related to the lack of semantics clarity and language's expressiveness in the

representation of service offerings (and types thereof), and service agreements in SoEA. These limitations were addressed by the proposal of service modeling patterns, as follows.

- **The proposal of service modeling patterns in ArchiMate**. We proposed three service modeling patterns (service offering type pattern, service offering pattern, and service agreement pattern) in order to address the limitations identified by means of the (aforementioned) ontological analysis. Instead of proposing structural changes in ArchiMate, this set of service modeling patterns characterizes a conservative/lightweight approach which favors: (i) better user acceptance, (ii) lower barrier for incorporation in ArchiMate, and (iii) tool reuse. The benefits of the proposed modeling patterns (and the underlying conceptualization offered by UFO-S) were corroborated by means of an empirical evaluation. This evaluation contrasted the interpretations of the 24 participants about service models in which the proposed patterns were applied against models without the usage of such patterns.

All of the aforementioned research contributions were published (or are under review process) in peer-review workshops, conferences, or journals. Such publications are the following:

NARDI, Julio Cesar; FALBO, Ricardo de Almeida; ALMEIDA, João Paulo A. **An Ontological Analysis of Service Modeling at ArchiMate's Business Layer**. In: Proceedings of the 2014 IEEE 18th International Enterprise Distributed Object Computing Conference, EDOC 2014. pp. 92-100. Set 03-05 2014, Ulm - Germany.

NARDI, Julio Cesar; FALBO, Ricardo de Almeida; ALMEIDA, João Paulo A. **Revealing Service Commitments in Service-Oriented Enterprise Architecture**. In: Proceedings of the 2014 IEEE 18th International Enterprise Distributed Object Computing Conference Workshops and Demonstrations (EDOCW 2014). pp. 286-295. Set 01-02, 2014, Ulm - Germany.

NARDI, Julio Cesar; FALBO, Ricardo de Almeida; ALMEIDA, João Paulo A.; GUIZZARDI, Giancarlo; PIRES, Luis Ferreira; SINDEREN, Marten J. van; GUARINO, Nicola. **Towards a Commitment-based Reference Ontology for Services**. In: 17th IEEE International EDOC Conference (2013). Sept 9-13 2013, Vancouver - Canada.

NARDI, Julio Cesar; FALBO, Ricardo de Almeida; ALMEIDA, João Paulo A.; GUIZZARDI, Giancarlo; PIRES, Luís Ferreira; SINDEREN, Marten J. van; GUARINO, Nicola; FONSECA, Claudenir Morais. **A Commitment-based Reference Ontology for Services**. Elsevier Information Systems, 2015.

Other publications developed along this research work and that contributed for the ideas discussed in this thesis are presented as follows:

MILOSEVIC, Zoran; ALMEIDA, João Paulo A.; NARDI, Julio Cesar. **Towards Better Semantics for Services in eHealth Standards: A Reference Ontology Approach**. In: Proceedings of the 2014 IEEE 18th International Enterprise Distributed Object Computing Conference Workshops and Demonstrations (EDOCW 2014). pp. 276-285. Set 01-02, 2014, Ulm - Germany.

CARVALHO, Victorio Albani de; NARDI, Julio Cesar; TEIXEIRA, Maria das Graças da Silva; GUIZZARDI, Renata; GUIZZARDI, Giancarlo. **Towards a Semantic Alignment of the ArchiMate Motivation Extension and the Goal-Question-Metric Approach**. In: 6º Seminírio de Ontologias no Brasil. Set 23-25 2013, Belo Horizonte - Brasil.

NARDI, Julio Cesar; FALBO, Ricardo de Almeida; ALMEIDA, João Paulo A. **Foundational Ontologies for Semantic Integration in EAI: A Systematic Literature Review**. In: 12th IFIP Conference on e-Business, e-Services, e-Society (I3E 2013). April 25-26 2013, Athens, Greece.

NARDI, Julio Cesar; FALBO, Ricardo de Almeida; ALMEIDA, João Paulo A. **A Panorama of the Semantic EAI Initiatives and the Adoption of Ontologies by these Initiatives**. In: International IFIP Working Conference on Enterprise Interoperability (IWEI 2013). March 27th- 28th, Enschede - The Netherlands.

FALBO, Ricardo de Almeida; BARCELLOS, Monalessa Perini; NARDI, Julio Cesar; GUIZZARDI, Giancarlo. **Organizing Ontology Design Patterns as Ontology Pattern Languages**. In: 10th Extended Semantic Web Conference (ESWC 2013). May 26-30 2013, Montpellier - France.

7.3 Implications to Other Research Works

Beyond the aforementioned research contributions, the impact of the results of this thesis in other works (i.e., works that are not part of this thesis) also shows the

relevance of this research. In this section, therefore, we describe three research initiatives in which UFO-S was applied.

Analysis of the SOA Healthcare Ontology. In (MILOSEVIC; ALMEIDA; NARDI, 2014), the SOA Healthcare Ontology (SHO) (MILOSEVIC et al., 2013) is analyzed in light of UFO-S in order to provide a sound ontological foundation to SHO. From this, it is expected to establish the basis for further improvement in the formalization and revision of SHO and in its conceptual representation. As already presented in Section 2.3.3, the SOA Healthcare Ontology is the result of an effort of the HL7 standardization organization towards responding to a wide range of interoperability requirements for eHealth. As such, SHO was built to be used as a reference conceptual model for guiding the definition of service-related aspects of future eHealth standards and solutions.

The analysis has revealed that certain notions of commitments/claims in UFO-S can guide further refinement of HL7 SHO, such as the incorporation of the notions of hired service provider commitments/claims and service customer commitments/ claims. The analysis has also revealed that the definition of business service description deserves some further attention in SHO, as the current text makes it ambiguous (denoting either a type of service offering or a particular service offering). On the other hand, the analysis revealed further requirements for UFO-S, such as the need to explicitly address the deontic aspects related to the notion of service commitments (e.g., obligations, prohibitions, and permissions). From this, it would be possible to capture the semantics of service commitments in a more comprehensive way. Also, to both UFO-S and SHO, this work revealed the importance of expanding on the descriptions of service offerings (business service descriptions in SHO) and service agreements (service contract descriptions of SHO) towards making explicit their structure and the content usually described in such descriptions (e.g., constraints, requirements, and types of actions).

Design of a Service Ontology Pattern Language (S-OPL). In (QUIRINO et al., 2014)[14], an Ontology Pattern Language for service is proposed, so-called S-OPL, whose ontology modeling patterns were extracted from UFO-S. An OPL is a network of interconnected ontology modeling patterns that support the development of ontologies in a given

[14] This paper is under review process.

field (FALBO et al., 2013a). S-OPL, therefore, comprises a set of ontology patterns plus a process describing how to combine them in order to build a domain service ontology (i.e., an ontology about services in a specific application domain). The fact of UFO-S is a core ontology (i.e., independent of a particular application domain) favors the adoption of the extracted ontology patterns in definition/refinement of service aspects in particular application domains. The current version of S-OPL comprises patterns that cover four aspects related to the service life cycle addressed by UFO-S, such as: (i) *Service Offering* (including patterns to model the offering of a service to a target community); (ii) *Provider and Target Customer* (definition of types of service providers and target customers); (iii) *Service Negotiation* (concerning the negotiation between provider and customer in order to get an agreement); and (iv) *Service Delivery* (aspects related to the actions performed for fulfilling a service agreement).

Analysis of the REA Ontology. In (BLUMS, 2014), the REA Ontology is analyzed in light of UFO-S (and of the correspondent foundational ontology UFO) with the aim at identifying additional concepts useful for the development of Accounting Information Systems (AIS). REA (Resource-Event-Agent) Ontology (GEERTS; MCCARTHY, 2000), as its name suggests, it is based on the notion of "resource" and on the events associated with these resources (e.g., usage, and access) in the context of economic transactions.

According to (BLUMS, 2014), the motivation of doing this work is that although REA offers a wide conceptualization about resources, events and agents, more detailed semantics is required on what it is called "transaction life-cycles". Thus, UFO was applied for enriching the understanding about fundamental concepts in REA[15], such as: "economic agents", "economic events", "economic commitments", and roles such as "seller", and "buyer". Also, the characterization of the service life cycle based on the notion of commitments/claims proposed by UFO-S was applied for revealing and characterizing similar aspects in the "transaction life-cycle" (such as offer, negotiation, and delivery/actualization of resources). As a result, the author proposes concepts correspondent to UFO-S, but with focus on resources, e.g.: "resource offer", "resource negotiation" and "resource delivery" (actualization) phases; "seller" and "buyer" (in correspondence to *service provider* and *service customer* in UFO-S); "seller actions",

[15] See also (GUIZZARDI; WAGNER, 2004) for a brief analysis between UFO and REA ontology regarding foundational aspects, such as, events, actions, social moments, and agents.

"buyer actions", and "seller-buyer interaction" (in correspondence to service delivery actions in UFO-S). Thus, the "transaction life-cycle" model within REA is built in close analogy with UFO-S service life cycle.

Finally, it is worthwhile to remark, among the benefits highlighted by the author: (i) the importance of the parthood relations of social agents in UFO (which favors the characterization of target communities as a collective of agents instead of a "concrete agent"); and (ii) the notion of "relator" in the characterization of what is called "control relator" (relator with "Economic Event" as a foundational event). This notion, according to the author, is rarely mentioned as a separate REA concept, but it is useful, since it puts together social aspects, e.g., "possession" and "right" inherent to economic relations. This reinforces the usefulness of "social relator" in the characterization of *service offerings* and *service agreements*, such as advocated in UFO-S.

7.4 Future Perspectives

The results presented in this thesis establish the basis for a number of future works. Following, we present and comment a list of possible future works, which encompasses (i) improvements in UFO-S, as well as (ii) applications of UFO-S in the solution of practical problems.

Improvements in UFO-S

- **Incorporation of deontic aspects**. Taking as basis the results of the application of UFO-S in the analysis of SHO (MILOSEVIC; ALMEIDA; NARDI, 2014), an important point of attention is the incorporation of deontic aspects behind service commitments. Despite service commitments and claims have an inherent deontic perspective, currently UFO-S does not explicitly account for obligations, prohibitions, permissions and other deontic notions. Having an explicit account for such notions would allow us to capture the semantics of service commitments in a more comprehensive way.
- **Detailing of commitment content and of service descriptions**. Another important aspect, also highlighted as a result of the application of UFO-S in SHO (MILOSEVIC; ALMEIDA; NARDI, 2014), concerns the description of the content

of service commitments/claims established along service life cycle. In the current version of UFO-S these descriptions are considered outside the scope of enquiry. A natural extension of this work, however, would take as a content-based perspective, exploring elements frequently referred by service commitments/claims (such as conditions, requirements, constraints, and types of action to be executed) in order to better specify the content of service offering and service agreement descriptions.

- **Incorporation of Quality-of-Service (QoS) aspects**. As future work, we intend to address Quality of Service (QoS) aspects in UFO-S (e.g., reliability, responsiveness, assurance, and empathy (PARASURAMAN; ZEITHAML; BERRY, 1988)). As such, we plan to address how the notion of service commitment may be related to the guarantee of QoS aspects along service life cycle. In this context, a particular point of attention for further investigation is that quality statements may concern entities of multiple ontological categories (e.g., quality in service offerings and agreements as something promised/expected, and quality in service delivery as something experienced). Finally, it is important to remark that an account for QoS should also address "vagueness" of quality statements and "subjectivity" in the assessment of qualities.
- **Extension of the service life cycle**. In this thesis we have focused on a core fragment of the service life cycle, which encompasses: service offer, service negotiation, and service delivery phases. As future work, we intend to address how the notion of service commitments impacts the dynamics of other service life cycle phases, such as service offering design, service search, and after sale. From that, we can better explore aspects related, e.g., to desires, believes, and intentions that lead service customers and service providers to enter in service relations, as well as the notion of value associated with service marketing. Also, we plan to explore, in light of the established commitments, the consequences that arise from service delivery execution, and how they impact, e.g., customer's satisfaction.
- **Incorporation of "Value", "Resource", and some "Behavioral" aspects**. Value, resource and some behavioral aspects (such as the detailing of service delivery actions in outcomes and effects), which are mentioned in the discussion about

how UFO-S can harmonize different service perspectives ("service as value co-creation", "service as capability / manifestation of competence", and "service as behavior") are not incorporated to the current version of UFO-S. In fact, with the current version of UFO-S, we intended to harmonize these various service perspectives around the notion of commitments and not necessarily incorporate them. As future work, however, we plan to provide a more detailed account for the origin of value propositions and to further explicate aspects of subjective value experience. We plan also to account for issues regarding resource allocation, usage and consumption in service delivery, as well as to explore behavioral aspects related to the result of the execution of actions/interactions (such as "outcomes" and "effects"), and the consequences related to the failure/success of these actions/interactions in fulfilling the established service commitments. From the incorporation of these aspects in UFO-S, we can improve the harmonization of service perspectives, as well as offer support for the extension of the service life cycle addressed by UFO-S, as above mentioned.

Applications of UFO-S in the solution of practical problems

- **Commitments-based SoEA view**. We intend to further investigate the characterization of the *commitment-based SoEA* view addressed in this thesis, and its harmonization with the *capability-based SoEA* view. As part of this effort, we plan to continue our analysis in widely adopted service-oriented approaches (such as SOA Reference Model by OASIS (OASIS, 2006), ITIL (ITSMF, 2007), and ArchiMate (THE OPEN GROUP, 2012)) with the aim of incorporating and/or making more evident this commitment-based view. Thus, we intend to identify to what degree this view contributes for enriching the practice of modeling, definition, and management of service relations in SoEA.
- **Service Modeling Patterns in ArchiMate**. Firstly, we intend to address the improvements suggested by participants of the empirical evaluation described in Chapter 6. (such as improving visualization aspects, and representing target customer and "service provision chains"). Moreover, we intend to address other aspects of service modeling at the Business layer that were not

addressed in this thesis, such as the use of behavioral elements (e.g., business process, and business interactions between service participants) for modeling 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). Thus, similarly to the service modeling patterns presented in Chapter 5, we plan to apply the service commitment notion to other layers of SoEA (based on the "commitment-based SoEA" view) towards extending the modeling patterns in order to represent service commitments also at the application and infrastructure layers.

- **Semantic Enterprise Application Integration (SEAI)**. In order to analyze some aspects related to SEAI initiatives (such as integration layers, types of ontologies used, and languages/formalisms adopted, among others), we conducted a *systematic literature mapping*[16] that offered a panorama of these initiatives along the years (NARDI; FALBO; ALMEIDA, 2013a). From this mapping, we conducted a *systematic literature review*[17] in order to go deeper in the analysis of the adoption of foundational ontologies in the context of these initiatives (NARDI; FALBO; ALMEIDA, 2013b). From these studies, we could noticed that SEAI initiatives that address enterprise application integration by focusing on the (message/) *service layer* tend to deal with services as a "piece of software". Most of these initiatives have been mainly characterized by the use of service as a mere means to integrate (enterprise) resources (e.g., software applications, information systems, and database management systems) and their capabilities (e.g., data processing, and data storing). As a consequence, social aspects inherent to service relations are frequently neglected. As discussed in Section 3.4.4, by offering a broad account for service based on commitments, UFO-S can harmonize business and computational views. From this, we believe that this broad account can also

[16] Systematic literature mapping is a *broad-scope review* that uses a well-defined and systematic method to identify, analyze, interpret, and synthesize the evidences available in empirical papers (KITCHENHAM; CHARTERS, 2007)

[17] Systematic literature review is a *narrow-scope review* that uses a well-defined and systematic method to identify, analyze, interpret, and synthesize the evidences available in empirical papers (KITCHENHAM; CHARTERS, 2007).

bring benefits for (semantic) EAI initiatives. Thus, inspired by the *commitment-based SoEA view* discussed in Chapter 4. , we plan to elaborate a "commitment-based EAI view" (to be harmonized to the prevailing "capability-based EAI view"). Finally, we expect to apply this view in benefits of approaches of definition and specification of services in the context of service-oriented EAI.

- **Experimentation and usage in real use cases**. Among our future perspectives, an important effort regards the continuing evaluation of the results of this thesis in real use cases. Such effort encompasses therefore the applicability/justification of UFO-S as a kind of service "theory", as well as the evaluation of the artifacts and views designed from the adoption of UFO-S (such as the service modeling patterns in ArchiMate, and the commitment-based views in SoEA and in EAI). By evaluating UFO-S and the derived artifacts/views in real use cases, we expect that new insights arise and be then incorporated naturally towards evolving them.

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Appendix A The Material Used in the Empirical Evaluation

This appendix presents the material used in Part 1 and Part 2 of the empirical evaluation described in Chapter 6. The material encompasses the participant's profile questionnaire, the instructional material (used for training the participants), the models analyzed by each group of participants (Group A and Group B), and the set of questions.

A.1 Introduction

In order to conduct the evaluation, the participants received instructions about the objectives of the evaluation as a whole, and how to proceed in each part (Part 1 and Part 2) of the evaluation. Also, the participants received the material necessary to conduct the evaluation, such as: questionnaires, models, and instructional material.

Firstly, all the participants answered the profile questionnaire. After that, in Part 1 of the evaluation, the participants received: (i) the instructional material about ArchiMate, (ii) the correspondent models to be analyzed ("Car Insurance" model for Group A, and "Online Book Selling" model for Group B), and (iii) the set of questions to be answered. In Part 2 of the evaluation, the participants received: (i) the instructional material about the theoretical foundation of service defined in this thesis, and about the proposed service modeling patterns, (ii) the models to be analyzed built on the modeling patterns ("Online Book Selling" model for Group A and "Car Insurance" model for Group B), and (iii) the set of questions to be answered. All of this material is presented in this appendix in order to offer details about what exactly the participants had access for performing the evaluation.

This appendix is structured as follows: Section A.2 presents the profile questionnaire; Section A.3 presents all material used in Part 1 of the evaluation, which encompasses the instructional material, the models to be analyzed, and the questions to be answered; Finally, Section A.4 presents the material used in Part 2 of the evaluation, which also encompasses the instructional material, models, and questions to be answered.

A.2 Participant's Profile Questionnaire

For gathering information about participants' profile, they were invited to answer a questionnaire, which is presented in Table 19. This questionnaire is composed, basically, of four parts: (i) participant identification (name and email); (ii) education background (the academic degree, and the correspondent course/area); (iii) experience in conceptual modeling (context of experience, and period of experience); and (iv) experience in ArchiMate (period of experience).

Table 19 – Form of the profile questionnaire.

Name	
E-mail	
Highest academic degree of education (mark as "Complete" or "Incomplete")	
☐ Graduation ☐ Postgraduation (*lato sensu*) ☐ MSc ☐ PhD ☐ Complete ☐ Incomplete	
Course/Area of the aforementioned academic degree of education	
Experience in Conceptual Modeling (you can mark the two options)	
☐ Academy ☐ Industry and/or Govern	
Period of experience in Conceptual Modeling	
☐ Under 1 year ☐ From 1 to 3 years ☐ From 3 to 5 years ☐ Above 5 years	
Period of experience in ArchiMate	
☐ No experience ☐ Under 1 year ☐ From 1 to 3 years ☐ From 3 to 5 years ☐ Above 5 years	

A.3 Material of Part 1

In this section, we present the material offered to the participants in order to perform the Part 1 of the evaluation. This material encompasses: (i) the instructional material (an ArchiMate tutorial), (ii) the model to be analyzed (each group of participants – Group A and Group B – received a model about a different application domain), and the set of questions to be answered taking as basis the received model.

