Ontology-Based Analysis of e-Service Bundles for Business Networks[1]

Abstract

To satisfy complex consumer needs, services increasingly are composed out of more elementary services offered by different suppliers, thereby allowing each supplier to focus on his core competences. When business developers engage in developing such multi-enterprise service bundles, the number of possible ways to do business soon increases, and hence a need arises for automated support for reasoning about commercially viable service bundles and related business models, implying also a selection of partners that provide these services. We present a conceptual, model-based, framework for automating such reasoning, and a four-step method for using this conceptual framework to perform a financial feasibility analysis of business models for cross-organizational service bundles. We discuss and exemplify theoretical fundaments for such a method, using a real-life case study in the energy sector.

KEYWORDS AND PHRASES: electronic services, design methodology, business modeling, ontology theory, business networks, new service development.

1 Introduction

Enabled by Internet technology and its diffusion, enterprises increasingly form networks to satisfy complex customer needs, so that every enterprise can utilize its core competences. Well known examples include IKEA [28] and Cisco Systems [35], but also in other industries this trend is inevitable. Such networks are often referred to as business networks, business webs [35], value constellations [28] or smart business networks [39].

In the past few years, a number of approaches have been proposed for constructing and

[1] This article is an extended and revised version of a paper in the proceedings of the 17th Bled eCommerce Conference [4].

evaluating networked business models in a model-based way [30, 29, 2, 11, 10]. "Modeling" refers here to expressing a business network in a more formal way than just informal text, so that computer-supported reasoning becomes possible (e.g., about consistency and profitability), and that a smooth transition can be made to information system design for such networks. Moreover, in the context of business network design, a model-based approach helps develop cross-organizational e-business initiatives, first by creating a shared understanding of the network, and second by providing a foundation for feasibility studies, e.g., a profitability assessment for all enterprises participating in the network. Another contribution of model-based approaches is to manage complexity. Business networks tend to become complex, given the number of enterprises participating, the variety of goods and services offered by each enterprise, let alone the number of bundles of goods and services that can be relevant. Structured modeling approaches can help cope with this complexity and enable automated reasoning support.

Our study partner, the electric utility TrønderEnergi AS from Trondheim, Norway, understood that structured, computer-based techniques can help reduce the complexity of the service offerings of their constellation, and joined forces with us in employing computer-based techniques to perform a business analysis and develop possible future business models. The question at hand was to find financially feasible service bundles that are of interest to customers, where 'interest to customers' implies that there is a fit between customer needs and the service outcomes of a service bundle. The main driver for this question is that electricity is a commodity; in order to differentiate from competitors, other services are needed that can be bundled with plain electricity supply.

Software-aided reasoning processes can support business developers in the selection of services to include in service bundles, implying also a selection of partners to work with. To put it differently, given a set of potential services to include in a new business model and dependencies between these services, we need tools to design (configure) one or more service bundles, and to provide information for assessing the pros and cons of service bundles. Then the business analysis can continue by calculating profitability of these service bundles. Designing such service bundles is in fact configuring a network organization. The configuration process takes into consideration inherent dependencies between available services and possibly other requirements related to service properties as price or quality.

In this article we present a model-based approach for designing and evaluating business models for network organizations offering service bundles. Our research approach, described in Section 2.3, employs *ontologies* to describe business domains formally. Ontologies are formal conceptualizations of a real-world domain such that they have a computational representation that is fit for automated reasoning [7].

To this end, we present *Serviguration*, a computational ontology for service bundling [2], and use it together with e^3value, a computational ontology for business models [11]. Using software tools that are based on these ontologies, we provide a four-step method for software-aided design and evaluation of cross-organizational business models for offering complex service bundles. We present an extensive study in which we combine the two ontologies to perform such an analysis for TrønderEnergi AS. Our study in the energy sector has a dual role. From a business perspective, the goal of TrønderEnergi AS was to enhance understanding of possible new business models for bundling electricity supply with other services. From a research perspective, the study was used for ontology development and validation, to contribute to the knowledge base of foundations and methodologies in IS research.

The rest of this article is structured as follows. In Section 2 we present the main output of our research, the *Serviguration* service ontology, we shortly present the e^3value ontology, and we discuss our research approach. In Section 3 we present our case study domain: energy services. Section 4 shortly presents a four-step method for business analysis. The four steps are discussed in detail, using the example of energy services, in Sections 5 through 8. Finally, in Section 9 we discuss our conclusions.