A.3.1 Instructional Material

This section presents the instructional material provided in Part 1: a tutorial about service modeling at ArchiMate's Business layer.

A.3.1.1 The ArchiMate Modeling Language: Business Layer

ArchiMate (currently a technical specification maintained by The Open Group) (THE OPEN GROUP, 2012) is a framework for enterprise architecture modeling that adopts the "service" construct as a basic structuring element through its three enterprise layers: Business, Application and Technology. This framework has been widely adopted for representing service-oriented enterprise architectures. Despite ArchiMate encompasses Business, Application and Technology layers, in this evaluation we will focus only on the Business layer.

The Business layer addresses the provision of business services to customers (internal and/or external to enterprise). In this layer, there are elements that refer to entities that composes the enterprise (such as, business actors, and business roles), elements that are defined for purposes of communication, so-called, "informational elements" (such as, products and contracts), and elements that are used for characterizing the dynamic aspects of the enterprise (such as, business service, and business process). All of these elements can be linked by means of various kinds of relationships. Figure 49 presents the metamodel fragment of Business layer used in the evaluation.

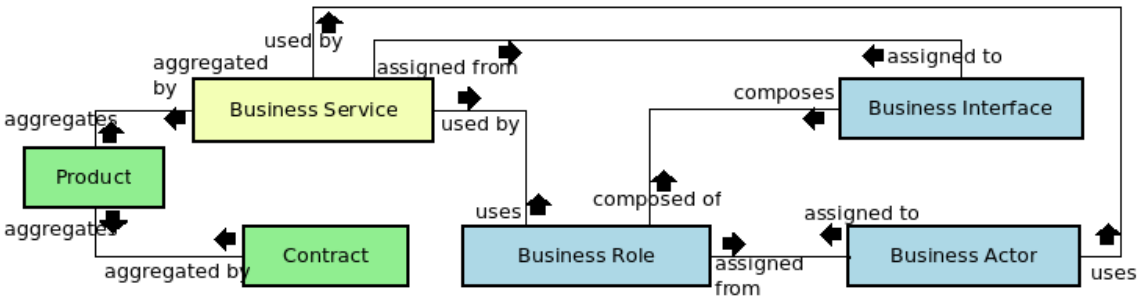

Figure 49 - Metamodel fragment of Business layer used in the evaluation.

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" (THE OPEN GROUP, 2012). A *business service* is "a service that fulfills a business need for a customer (internal or external to the organization)" (THE OPEN GROUP,

2012), and may be assigned from a business interface (services are provided through interfaces). A *business interface* is a "point of access where a business service is made available to the environment" (THE OPEN GROUP, 2012) (e.g., phone, and website). A *business actor* is "an organizational unit that is capable of performing behavior" (THE OPEN GROUP, 2012) (e.g., a person – "John" -, a department – the "Center of Data Processing (CDP)" of Federal University of Espírito Santo (UFES) -, and an enterprise – "UFES"). A *business role* refers to "the responsibility for performing specific behavior, to which an actor can be assigned" (THE OPEN GROUP, 2012) (e.g., "Manager", "IT Department", and "University"). In ArchiMate, by considering that a business role is composed of an interface, we can say that the interface is a means that the business role has for communicating with the environment.

Regarding the informational elements, a *product* is defined as "a coherent collection of service, accompanied by a contract/set of agreements, which is offered as a whole to (internal or external) customers" (THE OPEN GROUP, 2012). A contract is "a formal or informal specification of agreement that specifies the rights and obligations associated with a product" (THE OPEN GROUP, 2012).

Table 20 presents the definition and notation of the aforementioned modeling elements, as well as the relationships used in the evaluation.

Table 20 – Elements and relationships used in the evaluation (THE OPEN GROUP, 2012).

Element	Notation	Definition
Business Actor		"An organizational unit that is capable of performing behavior".
Business Role		"The responsibility for performing specific behavior, to which an actor can be assigned".
Business Interface		"Point of access where a business service is made available to the environment". "An interface provides an external view on the service provider and hides its internal structure".
Business Service		"A service that fulfills a business need for a customer (internal or external to the organization)".
Product		"A coherent collection of service, accompanied by a contract/set of agreements, which is offered as a whole to (internal or external) customers". "'Buying ['hiring'] a product gives the customer the right to

		use the associated services [to the product]".
Contract		"A formal or informal specification of agreement that specifies the rights and obligations associated with a product".
Relationships		
Relationship	**Notation**	**Definition**
"Used by"		"The 'used by' relationship models the use of services […]". "The 'used by' relationship describes the services that a role […] offers that are used by entities in the environment". **Obs.:** In the context of the evaluation, consider "entities in the environment" as *business actors* and *business roles*.
Assignment		"The assignment relationship links […] *business actors* with *business roles* that are fulfilled by them". "The assignment relationship can relate […] a *business interface* with a *business service* […]".
Composition		"The composition relationship indicates that an object is composed of one or more other objects". **Obs.:** In the evaluation, we address only the composition between *business interface* and *business role*.
Agregation		"The aggregation relationship indicates that a concept groups a number of other concepts". **Obs.:** In the evaluation, we address the aggregation relationship only between *product* and *business services*, and between *product* and *contracts*.
Association		"An association models a relationship between objects that is not covered by another, more specific relationship". **Obs.:** It indicates only that two objects are related.

A.3.2 Models

In Part 1 of the evaluation, the participants of Group A and the participants of Group B analyzed, respectively, the models presented by Figure 50, and Figure 51. The model of Figure 50 is about the "Car Insurance" application domain, whereas the model of Figure 51 regards the "Online Book Selling" application domain. In Part 1, the two models were built taking as basis strictly the ArchiMate Specification 2.0 (THE OPEN GROUP, 2012).

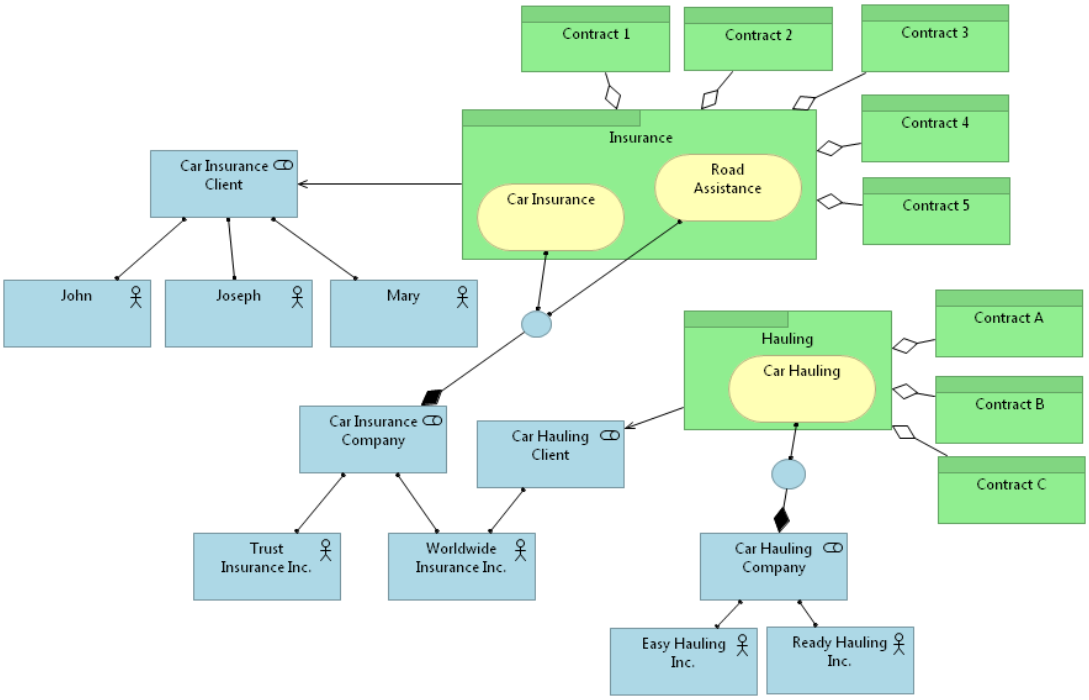

Figure 50 – The model analyzed by Group A in Part 1: "Car Insurance" application domain.

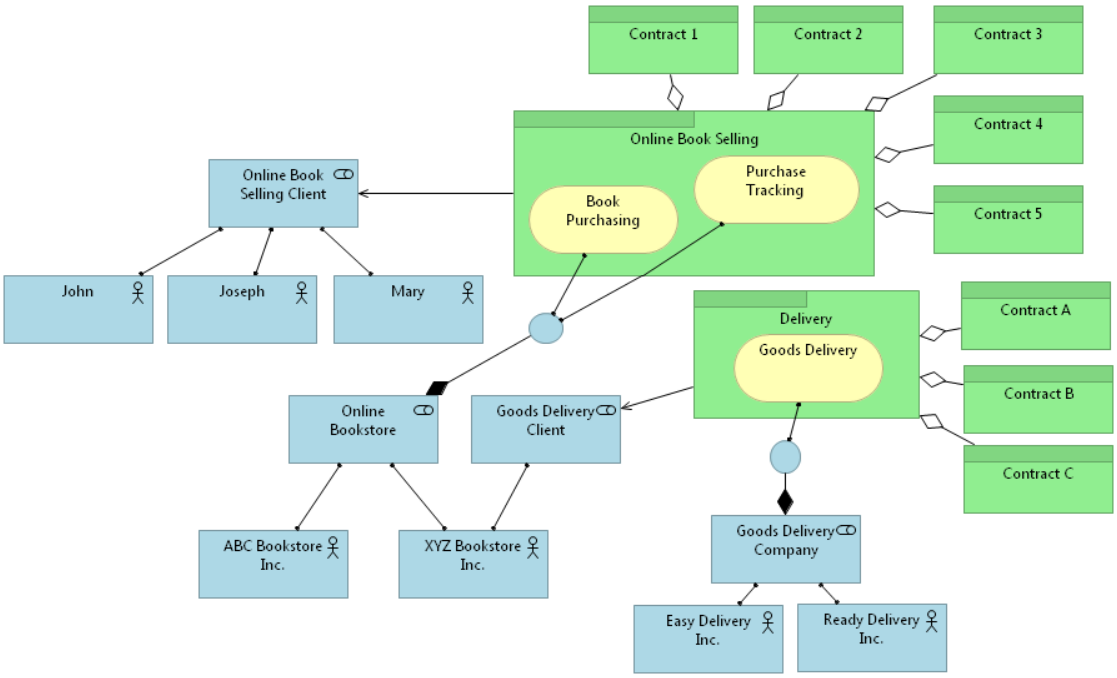

Figure 51 – The model analyzed by Group B in Part 1: "Online Book Selling" application domain.

A.3.3 Questions

In Part1, the participants answered the following questions about the analyzed model.

P1Q1) Does the model present service(s) being offered?

( ) Yes.

( ) No.

( ) It is not possible to identify.

If there is service being offered, FOR EACH actor that is offering a collection of service (organized in a product), say:

- The actor that is offering the collection of service (product).
- The name of the product(s) being offered, and the respective service(s).
- For whom (target customer) each product is being offered.

Obs.: If it is not possible to identify any of these three aforementioned items, say it explicitly.

_____

_____

_____

_____

_____

P1Q2) Does the model present hired services?

( ) Yes.

( ) No.

( ) It is not possible to identify.

If there is hired service, FOR EACH actor providing a collection of service (product) that was hired, say:

- The actor that was hired for provisioning the collection of services (product).
- The name of the hired product(s), and its respective service(s).
- The actor who hired the provisioning of the product(s).

Obs.: If it is not possible to identify any of these three aforementioned items, say it explicitly.

_____

_____

_____

_____

_____

P1Q3) For each "contract" element presented in the model, say (mark using a "X") what they represent/specify.

	Terms and conditions of a product/service offering	Terms and conditions of a product/service hiring	Other (say what!)	It is not possible to identify
Contract 1				
Contract 2				
Contract 3				
Contract 4				
Contract 5				
Contract A				
Contract B				
Contract C				

P1Q4) For each "contract" element (from "Contract 1" to "Contract 5", and from "Contract A" to "Contract C"), say who (actors) are involved in the contract.

- If the contract represents "Terms and conditions of a product/service offering", say: the contract, and who (actor) is offering the correspondent product/service.
- If the contract represents "Terms and conditions of a product/service hiring", say: the contract, and who (actor) hires and who (actor) is hired for provisioning the services.
- If the contract represents "Other", say what you consider convenient for describing who is involved in the contract element.
- If "it is not possible to identify" what the contract element represents, do not say anything.

Obs.: If it is not possible to identify any of the three first aforementioned items, say it explicitly.

_____

_____

_____

_____

_____

A.4 Material of Part 2

In this section, we present the material offered to the participants in order to perform the Part 2 of the evaluation. This material encompasses: (i) the instructional material (a theoretical foundation of service based on UFO-S, and a description about the proposed service modeling patterns), (ii) the model to be analyzed (each group of participants – Group A and Group B – received a model about a different application domain), and the set of questions to be answered taking as basis the service model.

A.4.1 Instructional Material

This section presents the instructional material offered in Part 2: (i) a theoretical foundation of service based on UFO-S, and (ii) the proposed service modeling patterns.

A.4.1.1 A Theoretical Foundation of Service

The service life cycle model used in the evaluation encompasses three basic phases: (i) Service Offer (when a service is offered towards a Target Customer Community), (ii) Service Negotiation (when providers and customers participates in a negotiation for, possibly, establishing a Service Agreement, leading to a service hiring), and (iii) Service Delivery (when actions are performed in order to fulfill the commitments established in a Service Agreement). These phases are illustrated, respectively, by the situations "1", "2" e "3" of Figure 52.

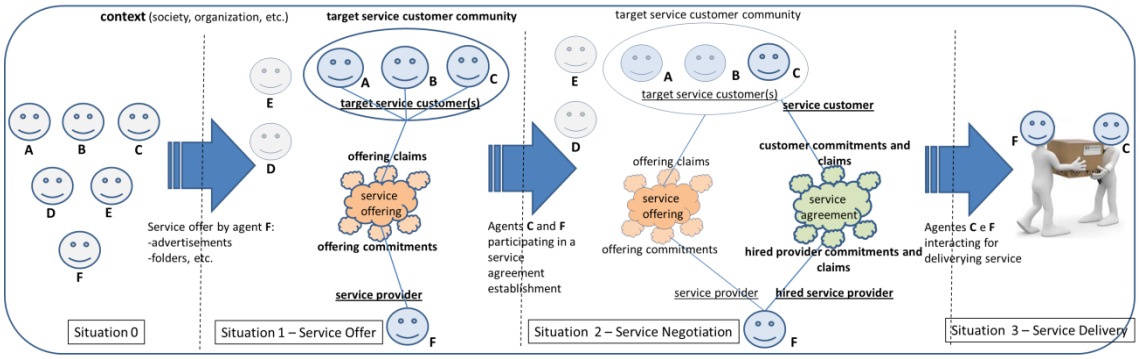

Figure 52 – Illustration of service life cycle model used in the evaluation.

Situation "0" is the start point of the service life cycle model, when agents do not participate yet in any service relation.

Situation "1" illustrates a Service Offering (when services were offered). In this case, the agent "F" offered, by means of advertisements, outdoors, folders, etc., the services that will be provided by him. Thus, by offering a service, a service offering relation is created, which is established between a Service Provider and a Target Service Customer Community. In a Service Offering, the Service Provider establishes a set of service commitments towards a target community and, consequently, towards all members of this community, so-called, Target Service Customers. Since the service provider agent establishes these commitments, the community (and, its members) can claim the fulfillment of these commitments. These commitments/claims can be described in what is called Service Offering Descriptions, such as: folders, outdoors, documents in chambers of commerce, etc. Thus, Service Provider is a role that an agent ("physical agent", e.g., people, or "social agent", e.g., enterprises, and departments) play when this agent offers services, i.e., when this agent commits himself towards a Target Service Customer Community (and, consequently, towards its members: the Target Service Customers) regarding a service offering.

Since services had been offered by a Service Provider, negotiations between this provider and target service customers may happen. Situation "2" illustrates the result of a service negotiation, when a Service Agreement (service hiring) was successfully established between the agent "F" and the agent "C". From the moment that a Service Agreement is established, the Service Provider agent starts to also play, in the context of this agreement, the role of Hired Service Provider. Analogously, the agent that played the role of Target Service Customer starts to play the Service

Customer role (as an actual customer). In this context, the Service Agreement mediates the service relation between the Hired Service Provider and the Service Customer. The Service Agreement is composed by the commitments and claims of all agents involved in the agreement (Hired Service Provider and Service Customers). The terms and conditions of service agreement (commitments and claims) can be described in which is so-called Service Agreement Description (e.g., Service Level Agreements (SLA), or general purpose contracts).

Finally, Situation "3" illustrates the Service Delivery. The Service Delivery phase is characterized as a (complex) event that may be composed by actions that are responsibility of the Hired Service Provider, actions that are responsibility of Service Customer, and actions that are responsibility of both (in tandem). Thus, Service Delivery regards to execution of actions that aim at fulfilling the commitments established in the Service Agreement.

A.4.1.2 Service Modeling Patterns in ArchiMate

Two service modeling patterns were defined for supporting service modeling at ArchiMate's Business layer. These modeling patterns are: (i) "Service offering pattern", and (ii) "Service agreement pattern". Each pattern is composed, basically, of four groups of elements: (a) product and its service(s), (b) providers of products/services, (c) customers of products/services, and (d) contracts. Associations and aggregations relationships are used for relating these elements. Contracts are the "central element" in each one of these modeling patterns. For understanding each pattern, it is important to visualize it as a whole, from the contract to the other elements. Such patterns are presented as follows.

A.4.1.2.1 Service Offering Modeling Pattern

The service offering modeling pattern is illustrated in Figure 53. This pattern is used for modeling service offerings. In a service offering, the actor (individual) that plays the role of service provider is, necessarily, represented. On the other hand, the individuals that play the role of service customer must not be represented (since in this pattern, the individuals that hire the services are not intended to be represented). This pattern is composed of the following elements:

[Product]: it groups the business service(s) that are offered in the terms of a specific individual (actor) acting as service provider.

[Service Customer]: it represents the role (type) of the individuals that will act as service customers, i.e., those one that will have the right of using the service(s) (as a result of a service agreement establishment).

[Service Provider]: it represents the role (type) of the individuals that act as service provider, i.e., those one that offer the service(s).

[Agent B]: it represents an individual that plays (instantiates) the role (type) of service provider and that, consequently, is responsible for a service offering. For each individual that instantiates the service provider role, there is a service offering. Each service offering has only one individual that acts as service provider.

[Terms and conditions of the service offering by 'Agent B']: it represents a service offering description, which describes the terms and conditions about the provision/using of the service(s) being offered by 'Agent B'. By being a specific service offering, these terms and conditions (e.g., price, and quality requirements) are defined by a specific individual, which is the service provider. By means of associations and aggregations relationships, the contract element is related to the other elements. Thus, the contract "[Terms and conditions of the service offering by 'Agent B']" (representing a description of the service offering by 'Agent B') is related to the product/service(s) to which it refers, to the business role that represents the service customer type (i.e., the type of the individual that will use, as a result of a service agreement, the product/service(s)), and to the specific individual ('Agent B') that instantiates the service provider role, which is committed to what is described in the service offering.

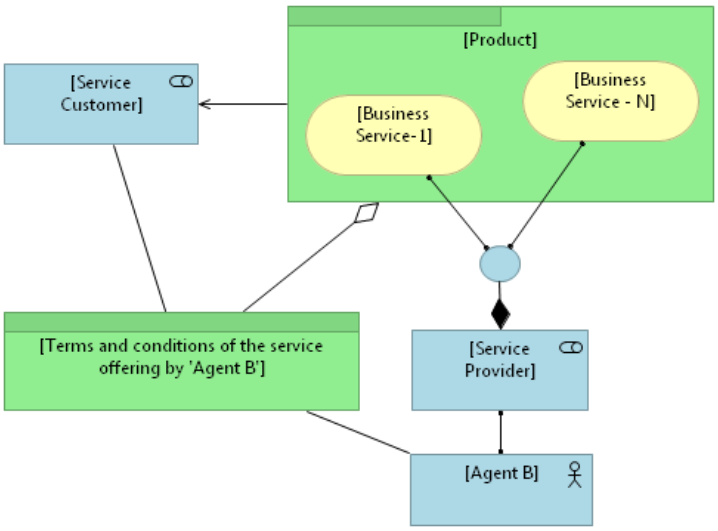

Figure 53 – Service offering modeling pattern.

A.4.1.2.2 Service Agreement Modeling Pattern

The service agreement modeling pattern is illustrated by Figure 54. This pattern is used to model service agreements. Considering that service agreements are established between specific agents (individuals), in this pattern all the agents involved in a service agreement must be represented. This pattern is composed by the following elements:

[Product]: it groups the business service(s) that the service agreement refers to. The service agreement is established between one specific individual acting as hired service provider and one or more individuals acting as service customer.

[Service Customer]: it represents the service customer role (type). This role represents the type of the individuals that are service customers, i.e., those one that have the right of using the service(s) (as a result of having established a service agreement).

[Service Provider]: it represents the role (type) of the individuals that are service providers, i.e., those one that offer services.

[Agent B]: it represents an individual that plays (instantiates) the service provider role. Also, by being related to a "contract" element that represents a service agreement description, we can say that this individual also plays the hired service provider role.

[Agent A]: it represents an individual that plays (instantiates) the service customer role. An individual that plays the service customer role must, necessarily, be associated with a "contract" element that represents a service agreement description. This indicates that this individual has established a service agreement (i.e., she hired service(s)).

[Service agreement description established between 'Agent A' and 'Agent B']: it represents a service agreement description, which contains specific terms and conditions related to the service hiring that involves the provider and customers agents (e.g., 'Agent A' and 'Agent B'). These terms and conditions can be a result of a service negotiation, but they must be in conformance with the terms and conditions of the correspondent service offering. Also, these terms and conditions are used for driving the actions in the subsequent service delivery phase. By means of associations and aggregations relationships, the "contract" element is related to the other elements of the pattern. Thus, the contract "[Service agreement description established between 'Agent A' and 'Agent B']" is related to the correspondent product/service(s), to the individual(s) that plays the service customer role (i.e., the individual(s) that has the right of using, as result of an agreement, the product/service(s)), and to the individual that acts as hired service provide. It is important to remark that there may be more than one service customer individual associated with the same service agreement description. However, there must be only one hired service provider individual associated with a service agreement description.

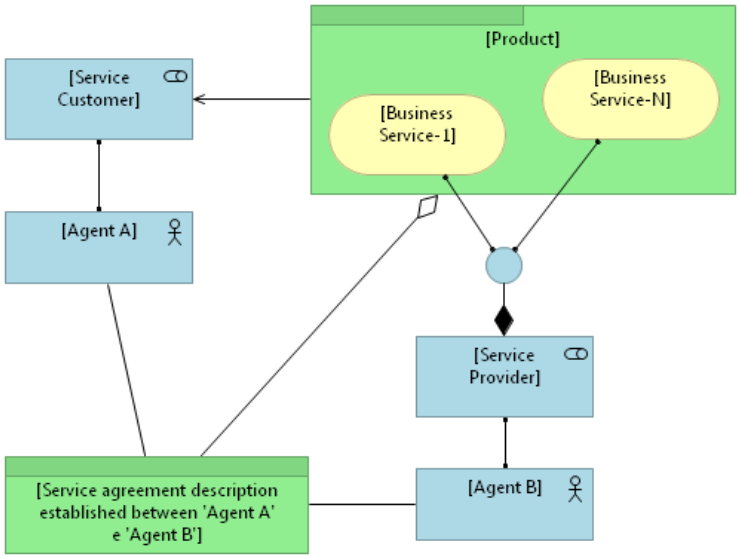

Figure 54 - Service Agreement modeling pattern.

A.4.1.2.3 Using the Patterns in tandem

The patterns can be combined as many times as necessary. Figure 55 illustrates the use in tandem of the service offering and the service agreement modeling patterns. In this case, each pattern was applied only once, therefore, we have one service offering (by

'Agent B' as service provider) and one service agreement (established between 'Agent B' and 'Agent A', which act, respectively, as hired service provider and service customer).

As shown by Figure 55, if it is necessary, the modeler can relate the "contract" elements, by means of an association relationship tagged as "<<conformance>>". This association indicates that a service agreement description is in conformance with a specific service offering description.

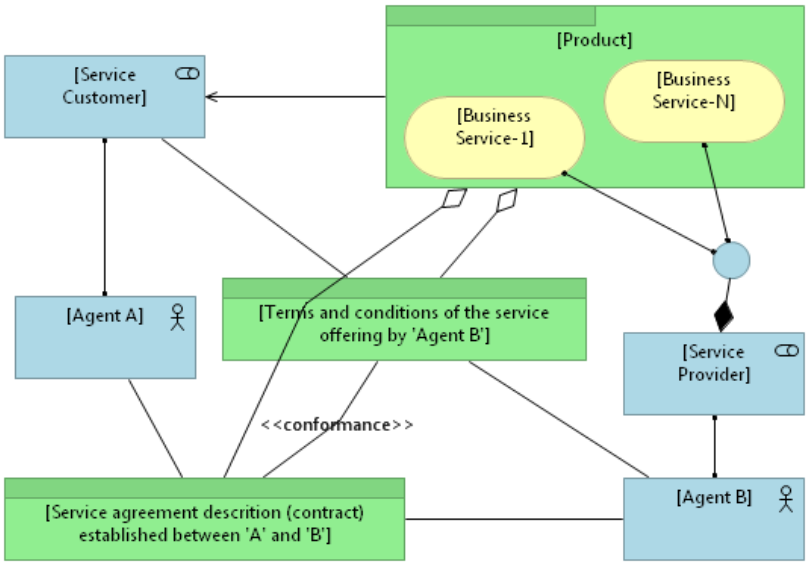

Figure 55 – Example of the using in tandem of the patterns.

A.4.2 Models

In Part 2 of the evaluation, the participants of Group A and the participants of Group B analyzed, respectively, the models presented by Figure 56, and Figure 57. The model of Figure 56 is about the "Online Book Selling" application domain, whereas the model of Figure 57 regards to "Car Insurance" application domain. From Part 1 to Part 2, the participants of Group A and the participants of Group B exchanged the analyzed application domains, as justified in Section 6.2. Also, whereas in Part 1, the models were built only taking as basis the ArchiMate Specification 2.0 (THE OPEN GROUP, 2012), in Part 2 the models were built considering the service modeling patterns.

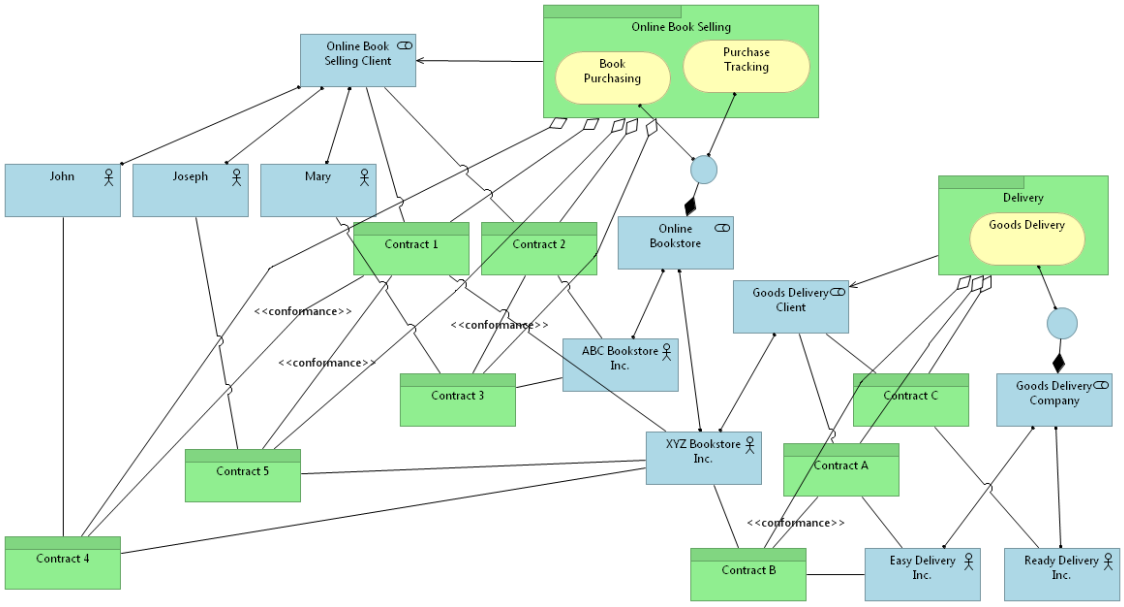

Figure 56 - The model analyzed by Group A in Part 2: "Online Book Selling" application domain.

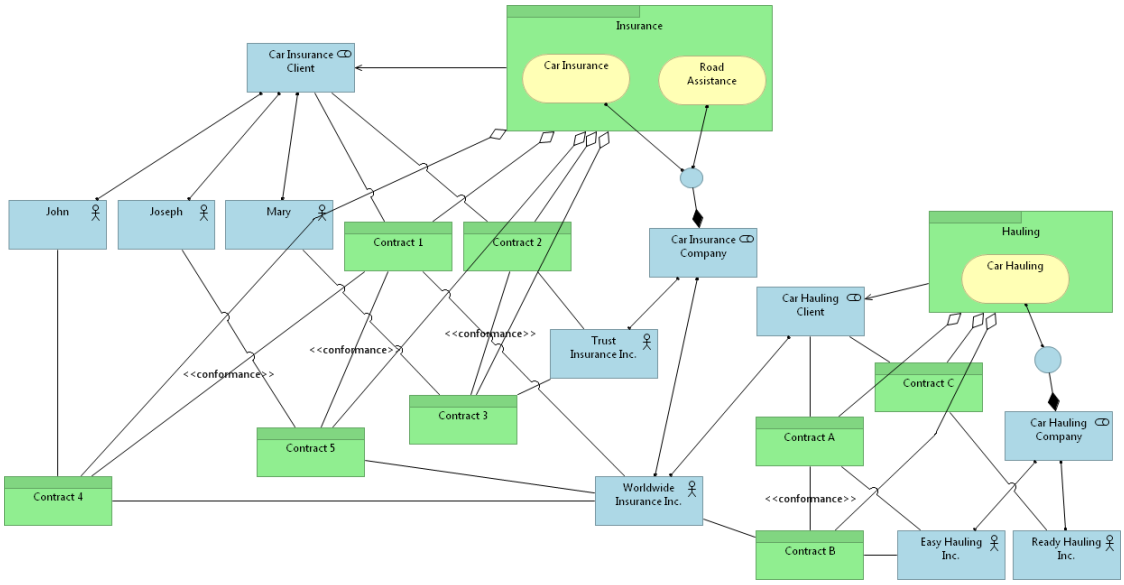

Figure 57 - The model analyzed by Group B in Part 2: "Car Insurance" application domain.

A.4.3 Questions

The four first questions answered in Part 2 were exactly the questions answered in Part 1 of the evaluation. Also, three new questions (P2Q5, P2Q6, and P2Q7) were included in Part 2 in order to gather general information about usability and possible improvements in the modeling patterns. In Part 2, therefore, the participants answered the following questions.

P2Q1) Does the model present service(s) being offered?

( ) Yes.

( ) No.

( ) It is not possible to identify.

If there is service being offered, FOR EACH actor that is offering a collection of service (organized in a product), say:

- The actor that is offering the collection of service (product).
- The name of the product(s) being offered, and the respective service(s).
- For whom (target customer) each product is being offered.

Obs.: If it is not possible to identify any of these three aforementioned items, say it explicitly.

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P2Q2) Does the model present hired services?

( ) Yes.

( ) No.

( ) It is not possible to identify.

If there is hired service, FOR EACH actor providing a collection of service (product) that was hired, say:

- The actor that was hired for provisioning the collection of services (product).
- The name of the hired product(s), and its respective service(s).
- The actor who hired the provisioning of the product(s).

Obs.: If it is not possible to identify any of these three aforementioned items, say it explicitly.

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P2Q3) For each "contract" element presented in the model, say (mark using a "X") what they represent/specify.

	Terms and conditions of a product/service offering	Terms and conditions of a product/service hiring	Other (say what!)	It is not possible to identify
Contract 1				
Contract 2				
Contract 3				
Contract 4				
Contract 5				
Contract A				
Contract B				
Contract C				

P2Q4) For each "contract" element (from "Contract 1" to "Contract 5", and from "Contract A" to "Contract C"), say who (actors) are involved in the contract.

- If the contract represents "Terms and conditions of a product/service offering", say: the contract, and who (actor) is offering the correspondent product/service.
- If the contract represents "Terms and conditions of a product/service hiring", say: the contract, and who (actor) hires and who (actor) is hired for provisioning the services.
- If the contract represents "Other", say what you consider convenient for describing who is involved in the contract element.

- If “it is not possible to identify” what the contract element represents, do not say anything.

Obs.: If it is not possible to identify any of the three first aforementioned items, say it explicitly.

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Describe, in the following questions, your (positive or negative) considerations about the adoption of the proposed modeling patterns.

P2Q5) Does the patterns adoption contribute for a better model understanding, minimizing ambiguities (mainly related to service offerings and agreements)? Comment.

_____

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P2Q6) What is the main benefit in adopting the patterns?

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P2Q7) What needs to be improved in the modeling patterns?

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Appendix B Formalization of UFO-S

This appendix presents the formalization of UFO-S. The formalization was a result of a "build-and-assess" iterative process. When necessary OCL constraints were added to the UFO-S models (represented in OntoUML) for guaranteeing a certain rigor, and avoid invalid model instantiations. The logical consistence of the models was analyzed by means of model simulations using Alloy Analyzer 4.2.

B.1 Introduction

When building conceptual models and ontologies, modelers often need to incorporate constrains (axioms) in the models in order to avoid invalid (unintended) model instantiations. This effort encompasses the analysis of the necessary constraints, and the incorporation of them in conceptual models or ontologies. In this thesis, we refer to this effort as "formalization".

The formalization of UFO-S was a result of a "build-and-assess" iterative process. In the "build" task, the OntoUML models were adjusted, and OCL constraints were incorporated in such models for guaranteeing a certain rigor (precision) in UFO-S. The "assess" task was conducted by means of model simulations using the Alloy Analyzer 4.2, which allowed to evaluate graphically if only intended instantiations were being generated. In successive "build-and-assess" cycles, we could refine the UFO-S models and their constraints.

This appendix is further structured as follows: Section B.2 describes the technologies used in the formalizations process; Section B.3 presents the UFO-S models generated from formalization process; Section B.4 presents the general constraints defined for the UFO-S models; Section B.5 presents the UFO-S constraints derived from the "social relator pattern", which is an ontological pattern of UFO; Section B.6 exemplifies the formalization process; Finally, Section B.7 presents the Alloy specification of UFO-S generated from formalization process.

B.2 Used Technologies

During formalization process, two technologies were used, which are presented below.

OntoUML (GUIZZARDI, 2005a): it is an UML profile that incorporates ontological distinctions offered by UFO (UFO-A and UFO-B). These distinctions are graphically

represented by means of stereotypes in UML Class diagram. Thus, by using OntoUML, it was possible to represent explicitly these distinctions in the representation of UFO-S. Table 21 presents the OntoUML stereotypes used in the formalization.

Table 21 - A subset of OntoUML stereotypes used in the formalization.

Stereotype	Corresponding Concept/Relations in UFO
<<category>>	Category
<<kind>>	Kind
<<collective>>	Collective Universal
<<rolemixin>>	Role Mixin
<<mode>>	Mode Universal
<<relator>>	Relator Universal
<<event>>	Event Universal
<<formal>>	Formal Relation
<<characterization>>	Characterization Relation (inherein)
<<mediation>>	Mediation Relation
<<participation>>	Participation Relation
<<sum>>	Mereological sum of parts
<<externaldependence>>	External Dependence

OLED[18]: it is an OntoUML editor that provides, among others, syntax verification, and model transformation from OntoUML+OCL to Alloy[19] specifications. From these specifications, it is possible to use the Alloy Analyzer tool for conducting model simulations over OntoUML models.

Figure 58 illustrates the simulation approach of OntoUML+OCL models used in this thesis. In this approach (GUERSON, 2013), the modeler "writes" OntoUML models and incorporates OCL constraints in order to better specify models, and then avoid unintended model instantiations. The OntoUML+OCL model is transformed in an Alloy specification. The Alloy specification then is analyzed using the Alloy Analyzer tool, which generates instances of the model and represents these instances in a graphical representation. By analyzing the instantiation, the modeler can assess the models and conduct new simulation cycles if necessary.

[18] Available at: https://code.google.com/p/ontouml-lightweight-editor/.
[19] Available at: http://alloy.mit.edu/alloy/.