2 Service and Value Ontologies

In information and computer science it is common practice to use *ontologies* to describe a domain formally. Ontologies are formal conceptualizations of a real-world domain such that they have a computational representation that is fit for automated reasoning. So, concepts used in reasoning are first-class citizens in ontologies. Another important feature of ontologies is that ontologies represent a shared view (by multiple stakeholders, e.g., by an industry) on a domain. Consequently, Borst et al. define ontology as "a formal specification of a shared conceptualization" [7]. Hence ontologies are formalizations of conceptual models, models that "describe some aspects of the physical and social world around us for purposes of understanding and communication" [26]. By capturing human knowledge and by describing it formally as a set of concepts and relations between concepts, ontologies facilitate automating reasoning processes that humans perform in their minds. Software, in its turn, can reason about knowledge only once it has been formalized.

Recent advances in computer science, namely international standards for knowledge representation on the Web such as RDFS (see http://www.w3.org/RDF/) and OWL (see http://www.w3.org/2004/OWL/), have made it possible to use ontologies for reasoning on the Internet in what is often referred to as the *Semantic Web* [6]. Although the way to the envisioned Semantic Web is still long, software can now reason online about domains that have been formalized by ontologies and expressed using Web-based knowledge representation standards. A main challenge in achieving this goal is how to formalize domains which are typically not well-structured or defined, in computational terms.

One such domain is services: economic activities, deeds and performances of a mostly intangible nature [13, 20, 41, 19]. In this article we present an ontology of services, that can be used by software to reason about how services can be combined into a service bundle, and how services (single ones, or bundles) satisfy customer needs and demands.

In Section 2.1 we present the *Serviguration* ontology for service bundling. In Section 2.2 we shortly review the e^3value ontology for business models design. Both ontologies are used in the rest of the article. Finally, in Section 2.3 we discuss our research method.

2.1 A Service Ontology for Service Bundling

2.1.1 Serviguration Service Ontology: Core Ideas

Serviguration is an ontology that describes services and constructs for service bundling. The following core ideas underlie our service ontology:

Distinguish between customer perspective and supplier perspective.

Customers typically use a different terminology and have a different view on their needs than suppliers [38]. For example, a remote control service to control the temperature at home via the Internet may be considered as an IT service by a service provider, but for the customer it provides flexibility and cost saving.

Customer centric bundle: a bundle of benefits.

Customers are typically not interested in products (goods or services) themselves, but in the benefits – the value – thereof [36, 21]. Kasper et al. write that “services can be defined as a bundle of benefits”, and add that “these benefits are mostly a combination of functional, efficiency and psychological qualities” [19, pg. 499]. Example benefits may be an experience (e.g., safety) or a capability (an ADSL service provides the capability to surf online). On account of these insights from service management and marketing literature, being the grounding of a service ontology, we match services with service requests based on the benefits that services deliver, rather than on functionality (as often done in computer science). Instead of searching for services that offer a functionality which can satisfy a given customer demand, we search for *service benefits* that can satisfy a customer demand. The process of designing customer need-driven service bundles is sketched in Figure 1; we termed it *Serviguration* for a reason that we will explain below. In brief, customers state their demands, which can (partly) be satisfied by a set of benefits (referred to as service outcomes). Services are described by their required inputs and by their service outcomes, i.e., customer benefits. Customer terminology (demands) is first transformed to supplier terminology (service outcomes). Because service outcomes are service descriptors, services that provide the requested service outcomes will satisfy a customer’s demand, and they therefore function as an initial solution (service bundle). The final service bundles are generated by applying business rules on this initial bundle.

******** Place Figure 1 approximately here *********

Service bundling as a configuration task.

Grönroos explains that a service is in fact “a package or bundle of different services, tangibles and intangibles, which together form the service” [13]. Thus, we regard a service as a bundle of small components, that together form a bigger component. Consequently, designing a service bundle is a constructive activity. From the knowledge systems literature it is known that such synthetic tasks can be reduced to more tractable tasks under certain assumptions on the knowledge structures of a domain [37, 34, 32]. In particular, configuration is a simpler constructive task, where predefined components are configured into a larger, complex component, based on the availability of a set of predefined connections, and associated parameters and constraints [25, 22, 14]. We describe services in accordance with the definition of components. Therefore, known configuration algorithms can be used to configure – or bundle – single (elementary) services. Our service ontology therefore enables representing the service bundling problem as a component configuration task, as studied in the knowledge systems literature. Hence service bundling is termed *Serviguration*: service configuration.