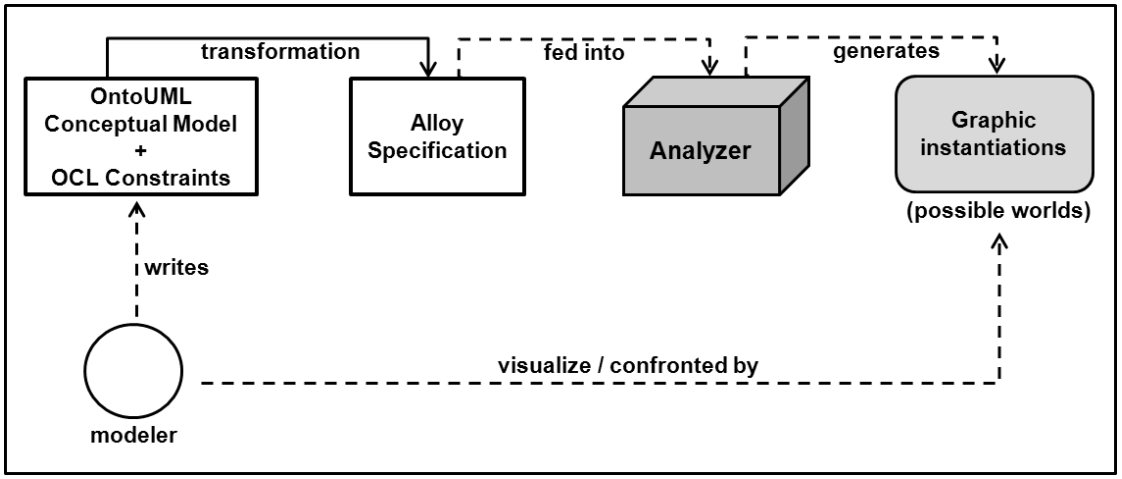

Figure 58 - Simulation approach of OntoUML + OCL using Alloy.

B.3 UFO-S Models

This section presents the UFO-S models generated from the formalization process.

Differently from the UFO-S models presented in Chapter 3. , which do not present some modeling aspects for sake of clarity (e.g., relationship's stereotypes), the models presented in this section incorporate such aspects by being useful in the context of the formalization process. The aspects are described, as follows:

- **Relationship's stereotypes**: OntoUML stereotypes play an important role in the simulation approach, in such way their semantics are taken in account in the model instantiations. During the formalization process, the model's relationships were characterized with OntoUML stereotypes.
- **The "{frozen}" constraint**: this constraint was used in some association-ends. If an association-end is defined as "frozen", once created, an instance of this association-end must not change (i.e., no update and no deletion). Also, "frozen" association-ends impact n-ary associations. Consider, e.g., that 'A' and 'B' are classes (types), and that 'A' is associated with 'B' by means of an association 'R'. Consider that 'R' is setted as "frozen" in the association-end with 'B'. Consider that 'a' and 'b' are, respectively, instances of 'A' and 'B', which are related by means of an association 'r' (instance of 'R'). Since this association is frozen in 'B', none new link can be created between 'a' and any instance of 'B', i.e., once created, the list of objects of 'B' related to 'a' is "frozen".

- **Elimination of minimum cardinality constraint "0" (optional cardinality)**: conceptual models without minimum cardinality constraints "0" (zero) are more suitable in terms of ontological adequacy (since there is no thing with an optional property), and of practical performance in problem-solving tasks (when a deeper understanding about a domain is required) (GUIZZARDI, 2005a). Thus, during the UFO-S formalization process, some optional cardinalities were removed with the purpose of better exploring the relationships among the concepts[20]. As a result, new concepts and relationships had to be included in the model.

Figure 59 presents the Service Offer model. According to this model, a *service offer* event creates a *service offering* that mediates the relation between a *service provider* and a *target service community*, which is a collective of *target service customers*. The service provider establishes *service offering commitments* towards the target service community for serving all of its members. The target service community, in contrast, bears the correspondent *service offering claims* (counter parts of the service offering commitments) that are externally dependent on *service provider*. Service offerings, besides mediating the relation between service providers and target customer communities, can also be characterized as mereological sums of the service commitments and claims established between service provider and target customer community. In case of interest in a service offering, service provider and target service customer(s) can enter in a service negotiation.

[20] It is important to remark the trade-off between "not using optional cardinalities in OntoUML models" (due to ontological adequacy) and "using optional cardinalities in a controlled way" (considering pragmatic aspects during the conceptual model design). In the line with (PRINCE, 2014), we advocate that it is useful, in some cases, use optional cardinalities (i.e., minimum cardinality "0"), and that this tradeoff must be take in account by the modeler when building their conceptual models.

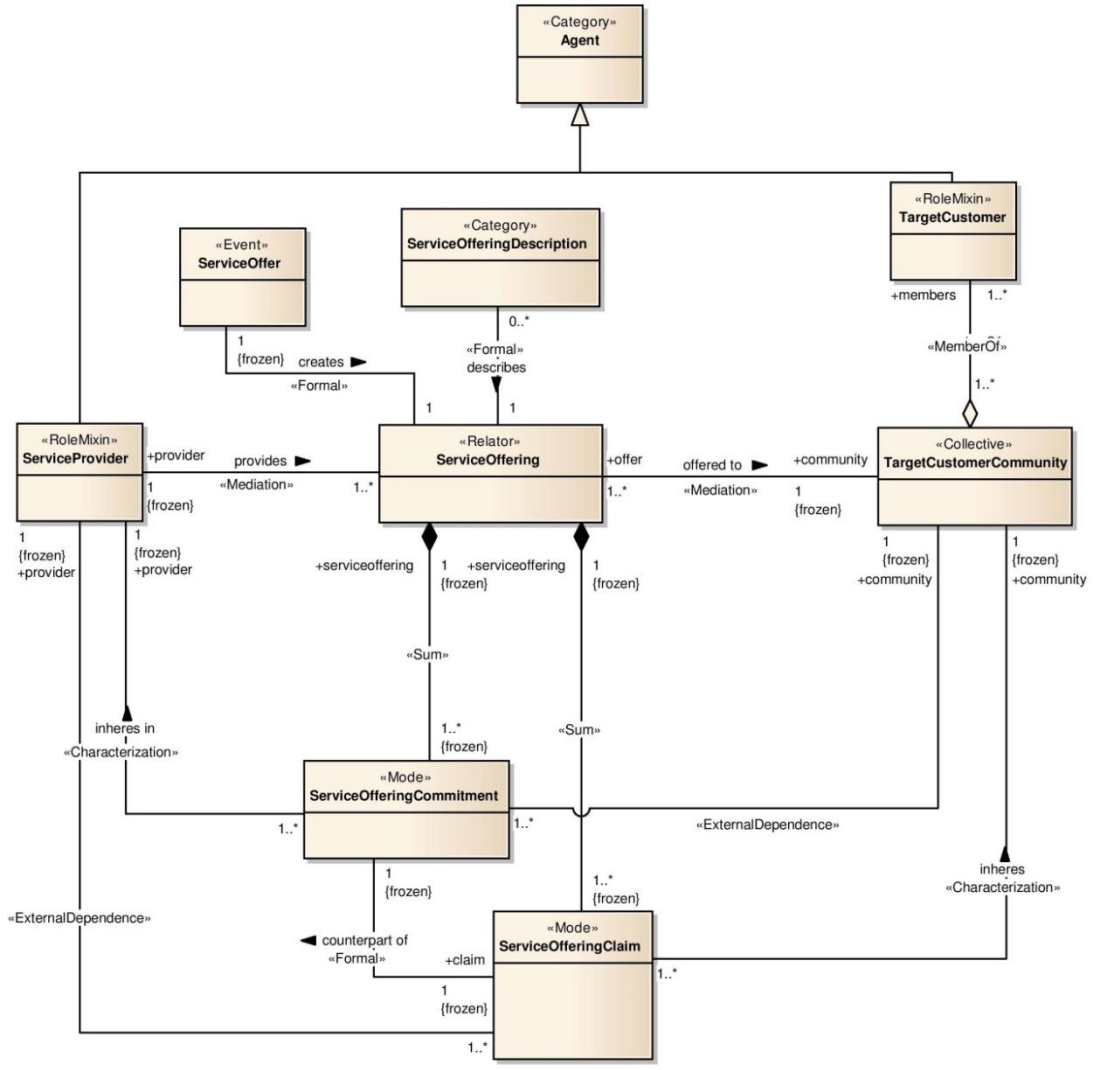

Figure 59 - Service Offer model.

Figure 60 presents the Service Negotiation model. According to this model, a service provider and a target service customer can participate in a *service negotiation* (respectively, as *service provided on negotiation*, and *target customer on negotiation*). A successful service negotiation results in a service agreement. In the context of a service agreement, the service provider plays the *hired service provider* role, whereas the target service customer plays the *service customer* role. A *service agreement* mediates the relation between hired service provider and service customer(s).

A hired service provider establishes one or more *hired provider commitments* towards the service customer(s). In contrast, the service customer(s) bears the correspondent *service customer claims* (counter parts of the hired provider commitments), which are externally dependent on the hired service provider.

In service relations in which the service customer(s) is also committed towards the hired service provider, a particular kind of service agreement characterizes the service relation: the Specialized Service Agreement. *Specialized service agreement* mediates the relation between a committed service customer and a claimed hired provider. Thus, the *committed service customer* establishes service customer commitments towards the claimed hired provider. In contrast, the *claimed hired provider* bears the correspondent hired provider claims (counter parts of the service customer commitments), which are externally dependent on the committed service customer.

The concepts *service provider on negotiation, target customer on negotiation, committed service customer*, and *specialized service agreement* (and their respective relationships) were included in the model as a way of eliminating optional cardinalities.

Finally, it is also important to remark that service agreements are mereological sums of the service commitments and claims established between hired service provider and service customer.

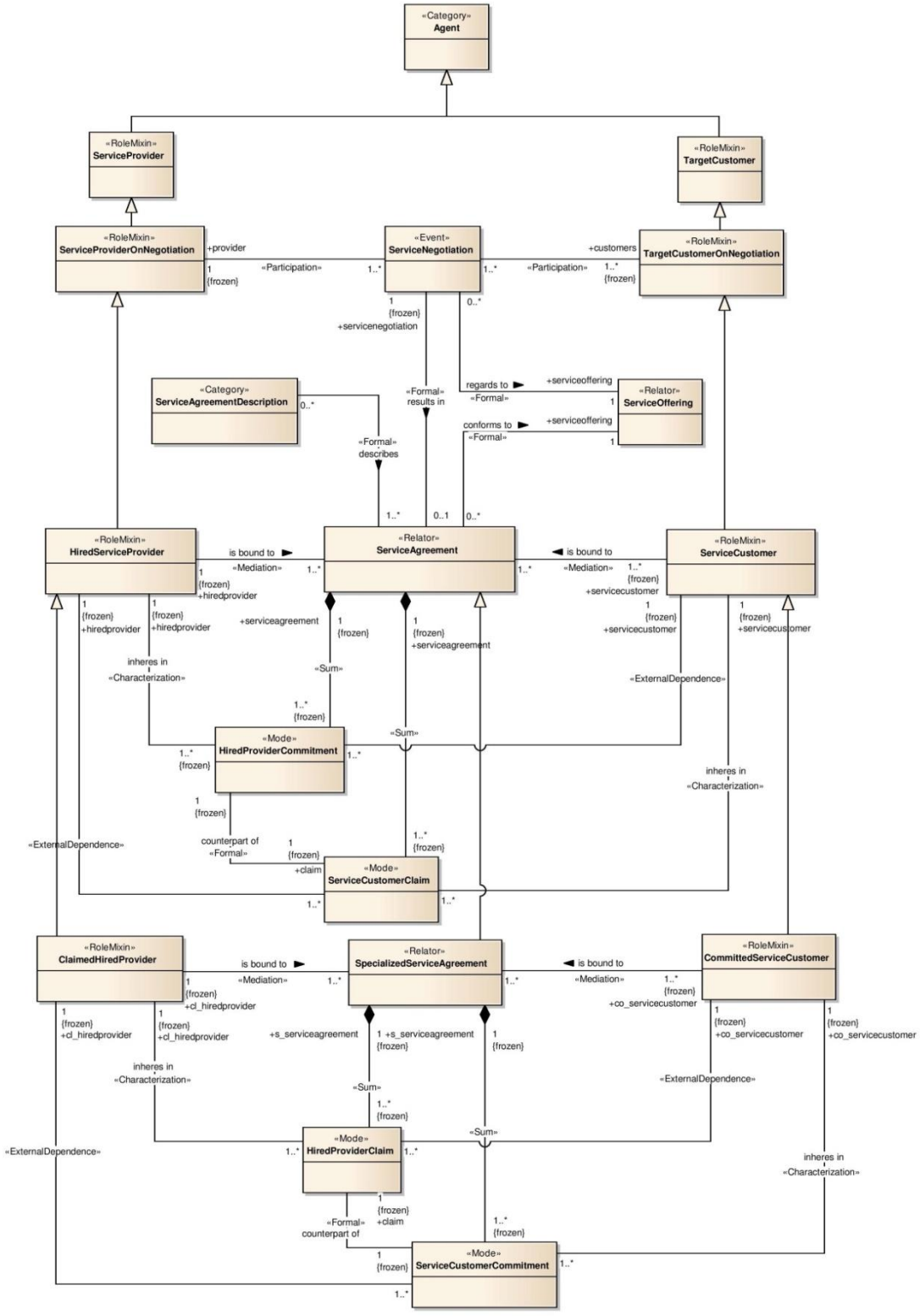

Figure 60 - Service Negotiation model.

Figure 61 presents the Service Delivery model. In this model, the service delivery event is a mereological sum of the events performed by the hired service provider and by the service customer (hired provider actions, service customer actions,

and/or interactions between hired service provider and service customer). These events are motivated by the service commitments established between these service participants in a service agreement.

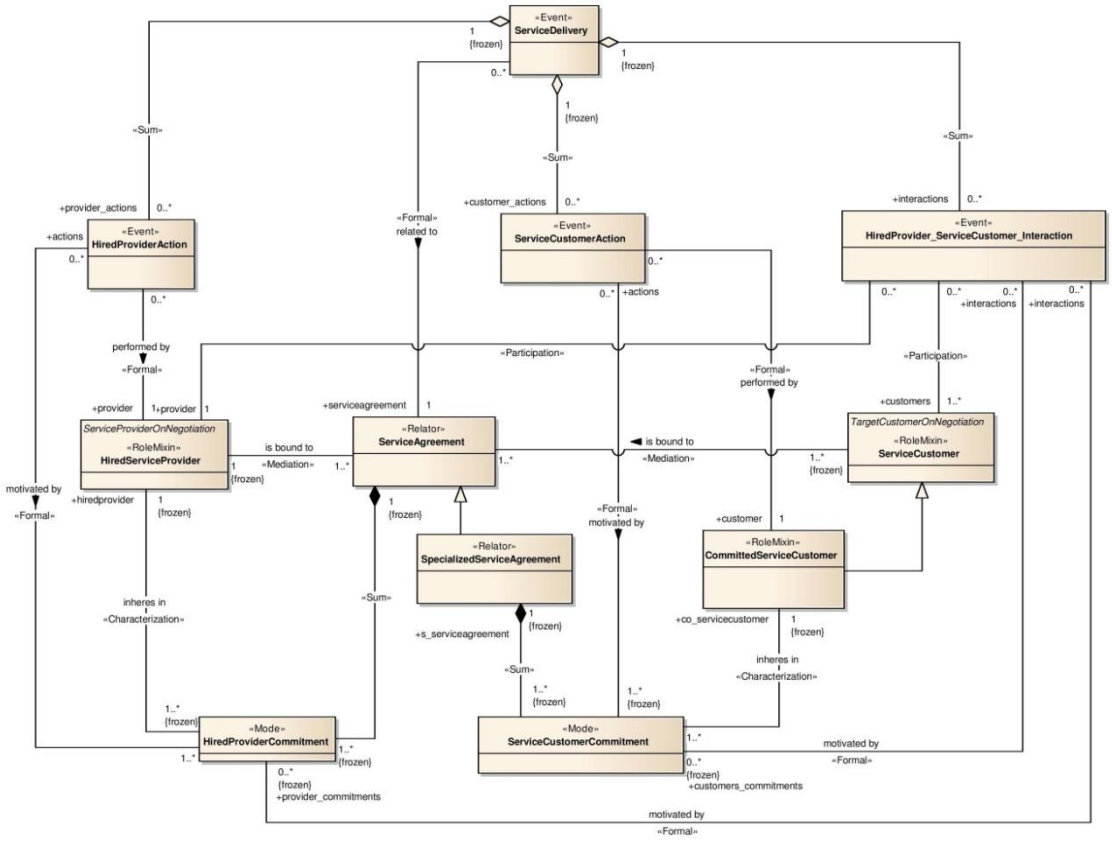

Figure 61 - Service Delivery model.

B.4 UFO-S General Constraints

This section presents the general constraints that accompany the UFO-S models. *General constraints* refer to the constraints defined for UFO-S, but that are not derived from any ontological foundational pattern (e.g., the "social relator pattern" described in Section B.5). Table 22 presents the constraints defined for the Service Negotiation model. Table 23 presents the constraints of the Service Delivery model. No general constraint was defined for the Service Offer model.

Table 22 - General constraints of the Service Negotiation model.

ID	OCL Constraint	Description
SN01R1	context ServiceAgreement inv SN01R1: self.serviceoffering = self.servicenegotiation.serviceoffering	When a *service negotiation* results in a *service agreement*, that *service agreement* must conform to the *service offering* to which the *service negotiation* refers to.
SN02R1	context ServiceNegotiation inv SN02R1: self.customers->excludes(self.provider.oclAsType(TargetCustomerOnNegotiation))	An agent can not play simultaneously the roles of *service provider* and *target customer* in the same *service negotiation*.
SN03R1	context ServiceNegotiation inv SN03R1: self.provider.oclAsType(ServiceProvider) = self.serviceoffering.provider	The *service provider* that participates in a *service negotiation* provides the *service offering* to which the negotiation regards to.
SN04R1	context ServiceNegotiation inv SN04R1: self.customers->forAll(customer | self.serviceoffering.community.members->includes(customer.oclAsType(TargetCustomer)))	Every *target customer* that participates in a *service negotiation* is a member of the *target customer community* to which the *service offering* is offered.
SN05R1	context ServiceAgreement inv SN05R1: self.servicecustomer->forAll(customer | self.servicenegotiation.customers->includes(customer.oclAsType(TargetCustomerOnNegotiation)))	The *hired service provider* and *service customer*(s) that are related by means of a *service agreement* (i.e., are bound to this *service agreement*) participated (as *service provider* and as *target service costumer*(s)) of the *service negotiation* that resulted in this *service agreement*.
SN05R2	context ServiceAgreement inv SN05R2: self.hiredprovider.oclAsType(ServiceProviderOnNegotiation) =	

	self.servicenegotiation.provider	

Table 23 - General constraints of the Service delivery model.

ID	OCL Constraint	Description
SD01R1	context ServiceDelivery inv SD01R1: self.provider_actions->size() + self.customer_actions->size() + self.interactions->size() >= 1	Every *service delivery* has at least one part which is a *hired provider action*, a *customer action*, or a *hired provider-customer interaction*.
SD02R1	context HiredProviderCommitment inv SD02R1: self.actions->forAll(action | self.hiredprovider = action.provider)	A *hired provider action* is motivated by a *hired provider commitment* that inheres in the *hired service provider* that performs this action.
SD03R1	context ServiceCustomerCommitment inv SD03R1: self.actions->forAll(action | self.co_servicecustomer = action.customer)	A *service customer action* is motivated by a *service customer commitment* that inheres in the *service customer* (*committed service customer*) that performs this action.
SD04R1	context HiredProvider_ServiceCustomer_Interaction inv SD04R1: self.provider_commitments->size() + self.customers_commitments->size() >= 1	Each *hired provider-customer interaction* is motivated by at least one commitment (a *hired provider commitment* or a *service customer commitment*).
SD05R1	context HiredProviderCommitment inv SD05R1: self.interactions->forAll(interaction | interaction.provider = self.hiredprovider)	A *hired provider-customer interaction* is motivated by *hired provider commitments* if these commitments inhere in the *hired service provider* that participates in the interaction.
SD06R1	context ServiceCustomerCommitment inv SD06R1: self.interactions->forAll(interaction | interaction.customers->includes(self.co_servicecustomer.oclAsType(ServiceCustomer)))	A *hired provider-customer interaction* is motivated by *service customer commitments* if these commitments inhere in a *service customer* that participates in the interaction.
SD07R1	context ServiceDelivery inv SD07R1: self.provider_actions->forAll(action | action.provider = self.serviceagreement.hiredprovider)	Each *hired provider action* that is part of a *service delivery* related to a *service agreement* is performed by the *hired service provider* bound to that *agreement*.
SD08R1	context ServiceDelivery inv SD08R1: self.customer_actions->forAll(action | self.serviceagreement.servicecustomer-	Each *customer action* that is part of a *service delivery* related to a *service agreement* is performed by the *service customer* bound to

	>includes(action.customer.oclAsType(ServiceCustomer)))	that *agreement*.
SD09R1	context ServiceDelivery inv SD09R1: self.interactions->forAll(interaction | interaction.provider = self.serviceagreement.hiredprovider)	Each *hired provider-customer interaction* which is part of the *service delivery* related to a *service agreement*, has the participation of the *hired service provider* and of some *service customers* bound to that agreement.
SD09R2	context ServiceDelivery inv SD09R2: self.interactions->forAll(interaction | self.serviceagreement.servicecustomer->includesAll(interaction.customers))	

B.5 UFO-S Constraints based on the "Social Relator Pattern"

This section presents the "social relator pattern" of UFO. Also, the UFO-S constraints derived from this pattern are presented. Figure 62 illustrates the mains concepts and relationships of this pattern.

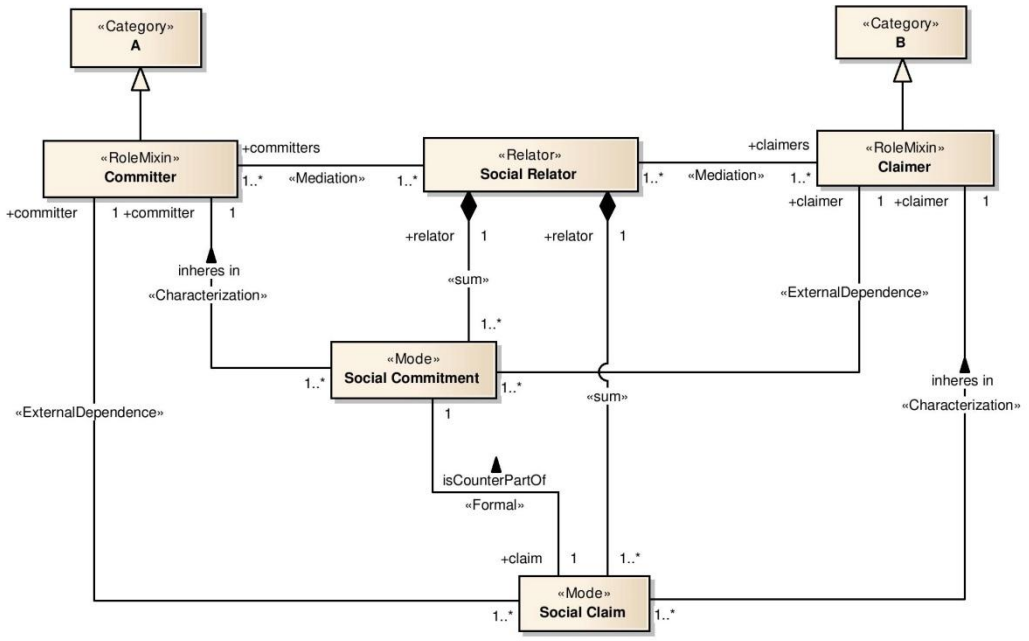

Figure 62 - Social relator pattern.

In this pattern, a social relator (e.g., a “marriage”) mediates a relation between two or more individuals (e.g., “John”, and “Mary”) that play different roles in the relation (e.g., “husband”, and “wife”). By participating in a social relator, the individuals bear a number of social commitments and claims. For example, “John”, as husband, bears a number of social commitments (e.g., obligations) that are externally dependent on “Mary”. “Mary”, as wife, bears the counter part social claims that are externally dependent on “John”. On the other hand, “Mary”, as wife, also bears a number of social commitments that are externally dependent on “John”, as husband. He bears the counter part

social claims that are externally dependent on “Mary”. The social relator (the “marriage”), besides relating the individuals (“John as husband” and “Mary as wife”), is the mereological sum of all social commitments and claims that inhere in the correspondent individuals.

For guaranteeing valid instantiations of this pattern, some constraints are necessary, which are presented in Table 24.

Table 24 - Social relator pattern’s constraints.

ID	OCL Constraint	Description
SR01	context SocialCommitment inv committer_upper_cycle: self.<relator>.<committers>->includes(self.<committer>)	A *social commitment*, which is part of a *social relator*, inheres in an individual that is related to (i.e., playing a role) such relator.
SR02	context SocialCommitment inv claimer_upper_cycle: self.<relator>.<claimers>->includes(self.<claimer>)	A *social commitment*, which is part of a *social relator*, is externally dependent on an individual that is related to (i.e., playing a role) in such relator.
SR03	context SocialCommitment inv claim_cycle: self.<relator> = self.<claim>.<relator>	A *social commitment* is counter part of the *social claim* that is part of the *social relator* in which this *social commitment* is part.
SR04	context SocialCommitment inv claimer_lower_cycle: self.<claimer> = self.<claim>.<claimer>	A *social claim* inheres in the individual in which the *social commitment* that is counter part of this claim is externally dependent on.
SR05	context SocialCommitment inv committer_lower_cycle: self.<committer> = self.<claim>.<committer>	A *social claim* is externally dependent on the individual in which the *social commitment* that is counter part of this claim inheres in.

In case of UFO-S, the “social relator pattern” is applied in the Service Offer model (when a *service offering*, as a social relator, is established between a service provider and a target customer community), and in the Service Negotiation model (when a *service agreement*, as a social relator, is established between hired service provider and service customer). The UFO-S constraints defined for the Service Offer model are presented Table 25, whereas those defined for the Service Negotiation model are presented in Table 26.

Table 25 - Constraints of the Service Offer model based on the social relator pattern.

ID	OCL Constraints	Source (Social Relator Pattern Constraint)
SO01SR1	context ServiceOfferingCommitment inv SO01SR1: self.serviceoffering = self.claim.serviceoffering	SR03
SO02SR1	context ServiceOfferingCommitment inv SO02SR1: self.provider = self.serviceoffering.provider	SR01
SO02SR2	context ServiceOfferingCommitment inv SO02SR2: self.community = self.serviceoffering.community	SR02
SO03SR1	context ServiceOfferingCommitment inv SO03SR1: self.community = self.claim.community	SR04
SO03SR2	context ServiceOfferingCommitment inv SO03SR2: self.provider = self.claim.provider	SR05

Table 26 - Constraints of Service Negotiation model based on social relator pattern.

ID	OCL Constraint	Source (Social Relator Pattern Constraint)
SNSR1R1	context HiredProviderCommitment inv SNSR1R1: self.serviceagreement = self.claim.serviceagreement	SR05
SNSR1R2	context HiredProviderCommitment inv SNSR1R2: self.hiredprovider = self.serviceagreement.hiredprovider	SR01
SNSR1R3	context HiredProviderCommitment inv SNSR1R3: self.serviceagreement.servicecustomer->includes(self.servicecustomer)	SR03
SNSR1R4	context HiredProviderCommitment inv SNSR1R4: self.hiredprovider = self.claim.hiredprovider	SR02

SNSR1R5	context HiredProviderCommitment inv SNSR1R5: self.servicecustomer = self.claim.servicecustomer	SR04
SNSR2R1	context ServiceCustomerCommitment inv SNSR2R1: self.s_serviceagreement = self.claim.s_serviceagreement	SR03
SNSR2R2	context ServiceCustomerCommitment inv SNSR2R2: self.s_serviceagreement.co_servicecustomer->includes(self.co_servicecustomer)	SR01
SNSR2R3	context ServiceCustomerCommitment inv SNSR2R3: self.cl_hiredprovider = self.s_serviceagreement.cl_hiredprovider	SR02
SNSR2R4	context ServiceCustomerCommitment inv SNSR2R4: self.cl_hiredprovider = self.claim.cl_hiredprovider	SR04
SNSR2R5	context ServiceCustomerCommitment inv SNSR2R5: self.co_servicecustomer = self.claim.co_servicecustomer	SR05

B.6 Exemplifying the Model Simulation Process

During model simulation, instantiations of UFO-S were generated and analyzed, and changes were done in the models for avoiding invalid instantiations. For exemplifying this process, two instantiations are presented and commented, as follows.

Figure 63 presents an invalid instantiation, in which an individual ("Agent #1") participates in a service negotiation ("Service negotiation #B") playing, at the same time, the "service provider" and the "target customer" roles. For avoiding this particular instantiation, we included in the UFO-S model, an OCL constraint (the SN02R1 constraint of Table 22). Figure 64, in turn, presents a valid instantiation of UFO-S after the inclusion of this constraint. As a result, the "service provider" and the "target customer" roles are then played by different individuals ("Agent #1" and "Agent #2"), which participant in a service negotiation ("Service negotiation #B").

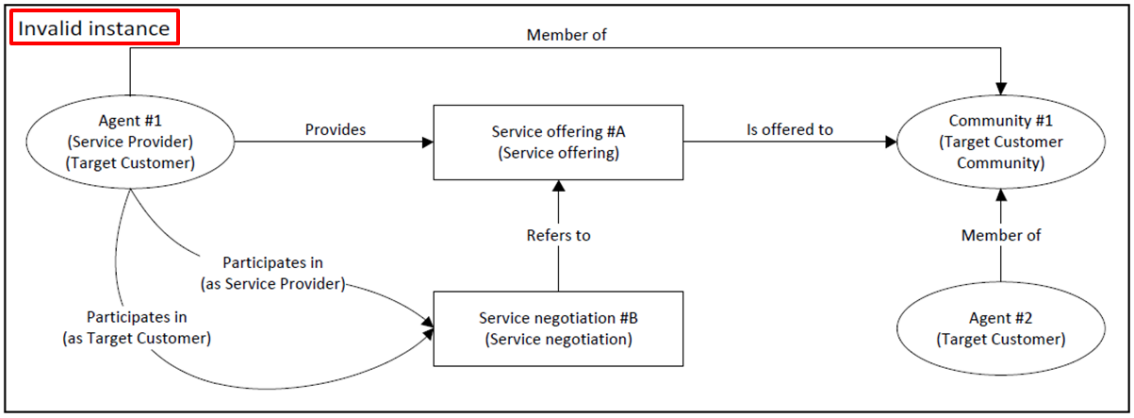

Figure 63 - Example of an UFO-S invalid instantiation.

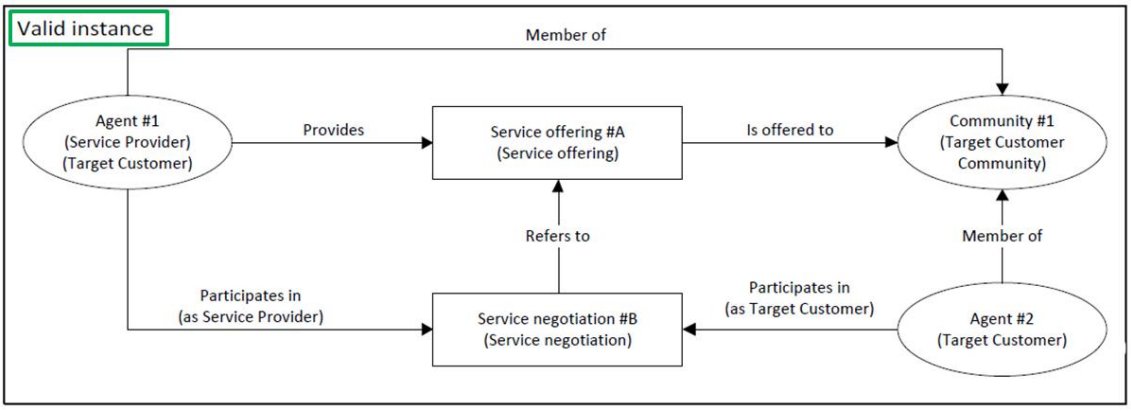

Figure 64 - Example of an UFO-S valid instantiation.