In the rest of this section we describe constructs of the *Serviguration* service ontology. A detailed description of the concepts is provided in [2].

2.1.2 Two Perspectives on a Service Ontology

An ontology for service bundling has to include a supplier description of services and business rules for bundling services, as well as a customer description of his demands for which services provide satisfiers. We therefore divide our ontology into these two distinct yet related perspectives. The service value (customer) perspective describes a hierarchy of customer (abstract) needs, wants and (concrete) demands [20]. The service offering (supplier) perspective describes actual service offerings in accordance with the description of components in the knowledge systems literature. In [3] we focus on the customer perspective and on how customer demands can be used as a trigger for the actual service configuration – or bundling – task. In the current article we focus on the supplier perspective. Together, both articles present the process that is sketched in Figure 1.

2.1.3 Service Bundle Design: a Configuration of Business Activities

Serviguration comprises of constructs to describe services as economic activities, as well as constructs to describe services as components for configuration. It includes a visualization of models, next to the formal notation [2]. Visualizations serve as a means of communication, and have shown to be an invaluable tool in exploring business initiatives with business partners who are not accustomed to formal modeling techniques [29]. Figure 2 shows a legend for the service ontology notation that we shall use in the rest of this article. We explain the *Serviguration* concepts (in **bold**) using a simple example in Figure 2, visualizing a service bundle where a subscription for an ADSL service and for a digital TV service are combined for a special price.

Suppliers offer **service elements**. A service element can be a composite element (i.e., a service bundle), meaning that it is composed of smaller service elements. Once a smaller element represents a non-separable service element that is offered by one supplier, we call it an **elementary service element** (e.g., ADSL and Digital TV in Figure 2). A **service bundle** is a complex service element, including other (often elementary) service elements. An elementary service element is always offered by one supplier, while a service bundle may include service elements that are offered by various suppliers. Every service element has two **service interfaces**: an **input interface** (visualized on the left side of a service element) and an **outcome interface** (visualized on the right side of a service element). **Service inputs** and **service outcomes** represent the costs and benefits (financial and non-financial) of services. A service interface indicates that certain service inputs (sacrifices) are required for the provisioning of a service (e.g., fee), or that certain service outcomes are the benefits of (consuming) the service (e.g., Internet connectivity). Service inputs and service outcomes can be described qualitatively and quantitatively by **service properties**. A service interface consists of **service ports**, which represent that service inputs/outcomes are offered to and requested from the supplier’s environment. A **service link** between two service ports models that one service port uses a service input/outcome that another service port provides. Since a service link can only exist in a service bundle (service ports of a single service cannot be linked because a service cannot provide an input for itself), a service link also indicates that the service elements that it connects are part of a service bundle. A **service dependency** is a dependency relationship between two or more service elements. It represents a constraint on how these service elements may or may not be bundled. We define the following service dependencies for all service elements $x \in A$ and $n \in B$, where A, B are disjoint sets of service elements, such that A includes services x, y,. . . z , and B includes several services a, b,. . . n:

1. **Core/enhancing (A, B)**: n adds value to the main service x, and is not sold independently of service x [23, 13].
2. **Core/supporting (A, B)**: n is required for the provisioning of x, and is not offered independently of service x. Often n will not present value as such for customers (e.g., billing services). Grönroos refers to supporting services as facilitating services [13].
3. **Bundled (A, B)**: If customers wish to buy service element x, they are obliged to buy also n. Unlike the *core/supporting* dependency, here n may be offered independently, and the reason for the obligatory consumption of n may be some business logic, such as cost effectiveness reasons, marketing reasons or legislation.
4. **OptionalBundle (A, B)**: Two services x and n are offered separately, but also as a combination (bundle). This is referred to as *mixed bundling* in the literature [16, 27, 5]. Typically, bundling these service elements presents added value to suppliers (e.g.,

lower operational costs) and to customers (lower price).

5. **Substitute (A, B)**: Customers consider service n to satisfy them at least as much as service x (and possibly better). Very often the service outcomes of service x are also made available by service n.

6. **Excluding (A, B)**: If service element x is offered, service element n must not be offered, for example because x and n are competing services, and suppliers do not want to provide them together, or because legislation prohibits selling both services together.