B.7 Alloy Specification of the UFO-S Models

This section presents the Alloy specification of the UFO-S formalized models.

```
module EA_Model

open world_structure[World]
open ontological_properties[World]
open util/relation
open util/ternary
open util/boolean

sig Object {}

sig Property {}

sig DataType {}

abstract sig World {
	exists: some Object+Property,
	Agent: set exists:>Object,
	ClaimedHiredProvider: set exists:>Object,
	CommittedServiceCustomer: set exists:>Object,
	HiredProvider_ServiceCustomer_Interaction: set exists:>Object,
	HiredProviderAction: set exists:>Object,
	HiredProviderClaim: set exists:>Property,
	HiredProviderCommitment: set exists:>Property,
	HiredServiceProvider: set exists:>Object,
	ServiceAgreement: set exists:>Property,
	ServiceAgreementDescription: set exists:>Object,
	ServiceCustomer: set exists:>Object,
	ServiceCustomerAction: set exists:>Object,
	ServiceCustomerClaim: set exists:>Property,
	ServiceCustomerCommitment: set exists:>Property,
	ServiceDelivery2: set exists:>Object,
	ServiceNegotiation2: set exists:>Property,
	ServiceOffer2: set exists:>Object,
	ServiceOffering: set exists:>Property,
	ServiceOfferingClaim: set exists:>Property,
	ServiceOfferingCommitment: set exists:>Property,
	ServiceOfferingDescription: set exists:>Object,
	ServiceProvider: set exists:>Object,
	ServiceProviderOnNegotiation: set exists:>Object,
	SpecializedServiceAgreement: set exists:>Property,
	TargetCustomer: set exists:>Object,
	TargetCustomerCommunity: set exists:>Object,
	TargetCustomerOnNegotiation: set exists:>Object,
	componentOf1: set ServiceDelivery2 one -> set HiredProvider_ServiceCustomer_Interaction,
	componentOf2: set ServiceDelivery2 one -> set ServiceCustomerAction,
	componentOf3: set SpecializedServiceAgreement one -> some HiredProviderClaim,
	componentOf4: set ServiceAgreement one -> some HiredProviderCommitment,
	componentOf5: set ServiceAgreement one -> some ServiceCustomerClaim,
	componentOf6: set SpecializedServiceAgreement one -> some ServiceCustomerCommitment,
	componentOf7: set ServiceOffering one -> some ServiceOfferingCommitment,
	componentOf8: set ServiceOffering one -> some ServiceOfferingClaim,
	componentOf: set ServiceDelivery2 one -> set HiredProviderAction,
	conformsto: set ServiceOffering one -> set ServiceAgreement,
	counterpartof1: set ServiceCustomerClaim one -> one HiredProviderCommitment,
	counterpartof2: set ServiceOfferingCommitment one -> one ServiceOfferingClaim,
	counterpartof: set ServiceCustomerCommitment one -> one HiredProviderClaim,
	creates: set ServiceOffering one -> one ServiceOffer2,
	describes1: set ServiceOfferingDescription set -> one ServiceOffering,
	describes: set ServiceAgreementDescription set -> some ServiceAgreement,
	externallydependenton1: set HiredProviderClaim some -> one CommittedServiceCustomer,
	externallydependenton2: set HiredProviderCommitment some -> one ServiceCustomer,
	externallydependenton3: set ServiceCustomerClaim some -> one HiredServiceProvider,
	externallydependenton4: set ServiceOfferingClaim some -> one ServiceProvider,
	externallydependenton5: set ServiceOfferingCommitment some -> one
TargetCustomerCommunity,
	externallydependenton: set ServiceCustomerCommitment some -> one ClaimedHiredProvider,
```

```
        inheresin1: set ServiceCustomerCommitment some -> one CommittedServiceCustomer,
        inheresin2: set HiredProviderCommitment some -> one HiredServiceProvider,
        inheresin3: set ServiceCustomerClaim some -> one ServiceCustomer,
        inheresin4: set ServiceOfferingClaim some -> one TargetCustomerCommunity,
        inheresin5: set ServiceOfferingCommitment some -> one ServiceProvider,
        inheresin: set HiredProviderClaim some -> one ClaimedHiredProvider,
        isboundto1: set SpecializedServiceAgreement some -> some CommittedServiceCustomer,
        isboundto2: set ServiceAgreement some -> one HiredServiceProvider,
        isboundto3: set ServiceAgreement some -> some ServiceCustomer,
        isboundto: set SpecializedServiceAgreement some -> one ClaimedHiredProvider,
        memberOf: set TargetCustomerCommunity some -> some TargetCustomer,
        motivatedby1: set ServiceCustomerCommitment set -> set
HiredProvider_ServiceCustomer_Interaction,
        motivatedby2: set HiredProviderCommitment set -> set
HiredProvider_ServiceCustomer_Interaction,
        motivatedby3: set ServiceCustomerCommitment some -> set ServiceCustomerAction,
        motivatedby: set HiredProviderCommitment some -> set HiredProviderAction,
        offeredto: set ServiceOffering some -> one TargetCustomerCommunity,
        participatesin1: set ServiceNegotiation2 some -> one ServiceProviderOnNegotiation,
        participatesin: set ServiceNegotiation2 some -> some TargetCustomerOnNegotiation,
        performedby1: set ServiceCustomer some -> set HiredProvider_ServiceCustomer_Interaction,
        performedby2: set HiredServiceProvider one -> set
HiredProvider_ServiceCustomer_Interaction,
        performedby3: set CommittedServiceCustomer one -> set ServiceCustomerAction,
        performedby: set HiredServiceProvider one -> set HiredProviderAction,
        provides: set ServiceOffering some -> one ServiceProvider,
        refersto: set ServiceOffering one -> set ServiceNegotiation2,
        relatedto: set ServiceAgreement one -> set ServiceDelivery2,
        resultsin: set ServiceNegotiation2 one -> lone ServiceAgreement
}{
        TargetCustomerOnNegotiation = ServiceCustomer+CommittedServiceCustomer
        TargetCustomer =
TargetCustomerOnNegotiation+ServiceCustomer+CommittedServiceCustomer
        ServiceProvider = HiredServiceProvider+ServiceProviderOnNegotiation+ClaimedHiredProvider
        Agent =
TargetCustomerOnNegotiation+ServiceCustomer+HiredServiceProvider+CommittedServiceCustomer+Se
rviceProvider+ServiceProviderOnNegotiation+TargetCustomer+ClaimedHiredProvider
        ServiceProviderOnNegotiation = HiredServiceProvider+ClaimedHiredProvider
        ServiceCustomer = CommittedServiceCustomer
        HiredServiceProvider = ClaimedHiredProvider
        exists:>Object in
TargetCustomerCommunity+HiredProvider_ServiceCustomer_Interaction+ServiceOffer2+HiredProviderA
ction+ServiceDelivery2+ServiceCustomerAction
        disj[TargetCustomerCommunity,HiredProvider_ServiceCustomer_Interaction,ServiceOffer2,Hire
dProviderAction,ServiceDelivery2,ServiceCustomerAction]
        exists:>Property in
ServiceOfferingCommitment+HiredProviderClaim+ServiceCustomerClaim+ServiceNegotiation2+ServiceO
fferingClaim+ServiceCustomerCommitment+ServiceOffering+SpecializedServiceAgreement+ServiceAgre
ement+HiredProviderCommitment
        disj[TargetCustomerCommunity,ServiceOfferingDescription+ServiceCustomerAction+HiredProvi
derAction+Agent+ServiceDelivery2+HiredProvider_ServiceCustomer_Interaction+ServiceOffer2+Service
AgreementDescription]
        disj[ServiceCustomerAction,ServiceOfferingDescription+HiredProviderAction+Agent+ServiceDeli
very2+HiredProvider_ServiceCustomer_Interaction+ServiceOffer2+TargetCustomerCommunity+Service
AgreementDescription]
        disj[ServiceOfferingDescription,ServiceCustomerAction+HiredProviderAction+Agent+ServiceDeli
very2+HiredProvider_ServiceCustomer_Interaction+ServiceOffer2+TargetCustomerCommunity+Service
AgreementDescription]
        disj[ServiceAgreementDescription,ServiceOfferingDescription+ServiceCustomerAction+HiredPro
viderAction+Agent+ServiceDelivery2+HiredProvider_ServiceCustomer_Interaction+ServiceOffer2+Targe
tCustomerCommunity]
        disj[ServiceDelivery2,ServiceOfferingDescription+ServiceCustomerAction+HiredProviderAction+
Agent+HiredProvider_ServiceCustomer_Interaction+ServiceOffer2+TargetCustomerCommunity+Service
AgreementDescription]
        disj[HiredProvider_ServiceCustomer_Interaction,ServiceOfferingDescription+ServiceCustomerAc
tion+HiredProviderAction+Agent+ServiceDelivery2+ServiceOffer2+TargetCustomerCommunity+Service
AgreementDescription]
        disj[HiredProviderAction,ServiceOfferingDescription+ServiceCustomerAction+Agent+ServiceDeli
very2+HiredProvider_ServiceCustomer_Interaction+ServiceOffer2+TargetCustomerCommunity+Service
AgreementDescription]
        disj[ServiceOffer2,ServiceOfferingDescription+ServiceCustomerAction+HiredProviderAction+Ag
```

```
ent+ServiceDelivery2+HiredProvider_ServiceCustomer_Interaction+TargetCustomerCommunity+Service
AgreementDescription]
	disj[Agent,ServiceOfferingDescription+ServiceCustomerAction+HiredProviderAction+ServiceDeli
very2+HiredProvider_ServiceCustomer_Interaction+ServiceOffer2+TargetCustomerCommunity+Service
AgreementDescription]
	disj[ServiceOfferingCommitment,ServiceCustomerClaim+ServiceOffering+ServiceCustomerCom
mitment+HiredProviderCommitment+ServiceNegotiation2+ServiceAgreement+HiredProviderClaim+Serv
iceOfferingClaim]
	disj[ServiceOfferingClaim,ServiceCustomerClaim+ServiceOfferingCommitment+ServiceOffering
+ServiceCustomerCommitment+HiredProviderCommitment+ServiceNegotiation2+ServiceAgreement+Hi
redProviderClaim]
	disj[HiredProviderClaim,ServiceCustomerClaim+ServiceOfferingCommitment+ServiceOffering+S
erviceCustomerCommitment+HiredProviderCommitment+ServiceNegotiation2+ServiceAgreement+Servi
ceOfferingClaim]
	disj[ServiceCustomerCommitment,ServiceCustomerClaim+ServiceOfferingCommitment+Service
Offering+HiredProviderCommitment+ServiceNegotiation2+ServiceAgreement+HiredProviderClaim+Servi
ceOfferingClaim]
	disj[ServiceCustomerClaim,ServiceOfferingCommitment+ServiceOffering+ServiceCustomerCom
mitment+HiredProviderCommitment+ServiceNegotiation2+ServiceAgreement+HiredProviderClaim+Serv
iceOfferingClaim]
	disj[ServiceNegotiation2,ServiceCustomerClaim+ServiceOfferingCommitment+ServiceOffering+
ServiceCustomerCommitment+HiredProviderCommitment+ServiceAgreement+HiredProviderClaim+Servi
ceOfferingClaim]
	disj[ServiceAgreement,ServiceCustomerClaim+ServiceOfferingCommitment+ServiceOffering+S
erviceCustomerCommitment+HiredProviderCommitment+ServiceNegotiation2+HiredProviderClaim+Serv
iceOfferingClaim]
	disj[HiredProviderCommitment,ServiceCustomerClaim+ServiceOfferingCommitment+ServiceOff
ering+ServiceCustomerCommitment+ServiceNegotiation2+ServiceAgreement+HiredProviderClaim+Serv
iceOfferingClaim]
	disj[ServiceOffering,ServiceCustomerClaim+ServiceOfferingCommitment+ServiceCustomerCom
mitment+HiredProviderCommitment+ServiceNegotiation2+ServiceAgreement+HiredProviderClaim+Serv
iceOfferingClaim]
}

fact additionalFacts {
	continuous_existence[exists]
	elements_existence[Object+Property,exists]
}

fact weakSupplementationConstraint {
	all w: World | all x: w.TargetCustomerCommunity | # (x.(w.memberOf)) >= 2
}

fact relatorConstraint {
	all w: World | all x: w.ServiceAgreement | # (x.(w.isboundto2)+x.(w.isboundto3)) >= 2
}

fact weakSupplementationConstraint {
	all w: World | all x: w.ServiceDelivery2 | #
(x.(w.componentOf2)+x.(w.componentOf1)+x.(w.componentOf)) >= 2
}

fact relatorConstraint {
	all w: World | all x: w.ServiceOffering | # (x.(w.provides)+x.(w.offeredto)) >= 2
}

fact relatorConstraint {
	all w: World | all x: w.ServiceNegotiation2 | # (x.(w.participatesin)+x.(w.participatesin1)) >= 2
}

fact relatorConstraint {
	all w: World | all x: w.SpecializedServiceAgreement | #
(x.(w.isboundto1)+x.(w.isboundto)+x.(w.isboundto2)+x.(w.isboundto3)) >= 2
}

fact acyclicMeronymic {
	all w: World | acyclic[w.componentOf,w.ServiceDelivery2]
}

fact acyclicMeronymic {
	all w: World | acyclic[w.componentOf5,w.ServiceAgreement]
```

```
}

fact acyclicMeronymic {
	all w: World | acyclic[w.componentOf3,w.SpecializedServiceAgreement]
}

fact acyclicMeronymic {
	all w: World | acyclic[w.componentOf8,w.ServiceOffering]
}

fact acyclicMeronymic {
	all w: World | acyclic[w.componentOf4,w.ServiceAgreement]
}

fact acyclicMeronymic {
	all w: World | acyclic[w.componentOf1,w.ServiceDelivery2]
}

fact acyclicMeronymic {
	all w: World | acyclic[w.memberOf,w.TargetCustomerCommunity]
}

fact acyclicMeronymic {
	all w: World | acyclic[w.componentOf6,w.SpecializedServiceAgreement]
}

fact acyclicMeronymic {
	all w: World | acyclic[w.componentOf7,w.ServiceOffering]
}

fact acyclicMeronymic {
	all w: World | acyclic[w.componentOf2,w.ServiceDelivery2]
}

fact acyclicCharacterization {
	all w: World | acyclic[w.inheresin3,w.ServiceCustomerClaim]
}

fact acyclicCharacterization {
	all w: World | acyclic[w.externallydependenton5,w.ServiceOfferingCommitment]
}

fact acyclicCharacterization {
	all w: World | acyclic[w.externallydependenton4,w.ServiceOfferingClaim]
}

fact acyclicCharacterization {
	all w: World | acyclic[w.externallydependenton3,w.ServiceCustomerClaim]
}

fact acyclicCharacterization {
	all w: World | acyclic[w.inheresin,w.HiredProviderClaim]
}

fact acyclicCharacterization {
	all w: World | acyclic[w.inheresin2,w.HiredProviderCommitment]
}

fact acyclicCharacterization {
	all w: World | acyclic[w.externallydependenton2,w.HiredProviderCommitment]
}

fact acyclicCharacterization {
	all w: World | acyclic[w.inheresin5,w.ServiceOfferingCommitment]
}

fact acyclicCharacterization {
	all w: World | acyclic[w.inheresin1,w.ServiceCustomerCommitment]
}

fact acyclicCharacterization {
```

```
        all w: World | acyclic[w.externallydependenton,w.ServiceCustomerCommitment]
}

fact acyclicCharacterization {
        all w: World | acyclic[w.externallydependenton1,w.HiredProviderClaim]
}

fact acyclicCharacterization {
        all w: World | acyclic[w.inheresin4,w.ServiceOfferingClaim]
}

fact rigidity {
        rigidity[ServiceOfferingDescription,Object,exists]
}

fact rigidity {
        rigidity[HiredProviderAction,Object,exists]
}

fact rigidity {
        rigidity[Agent,Object,exists]
}

fact rigidity {
        rigidity[ServiceDelivery2,Object,exists]
}

fact rigidity {
        rigidity[ServiceOfferingCommitment,Property,exists]
}

fact rigidity {
        rigidity[HiredProvider_ServiceCustomer_Interaction,Object,exists]
}

fact rigidity {
        rigidity[ServiceCustomerCommitment,Property,exists]
}

fact rigidity {
        rigidity[HiredProviderClaim,Property,exists]
}

fact rigidity {
        rigidity[ServiceCustomerAction,Object,exists]
}

fact rigidity {
        rigidity[ServiceCustomerClaim,Property,exists]
}

fact rigidity {
        rigidity[ServiceOffering,Property,exists]
}

fact rigidity {
        rigidity[ServiceOffer2,Object,exists]
}

fact rigidity {
        rigidity[TargetCustomerCommunity,Object,exists]
}

fact rigidity {
        rigidity[HiredProviderCommitment,Property,exists]
}

fact rigidity {
        rigidity[ServiceAgreementDescription,Object,exists]
}
```

```
fact rigidity {
	rigidity[SpecializedServiceAgreement,Property,exists]
}

fact rigidity {
	rigidity[ServiceNegotiation2,Property,exists]
}

fact rigidity {
	rigidity[ServiceAgreement,Property,exists]
}

fact rigidity {
	rigidity[ServiceOfferingClaim,Property,exists]
}

fact generalization {
	ServiceCustomer in TargetCustomerOnNegotiation
}

fact generalization {
	ClaimedHiredProvider in HiredServiceProvider
}

fact generalization {
	ServiceProviderOnNegotiation in ServiceProvider
}

fact generalization {
	TargetCustomerOnNegotiation in TargetCustomer
}

fact generalization {
	TargetCustomer in Agent
}

fact generalization {
	ServiceProvider in Agent
}

fact generalization {
	SpecializedServiceAgreement in ServiceAgreement
}

fact generalization {
	HiredServiceProvider in ServiceProviderOnNegotiation
}

fact generalization {
	CommittedServiceCustomer in ServiceCustomer
}

fun visible : World -> univ {
	exists
}

fact associationProperties {
	immutable_target[ServiceCustomerClaim,inheresin3]
	immutable_target[SpecializedServiceAgreement,isboundto1]
	immutable_source[HiredProvider_ServiceCustomer_Interaction,motivatedby1]
	immutable_target[ServiceCustomerCommitment,inheresin1]
	immutable_target[ServiceOfferingClaim,inheresin4]
	immutable_source[HiredProvider_ServiceCustomer_Interaction,motivatedby2]
	immutable_source[HiredProviderClaim,counterpartof]
	immutable_target[ServiceCustomerCommitment,counterpartof]
	immutable_target[ServiceNegotiation2,participatesin1]
	immutable_target[ServiceAgreement,isboundto2]
	immutable_target[ServiceOfferingClaim,externallydependenton4]
	immutable_target[ServiceCustomerClaim,externallydependenton3]
	immutable_source[ServiceAgreement,resultsin]
	immutable_source[HiredServiceProvider,inheresin2]
```

```
        immutable_target[HiredProviderCommitment,inheresin2]
        immutable_source[ServiceOfferingClaim,counterpartof2]
        immutable_target[ServiceOfferingCommitment,counterpartof2]
        immutable_target[ServiceOfferingCommitment,inheresin5]
        immutable_source[HiredProviderClaim,componentOf3]
        immutable_target[SpecializedServiceAgreement,componentOf3]
        immutable_source[ServiceOfferingClaim,componentOf8]
        immutable_target[ServiceOffering,componentOf8]
        immutable_target[ServiceOfferingCommitment,externallydependenton5]
        immutable_source[ServiceCustomerAction,motivatedby3]
        immutable_target[HiredProviderClaim,inheresin]
        immutable_source[HiredProviderCommitment,componentOf4]
        immutable_target[ServiceAgreement,componentOf4]
        immutable_target[ServiceAgreement,isboundto3]
        immutable_source[HiredProvider_ServiceCustomer_Interaction,componentOf1]
        immutable_target[ServiceDelivery2,componentOf1]
        immutable_target[HiredProviderCommitment,externallydependenton2]
        immutable_target[ServiceOffering,provides]
        immutable_source[ServiceCustomerCommitment,componentOf6]
        immutable_target[SpecializedServiceAgreement,componentOf6]
        immutable_source[ServiceOfferingCommitment,componentOf7]
        immutable_target[ServiceOffering,componentOf7]
        immutable_target[HiredProviderClaim,externallydependenton1]
        immutable_source[HiredProviderAction,componentOf]
        immutable_target[ServiceDelivery2,componentOf]
        immutable_source[ServiceCustomerClaim,componentOf5]
        immutable_target[ServiceAgreement,componentOf5]
        immutable_target[ServiceOffering,creates]
        immutable_target[ServiceNegotiation2,participatesin]
        immutable_target[ServiceOffering,offeredto]
        immutable_target[ServiceCustomerCommitment,externallydependenton]
        immutable_target[SpecializedServiceAgreement,isboundto]
        immutable_source[HiredProviderCommitment,counterpartof1]
        immutable_target[ServiceCustomerClaim,counterpartof1]
        immutable_source[ServiceCustomerAction,componentOf2]
        immutable_target[ServiceDelivery2,componentOf2]
}

fun community [x: World.ServiceOffering,w: World] : set World.TargetCustomerCommunity {
        x.(w.offeredto)
}

fun serviceagreement [x: World.ServiceDelivery2,w: World] : set World.ServiceAgreement {
        (w.relatedto).x
}

fun serviceagreement1 [x: World.HiredProviderCommitment,w: World] : set World.ServiceAgreement {
        (w.componentOf4).x
}

fun servicecustomer1 [x: World.ServiceAgreement,w: World] : set World.ServiceCustomer {
        x.(w.isboundto3)
}

fun hiredprovider1 [x: World.ServiceAgreement,w: World] : set World.HiredServiceProvider {
        x.(w.isboundto2)
}

fun provider5 [x: World.ServiceOfferingCommitment,w: World] : set World.ServiceProvider {
        x.(w.inheresin5)
}

fun hiredprovider [x: World.HiredProviderCommitment,w: World] : set World.HiredServiceProvider {
        x.(w.inheresin2)
}

fun provider2 [x: World.ServiceNegotiation2,w: World] : set World.ServiceProviderOnNegotiation {
        x.(w.participatesin1)
}

fun serviceagreement5 [x: World.ServiceCustomerClaim,w: World] : set World.ServiceAgreement {
```

```
        (w.componentOf5).x
}

fun provider3 [x: World.ServiceOffering,w: World] : set World.ServiceProvider {
        x.(w.provides)
}

fun s_serviceagreement [x: World.HiredProviderClaim,w: World] : set
World.SpecializedServiceAgreement {
        (w.componentOf3).x
}

fun customers1 [x: World.ServiceNegotiation2,w: World] : set World.TargetCustomerOnNegotiation {
        x.(w.participatesin)
}

fun co_servicecustomer [x: World.ServiceCustomerCommitment,w: World] : set
World.CommittedServiceCustomer {
        x.(w.inheresin1)
}

fun co_servicecustomer2 [x: World.HiredProviderClaim,w: World] : set
World.CommittedServiceCustomer {
        x.(w.externallydependenton1)
}

fun servicecustomer [x: World.HiredProviderCommitment,w: World] : set World.ServiceCustomer {
        x.(w.externallydependenton2)
}

fun servicecustomer2 [x: World.ServiceCustomerClaim,w: World] : set World.ServiceCustomer {
        x.(w.inheresin3)
}

fun actions1 [x: World.ServiceCustomerCommitment,w: World] : set World.ServiceCustomerAction {
        x.(w.motivatedby3)
}

fun community1 [x: World.ServiceOfferingClaim,w: World] : set World.TargetCustomerCommunity {
        x.(w.inheresin4)
}

fun provider1 [x: World.HiredProvider_ServiceCustomer_Interaction,w: World] : set
World.HiredServiceProvider {
        (w.performedby2).x
}

fun claim1 [x: World.HiredProviderCommitment,w: World] : set World.ServiceCustomerClaim {
        (w.counterpartof1).x
}

fun interactions2 [x: World.ServiceDelivery2,w: World] : set
World.HiredProvider_ServiceCustomer_Interaction {
        x.(w.componentOf1)
}

fun claim [x: World.ServiceCustomerCommitment,w: World] : set World.HiredProviderClaim {
        x.(w.counterpartof)
}

fun interactions [x: World.ServiceCustomerCommitment,w: World] : set
World.HiredProvider_ServiceCustomer_Interaction {
        x.(w.motivatedby1)
}

fun customer_actions [x: World.ServiceDelivery2,w: World] : set World.ServiceCustomerAction {
        x.(w.componentOf2)
}

fun cl_hiredprovider1 [x: World.SpecializedServiceAgreement,w: World] : set
World.ClaimedHiredProvider {
```

```
        x.(w.isboundto)
}

fun serviceoffering3 [x: World.ServiceOfferingCommitment,w: World] : set World.ServiceOffering {
        (w.componentOf7).x
}

fun s_serviceagreement1 [x: World.ServiceCustomerCommitment,w: World] : set
World.SpecializedServiceAgreement {
        (w.componentOf6).x
}

fun provider_commitments [x: World.HiredProvider_ServiceCustomer_Interaction,w: World] : set
World.HiredProviderCommitment {
        (w.motivatedby2).x
}

fun serviceoffering4 [x: World.ServiceOfferingClaim,w: World] : set World.ServiceOffering {
        (w.componentOf8).x
}

fun customer [x: World.ServiceCustomerAction,w: World] : set World.CommittedServiceCustomer {
        (w.performedby3).x
}

fun cl_hiredprovider [x: World.HiredProviderClaim,w: World] : set World.ClaimedHiredProvider {
        x.(w.inheresin)
}

fun offer [x: World.TargetCustomerCommunity,w: World] : set World.ServiceOffering {
        (w.offeredto).x
}

fun servicenegotiation [x: World.ServiceAgreement,w: World] : set World.ServiceNegotiation2 {
        (w.resultsin).x
}

fun claim2 [x: World.ServiceOfferingCommitment,w: World] : set World.ServiceOfferingClaim {
        x.(w.counterpartof2)
}

fun customers [x: World.HiredProvider_ServiceCustomer_Interaction,w: World] : set
World.ServiceCustomer {
        (w.performedby1).x
}

fun provider [x: World.HiredProviderAction,w: World] : set World.HiredServiceProvider {
        (w.performedby).x
}

fun serviceoffering1 [x: World.ServiceNegotiation2,w: World] : set World.ServiceOffering {
        (w.refersto).x
}

fun provider_actions [x: World.ServiceDelivery2,w: World] : set World.HiredProviderAction {
        x.(w.componentOf)
}

fun provider4 [x: World.ServiceOfferingClaim,w: World] : set World.ServiceProvider {
        x.(w.externallydependenton4)
}

fun cl_hiredprovider2 [x: World.ServiceCustomerCommitment,w: World] : set
World.ClaimedHiredProvider {
        x.(w.externallydependenton)
}

fun hiredprovider2 [x: World.ServiceCustomerClaim,w: World] : set World.HiredServiceProvider {
        x.(w.externallydependenton3)
}
```

```
fun community2 [x: World.ServiceOfferingCommitment,w: World] : set World.TargetCustomerCommunity {
	x.(w.externallydependenton5)
}

fun customers_commitments [x: World.HiredProvider_ServiceCustomer_Interaction,w: World] : set World.ServiceCustomerCommitment {
	(w.motivatedby1).x
}

fun interactions1 [x: World.HiredProviderCommitment,w: World] : set World.HiredProvider_ServiceCustomer_Interaction {
	x.(w.motivatedby2)
}

fun actions [x: World.HiredProviderCommitment,w: World] : set World.HiredProviderAction {
	x.(w.motivatedby)
}

fun serviceoffering [x: World.ServiceAgreement,w: World] : set World.ServiceOffering {
	(w.conformsto).x
}

fun members [x: World.TargetCustomerCommunity,w: World] : set World.TargetCustomer {
	x.(w.memberOf)
}

fun co_servicecustomer1 [x: World.SpecializedServiceAgreement,w: World] : set World.CommittedServiceCustomer {
	x.(w.isboundto1)
}

run { } for 10 but 3 World, 7 int

fact SD01 {
	all w: World | all self: w.ServiceDelivery2 | ((((#self.provider_actions[w])).plus[(#self.customer_actions[w])]).plus[(#self.interactions2[w])] >= 1)
}

fact SD02 {
	all w: World | all self: w.HiredProviderCommitment | (all action: self.actions[w] | (self.hiredprovider[w] = action.provider[w]))
}

fact SD03 {
	all w: World | all self: w.ServiceCustomerCommitment | (all action: self.actions1[w] | (self.co_servicecustomer[w] = action.customer[w]))
}

fact SD04 {
	all w: World | all self: w.ServiceCustomerCommitment | (all interaction: self.interactions[w] | (self.co_servicecustomer[w] in interaction.customers[w]))
}

fact SD05 {
	all w: World | all self: w.HiredProviderCommitment | (all interaction: self.interactions1[w] | (interaction.provider1[w] = self.hiredprovider[w]))
}

fact SD06 {
	all w: World | all self: w.HiredProvider_ServiceCustomer_Interaction | (((#self.provider_commitments[w])).plus[(#self.customers_commitments[w])] >= 1)
}

fact SD07 {
	all w: World | all self: w.ServiceDelivery2 | (all action: self.provider_actions[w] | (action.provider[w] = self.serviceagreement[w].hiredprovider1[w]))
}

fact SD08 {
	all w: World | all self: w.ServiceDelivery2 | (all action: self.customer_actions[w] |
```

```
(action.customer[w] in self.serviceagreement[w].servicecustomer1[w]))
}

fact SD09 {
	all w: World | all self: w.ServiceDelivery2 | (all interaction: self.interactions2[w] |
(interaction.provider1[w] = self.serviceagreement[w].hiredprovider1[w]))
}

fact SD10 {
	all w: World | all self: w.ServiceDelivery2 | (all interaction: self.interactions2[w] |
(interaction.customers[w] in self.serviceagreement[w].servicecustomer1[w]))
}

fact SN01 {
	all w: World | all self: w.ServiceAgreement | (self.serviceoffering[w] =
self.servicenegotiation[w].serviceoffering1[w])
}

fact SN02 {
	all w: World | all self: w.ServiceNegotiation2 | (self.provider2[w] !in self.customers1[w])
}

fact SN03 {
	all w: World | all self: w.ServiceNegotiation2 | (self.provider2[w] =
self.serviceoffering1[w].provider3[w])
}

fact SN04 {
	all w: World | all self: w.ServiceNegotiation2 | (all customer: self.customers1[w] | (customer in
self.serviceoffering1[w].community[w].members[w]))
}

fact SN05 {
	all w: World | all self: w.ServiceAgreement | (all customer: self.servicecustomer1[w] |
(customer in self.servicenegotiation[w].customers1[w]))
}

fact SN06 {
	all w: World | all self: w.ServiceAgreement | (self.hiredprovider1[w] =
self.servicenegotiation[w].provider2[w])
}

fact SNSR01 {
	all w: World | all self: w.HiredProviderCommitment | (self.hiredprovider[w] =
self.serviceagreement1[w].hiredprovider1[w])
}

fact SNSR02 {
	all w: World | all self: w.HiredProviderCommitment | (self.hiredprovider[w] =
self.claim1[w].hiredprovider2[w])
}

fact SNSR03 {
	all w: World | all self: w.HiredProviderCommitment | (self.servicecustomer[w] in
self.serviceagreement1[w].servicecustomer1[w])
}

fact SNSR04 {
	all w: World | all self: w.HiredProviderCommitment | (self.servicecustomer[w] =
self.claim1[w].servicecustomer2[w])
}

fact SNSR05 {
	all w: World | all self: w.HiredProviderCommitment | (self.serviceagreement1[w] =
self.claim1[w].serviceagreement5[w])
}

fact SNSR06 {
	all w: World | all self: w.ServiceCustomerCommitment | (self.co_servicecustomer[w] in
self.s_serviceagreement1[w].co_servicecustomer1[w])
}
```

```
fact SNSR07 {
	all w: World | all self: w.ServiceCustomerCommitment | (self.cl_hiredprovider2[w] = self.s_serviceagreement1[w].cl_hiredprovider1[w])
}

fact SNSR08 {
	all w: World | all self: w.ServiceCustomerCommitment | (self.s_serviceagreement1[w] = self.claim[w].s_serviceagreement[w])
}

fact SNSR09 {
	all w: World | all self: w.ServiceCustomerCommitment | (self.cl_hiredprovider2[w] = self.claim[w].cl_hiredprovider[w])
}

fact SNSR10 {
	all w: World | all self: w.ServiceCustomerCommitment | (self.co_servicecustomer[w] = self.claim[w].co_servicecustomer2[w])
}

fact SOSR01 {
	all w: World | all self: w.ServiceOfferingCommitment | (self.provider5[w] = self.serviceoffering3[w].provider3[w])
}

fact SOSR02 {
	all w: World | all self: w.ServiceOfferingCommitment | (self.community2[w] = self.serviceoffering3[w].community[w])
}

fact SOSR03 {
	all w: World | all self: w.ServiceOfferingCommitment | (self.serviceoffering3[w] = self.claim2[w].serviceoffering4[w])
}

fact SOSR04 {
	all w: World | all self: w.ServiceOfferingCommitment | (self.community2[w] = self.claim2[w].community1[w])
}

fact SOSR05 {
	all w: World | all self: w.ServiceOfferingCommitment | (self.provider5[w] = self.claim2[w].provider4[w])
}
```

Annex A The Unified Foundation Ontology (UFO)

This annex presents UFO focusing on its three main parts: UFO-A, UFO-B, and UFO-C. It addresses the UFO's fragments that are relevant for this thesis. Also, the OntoUML ontology modeling language (which incorporates the ontological distinction of UFO) is briefly presented.

A.1 Introduction

The Unified Foundational Ontology (UFO) (GUIZZARDI, 2005a)(GUIZZARDI; FALBO; GUIZZARDI, 2008)(GUIZZARDI et al., 2013)(GUIZZARDI, 2006) is constituted by three main parts, as illustrated by Figure 65.

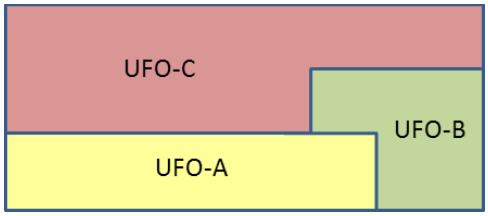

Figure 65 - The three main parts of UFO: UFO-A, UFO-B, and UFO-C.

UFO-A is an an ontology of endurants (objects) (GUIZZARDI, 2005a), UFO-B, an ontology of events (perdurants) (GUIZZARDI; FALBO; GUIZZARDI, 2008), and UFO-C (GUIZZARDI; FALBO; GUIZZARDI, 2008) (GUIZZARDI, 2006), an ontology of social entities built on the top of UFO-A and UFO-B. All of these three parts follow the fundamental distinction in UFO between *individuals* (as entities that exist in reality and possess a unique identity, e.g., Pelé, and Maracanã) and *universals* (as patterns of features that can be realized in a number of different individuals, e.g., the kinds Person, and Soccer Stadium) (GUIZZARDI, 2005a). The fragments of these parts that are relevant for this thesis are addressed in Sections A.2, A.3, and A.4.

OntoUML is an UML profile designed for incorporating the ontological distinctions of UFO (UFO-A and UFO-B). Thus, OntoUML is considered a well-founded ontology modeling language, and incorporates such distinctions in UML class diagram by means of stereotypes. Fragments of the meta-model of this language, as well as an illustrative example are presented in Section A.5.

A.2 UFO-A: An Ontology of Endurants

UFO-A is an ontology of *endurants* whose patterns of features are called *endurant universals* (GUIZZARDI, 2005a). Figure 66 presents a fragment of UFO-A that focuses on categories of endurants (individuals).

Endurants are individuals that are wholly present whenever they are present (differently of *events* that are composed of temporal parts), and can be divided into substantials and moments. *Substantials* are existentially independent endurants (e.g., a person, a car). *Moments* are individuals that can only exist in other individuals, and, thus, they are existentially dependent on their bearers (e.g., a person's headache, a covalent bond between atoms) (GUIZZARDI, 2005a).

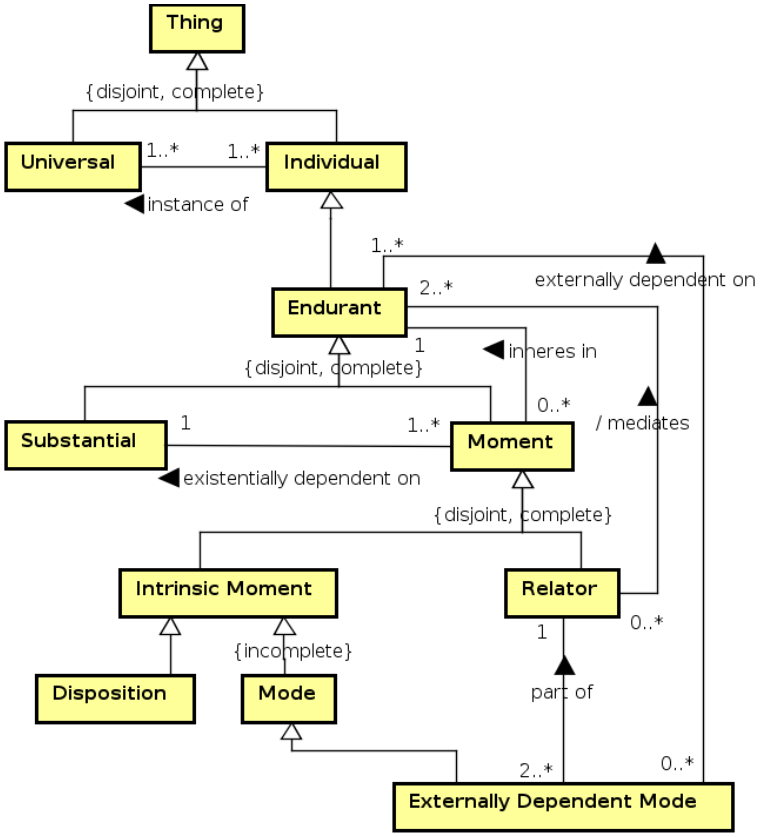

Figure 66 – A fragment of the hierarchy of endurants in UFO-A.

Intrinsic moments are dependent on one single individual (e.g., an apple's color). *Modes* are intrinsic moments that are not directly measurable (e.g., John's desires, intentions, perceptions, symptoms, skills) (GUIZZARDI, 2005a). Following (HEIL, 2005) (MUMFORD, 2003), *dispositions* in UFO are intrinsic moments (e.g., the fragility of a glass, and the capacity of performing an specific behavior) that are manifested in particular situations through the occurrence of certain events, and that can also fail to

be manifested. Take for example, the disposition of a magnet to attract metallic material. The magnet has this disposition even if it is never manifested, e.g., because the magnet was never close to any magnetic material. A person could also have the disposition of making coffee, but has never manifested it. Nonetheless, the magnet and the person can certainly be said to possess that intrinsic property.

Relators are moments that existentially depend on two or more endurants (e.g., an employment, an enrollment, a medical treatment, a marriage) (GUIZZARDI, 2005a). For example, consider that John and Mary are married. In this case, the relator (their marriage) aggregates all externally-dependent modes that they acquire by virtue of participating in this relation (e.g, all commitments and claims towards each other) and that share the same foundational event (in this case the wedding event). In this example, *John* bears responsibilities and rights towards Mary. As counterpart, *Mary* bears the properties she acquires by being married with John.

Besides the endurants (individuals), UFO-A also has a hierarchy of endurant universals, whose a fragment is presented by Figure 67.

In UFO-A, *substantial universal* and *moment universal* are kinds of universals whose individuals are, respectively, substantial individuals and moments (GUIZZARDI, 2005a). Concerning the *substantial universal* hierarchy, *sortal universals* are substantial universals that carry a principle of identity for their individuals (e.g., Apple, Person, Student). The specialization of *sortal universal* is based on a metaproperty called rigidity. A universal is *rigid* if it necessarily applies to its instances in every possible world (e.g., Apple, Person). *Kinds* are rigid sortal universals that provide a principle of identity for substantial individuals that instantiate them (e.g., Person). *Collective Universals* are rigid universals that represent collections of individuals with uniform structure (e.g., deck of cards, a forest, a group of people, a pile of bricks). This universal provides a principle of identity for the instances of that collection (but not for every individual in the collection), which can be intentional or extensional (GUIZZARDI, 2005a).

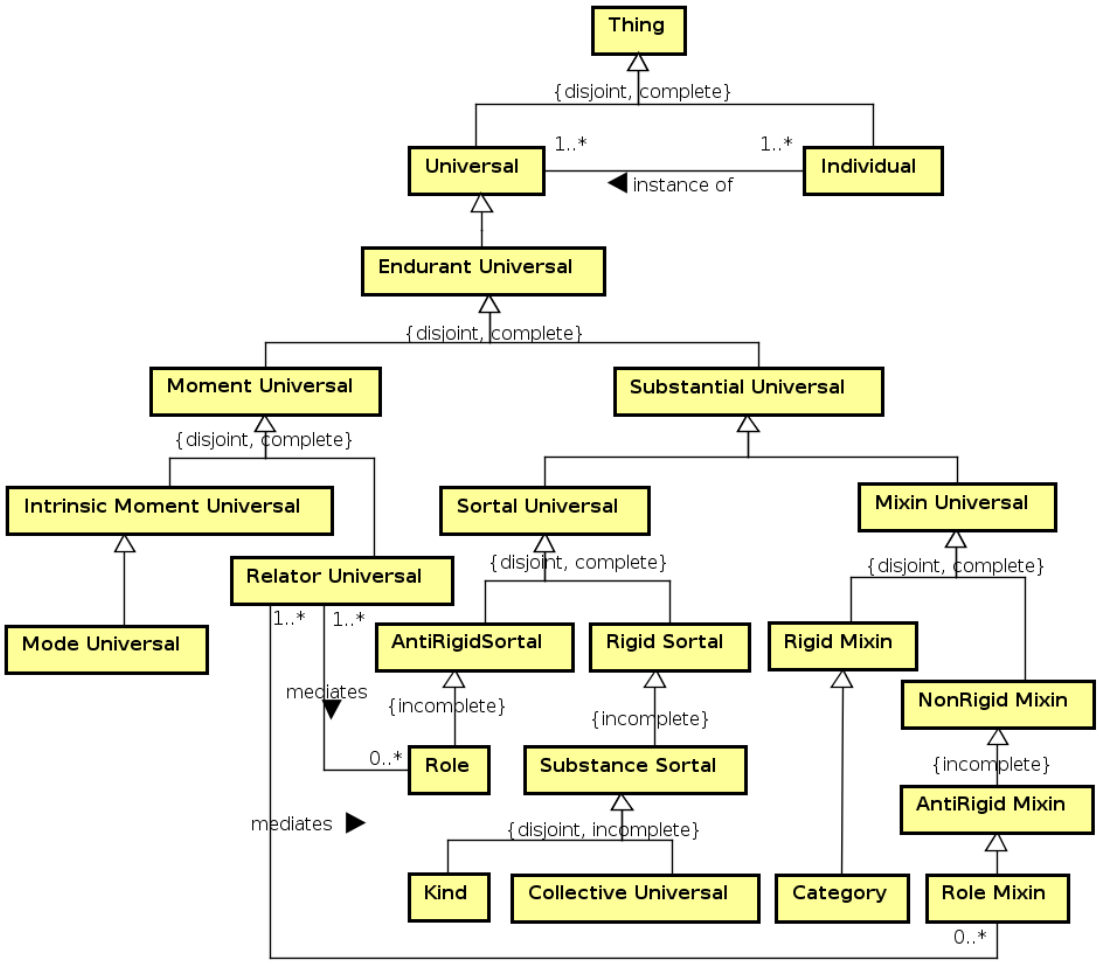

Figure 67 – A fragment of the hierarchy of universals in UFO-A.

In contrast to rigid universals, a universal is *anti-rigid* if it does not apply necessarily to all its instances. For example, an individual *x*, which is an instance of the universal Student in a world *w1* can cease to instantiate this universal in another world *w2* without ceasing to exist as the same individual (i.e., as the same Person). *Roles* are anti-rigid and relationally-dependent sortal universals (e.g., Student) (GUIZZARDI, 2005a). This means that roles are played by an object whenever there is a relator connecting it to other objects.

Mixin universals are substantial universals that represent an abstraction of properties that are common to multiple disjoint kinds and, therefore, do not carry a unique principle of identity for their instances (e.g., Living Entity). *Category* represents a rigid and relationally independent mixin universal that aggregates essential properties that are common to different kinds (e.g., Intelligent Agent). *Role Mixin*, in turn, represents an anti-rigid and externally-dependent non-sortal universal, which aggregates properties that are common to different roles.

A.3 UFO-B: An Ontology of Events (Perdurants)

UFO-B is an ontology of events (perdurants) whose patterns of features are event universals (GUIZZARDI; FALBO; GUIZZARDI, 2008). Figure 68 presents a fragment of UFO-B that addresses event individual as well as event universal.

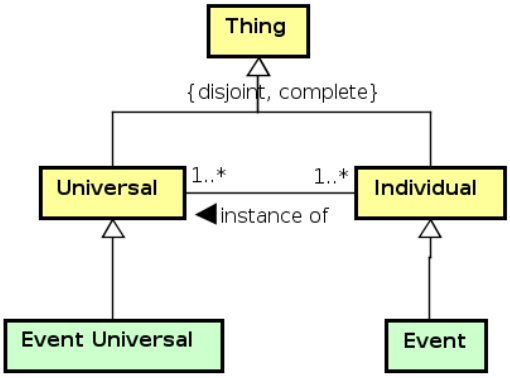

Figure 68 – A fragmento of UFO-B: event individual and event universal.

As opposed to endurants, *events* are individuals composed of temporal parts. They happen in time, in the sense that they extend in time and accumulate temporal parts (e.g., a conversation, a business process). Whenever an event is present, it is not the case that all its temporal parts are present. *Event universals* are patterns of features that can be realized in a number of different events (GUIZZARDI; FALBO; GUIZZARDI, 2008). Events can be complex or atomic. *Atomic events* have no proper parts. *Complex events* are aggregations of at least two disjoint events (GUIZZARDI; FALBO; GUIZZARDI, 2008). The notion of *foundation* as a type of *historical dependence* (GUIZZARDI, 2005b) (FERRARIO; OLTRAMARI, 2004) offers an important grounding for associating events to relators, since relators are founded by events. For example, the *marriage* relator is founded on a particular *wedding* event (GUIZZARDI, 2005b). In this work, this notion is important because it offers means to explain the association between events in a service life cycle, and the relators created among service participants, as discussed in Chapter 3.

A.4 UFO-C: An Ontology of Social Entities

UFO-C is an ontology of social entities that specializes UFO-A and UFO-B (GUIZZARDI; FALBO; GUIZZARDI, 2008) (GUIZZARDI, 2006).

A basic distinction in UFO-C is related to agents and (non-agentive) objects. *Agents* are agentive substantial individuals that are classified as *physical agents* (e.g., a

person) or *social agents* (e.g., an organization, a society). *Objects* are non-agentive substantial individuals that are classified in *physical objects* (e.g., a book, a table) and *social objects* (e.g., money, language). A *normative description* is a type of social object that defines one or more rules/norms recognized by at least one social agent, and that can define nominal universals, such as social moment universals (e.g., social commitment types), social objects (e.g., the crown of the King of Spain) and *social roles* (e.g., president, or pedestrian). Examples of normative descriptions include contracts in general, but also sets of directives on how to perform actions within an organization. A *plan description* is a special type of normative description that describes complex action universals (complex plans) (BRINGUENTE; FALBO; GUIZZARDI, 2011) (e.g., process, and guidelines). Figure 69 presents a fragment of UFO-C that focuses on the distinction between agents and objects, and on the definition of normative description.

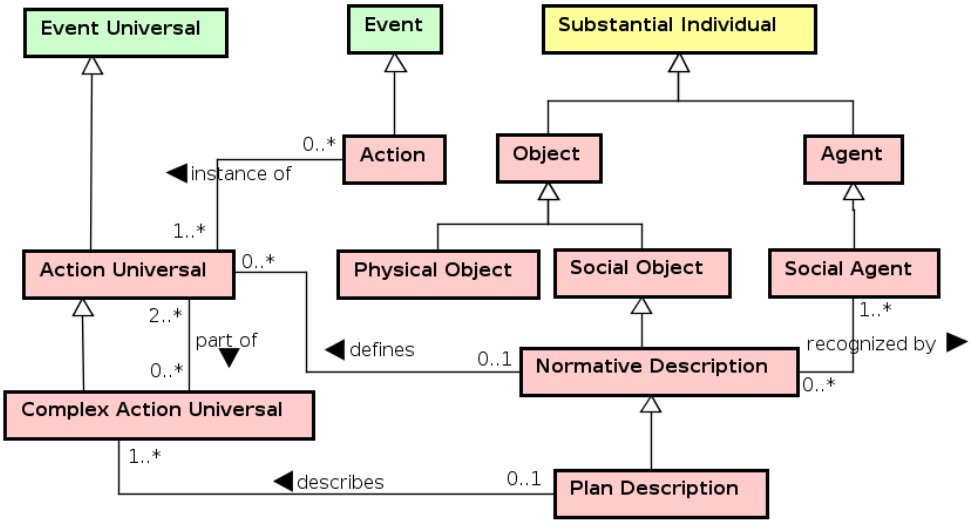

Figure 69 – A fragment of UFO-C: Agent, Object, and Normative Description.

Figure 70 presents a fragment of UFO-C that focuses on types of intentional moments. *Agents* are substantials that can bear special types of modes named *intentional moments*. In this case, intentionality refers to the capacity of some properties of certain individuals to refer to possible situations in reality. Thus, intentional moments have a propositional content (*proposition*), which is an abstract representation of a class of situations referred by that intentional moment.

Intentional moments inhere in agents and can be mental or social. Mental moments are specialized in intentions (internal commitments), beliefs, and desires.

Belief can be justified by situations in reality (e.g., my belief that the Moon orbits the Earth). Desires and intentions can be fulfilled or frustrated. Whilst a desire expresses a will of an agent towards a state of affairs in reality, intentions are desired state of affairs for which the agent commits to pursuing (SEARLE, 2000)(CASTELFRANCHI, 1995). Intentions cause the agent to perform actions. Actions are types of events that can be complex or atomic.

Communicative acts (a speech act such as inform, ask or promise in the sense of (SEARLE, 2000)) are types of atomic actions (GUIZZARDI; FALBO; GUIZZARDI, 2008). Interactions are types of complex actions composed of action contributions from different agents. Social moments are types of intentional moments that are created by social actions (e.g., an interaction composed of the exchange of communicative acts).

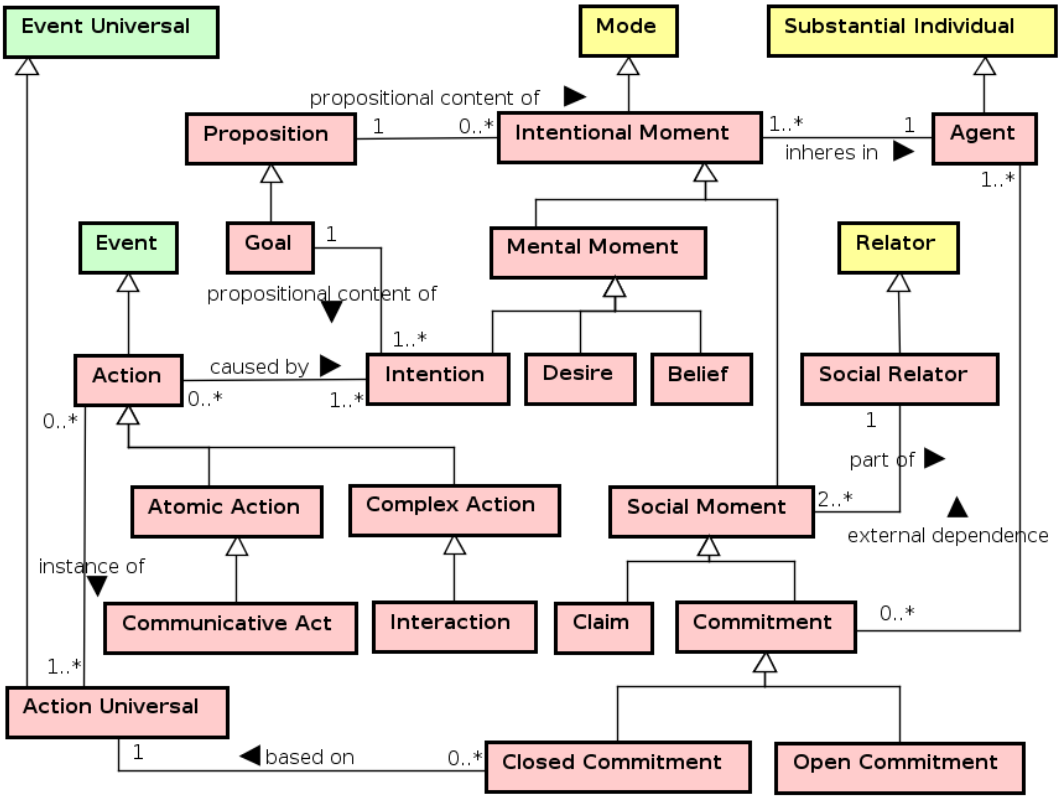

Figure 70 – A fragment of UFO-C: action, mental moment and social moment.

Social commitments and social claims are types of social moments. Social relators are relators composed of one or more pairs of social commitments and social claims (BRINGUENTE; FALBO; GUIZZARDI, 2011). As with all relators, social relators are founded in particular events. What "counts as" the founding event of a social relator, as well as the social responsibility and claims entailed by that social relator, depends on a normative description valid in that social context. For example, a particular

constitution can define the responsibility and claims entailed by the marriage relator type, and that a particular speech act (e.g., “I hereby declare you husband and wife”) uttered by a Judge in a specific context (e.g., in the presence of witnesses) is sufficient for the creation of a relator of that type.

As an additional example, suppose that “John” rents a car at a car rental office. When signing a business contract, “John” performs a communicative act (a promise). This act creates a commitment (a social commitment towards that organization) to return the car in a certain state. It also creates a social claim of the rental car office towards “John” with respect to that particular propositional content. Commitments and claims always form a pair that refers to a unique propositional content (GUIZZARDI, 2006).

Commitments are classified in open and closed. In an *open commitment*, the agents responsible for fulfilling the commitment are free to define how they will do this. In a *closed commitment*, the agent must fulfill the commitment by performing an action that is an instance of a plan defined by another agent (GUIZZARDI, 2006).

A.5 OntoUML

OntoUML (GUIZZARDI, 2005a) is a well-founded ontology modeling language that incorporates some ontological distinctions offered by UFO in UML class diagram profile. By that, OntoUML represents an important attempting to incorporate ontological foundations in an ontology representation language. Thus, OntoUML can be considered an *ontological level* modeling language (GUIZZARDI, 2007).

Figure 71 and Figure 72 present two fragments of OntoUML’s meta-model. The former focuses on the elements of the language (specializations of “Class”) used to map the hierarchy of *endurant universals* and *event universals* in UFO. The latter, in turn, focuses on the elements (specializations of “Relationship”) used to map the hierarchy of *relation universals* in UFO. Each leaf-element (in gray) in the hierarchies is represented as a stereotype in UML Class diagram.

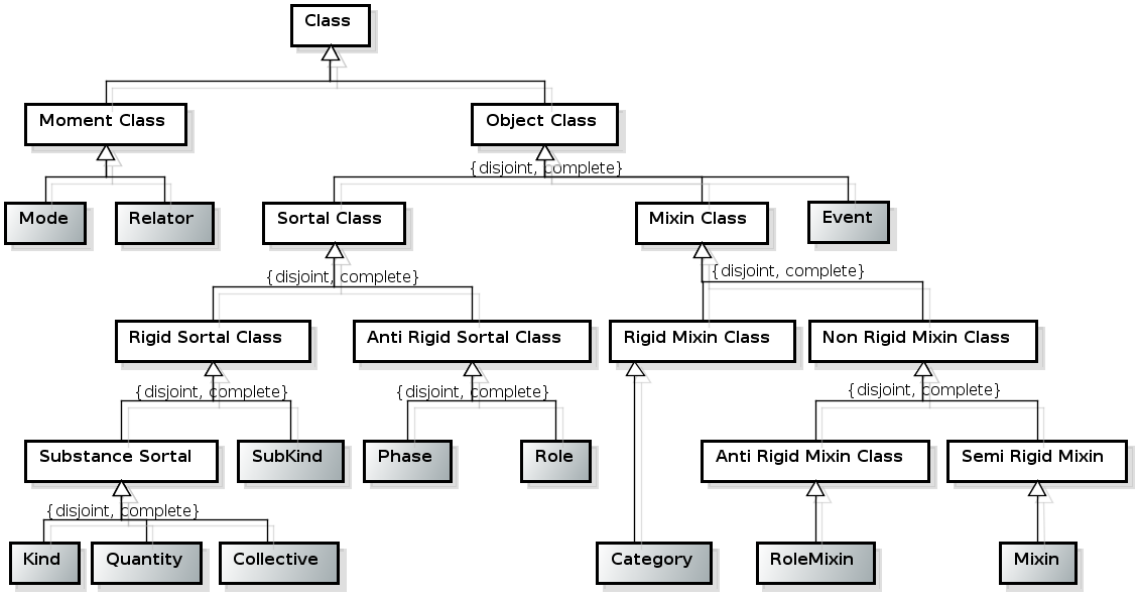

Figure 71 - A fragment of OntoUML metamodel: Class hierarchy (based on (GUIZZARDI, 2005a)).

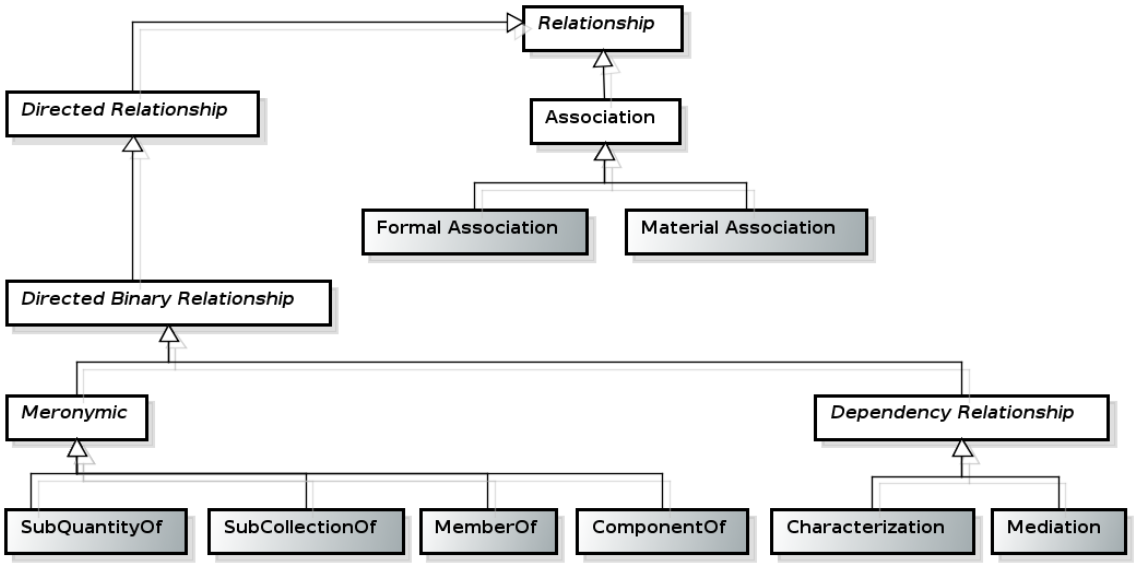

Figure 72 - A fragment of OntoUML metamodel: Relationship hierarchy (based on (GUIZZARDI, 2005a)).

In order to exemplify the use of OntoUML, Figure 73 presents a fragment of an ontology about the domain of "university". In this ontology, **Person** represents a *kind* that is specialized in two *subkinds* **Man** and **Woman**. So, an instance of **Person** must be a **Man** or a **Woman**. A **Person**, when enrolled in an **Active University** and in a **Course** of this university, is said to play the *role* of **Student**. The material relation "is enrolled in" between **Student** and **Active University** is mediated by the *relator* **Enrollment**. An **Active University** is a *role* played by a university when this university has, at least, one

Enrollment. Also, **Pedagogic Project** is a *relator* that mediates the relation between a **Course** and a **Grid of Subjects**, which is a *collective* of **Subjects**.

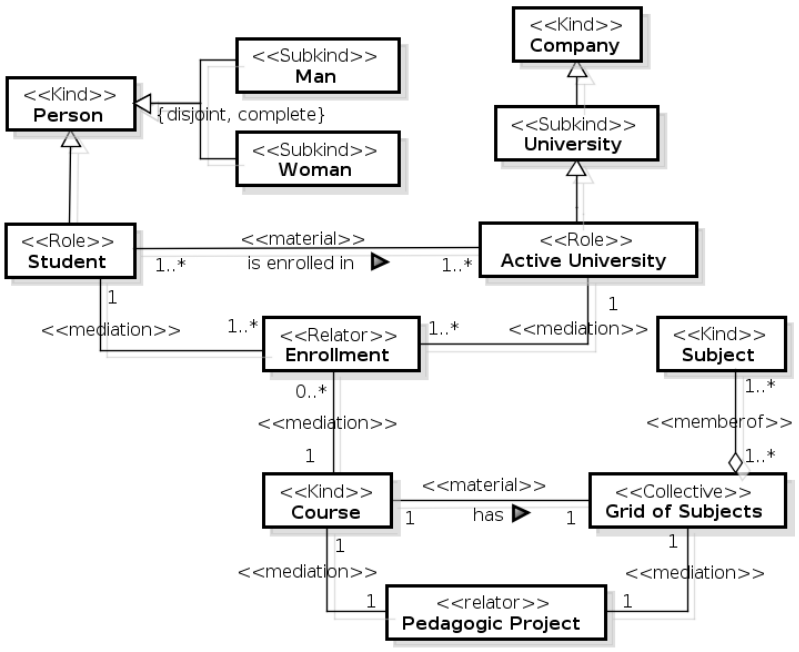

Figure 73- An example of a domain ontology in OntoUML.

Finally, OntoUML is an ontology modeling language that focuses on theoretical soundness and high expressiveness, instead of on computational properties (e.g., computational efficiency and tractability). Therefore, OntoUML is suitable for the conceptual phases of the ontological engineering process, when reference ontologies are built. If necessary, however, from an OntoUML model a number of operational ontologies, with focus on computational properties, can be generated, e.g., through model transformations, as presented in (ZAMBORLINI; GUIZZARDI, 2010).