******** Place Figure 2 approximately here *********

2.1.4 Discussion

First, we make a distinction between products and goods. The term product is often used to refer to goods, but in fact it is the supertype of both goods and services. ‘Product’ is defined as “the core output of any type of industry”; goods can be described as “physical objects or devices”, and “services are actions or performances” [23].

Second, our ontology focuses on services, and not on goods. A main difference between services and goods is the intangibility of services [13, 23, 41]. Goods are objects that one can hold in your hands and drop on the floor. Services, on the other hand, are of an intangible nature; they provide experiences and capabilities.

Even when a service is accompanied by a so-called physical evidence, for example a transportation ticket for a train trip, this physical evidence merely functions as an enhancer of customers’ impression, but it is not the essence of the service itself. Due to the intangibility of services, they cannot be described unambiguously by their physical properties, as is the case for goods. Instead, we describe them based on the exchange of economic values (costs and benefits) that they encapsulate. One may claim that also goods can be described similarly, so in fact our ontology is not a service ontology, but a product ontology. However, goods can be (and are being) described unambiguously by customers and suppliers using their physical properties, and hence the need for a different goods description does not arise.

Third, our work is not limited only to e-services, but applies also to offline services. Nevertheless, our work is of greater importance for e-services, since they require automating processes that may otherwise be performed in the minds of service personnel. Consequently, a prerequisite for e-services realization is that domain knowledge is conceptualized, formalized and made machine-interpretable. This is what we aim to achieve in our work.

Fourth, bundling is often driven by a business strategy. Our service ontology includes constructs for modeling business rules for bundling services, for example substitution or service enhancement. However, the ontology assumes that these rules – often based on strategic considerations – are known, and it does not model knowledge on reasons for such business rules, for example product differentiation, strategic alliances or cost effectiveness. Consequently, our ontology does not facilitate automating the reasoning about strategic considerations behind a service bundle. To achieve this, our ontology will have to be extended with an ontology for modeling business strategies, based on which the business rules that we use are derived.

2.2 A Value Ontology for Business Models

Services are provisioned and consumed in a network of enterprises. Such a network can be expressed using the e^3value ontology, which has been developed in previous research. The e^3value ontology [11, 12] can be used for designing and evaluating networked business models. As it assumes a value perspective on businesses, it describes who (which actor) does what and why, but not how (process perspective). This is an explicit design choice; to our experience, it is already sufficiently complex to decide about the enterprises involved, and what they offer each other of economic value. Consequently, e^3value abstracts away from how processes are actually put into practice, to reduce complexity. Figure 3 shows an educational example of a buyer who obtains goods from a seller and offers a payment in return. This can be modeled with the following e^3value constructs (in **bold**). **Actors** such as the buyer and seller are economically independent entities. Actors transfer **value objects** (payment, goods, or anything that at least one party perceives as worth money) by means of **value transfers**. For value objects, some actor should be willing to pay, which is shown by a **value interface**. A value interface models the principle of economic reciprocity: only if you pay, can you obtain the goods (and vice versa). A value interface consists of **value ports**, which represent that value objects are offered to and requested from the actor's environment. Actors may have a **consumer need**, which, following a path of dependencies, will result in the transfer of value objects. Transfers may be dependent on other transfers, or lead to a **boundary element**. In such a case, we do not consider additional transfers anymore.

******** Place Figure 3 approximately here *********

The e^3value ontology is a multi-actor approach for developing e-business models, taking into consideration the importance of economic value for all actors involved. Similar to the *Serviguration* ontology, it is based on the understanding that business activities involve an exchange of economic values between the involved actors. An e^3value business model does not provide a logical framework for reasoning about how to bundle services; it only states *that* such bundles exist and not *how* you can find them. Such a business model cannot describe in detail the variety and complicated nature of potential service bundles. Nor does it handle inherent dependencies between multiple services, such as 'service X may not be offered without service Y'. This information is necessary in order to configure feasible service bundles and to point out differences between and redundancies among service bundles. Thus, we need extra information on services, to facilitate a complete business model analysis of service offerings. Consequently, we suggest using the e^3value ontology with our *Serviguration* ontology that provides a conceptualization of special service characteristics, not present in a value ontology. This paves the way for dynamically building networking value constellations for satisfying service needs, based on catalogues of services that can be provisioned by suppliers. Our service ontology, presented in Section 2.1, provides a conceptualization of services, seen as components that require some inputs and provide some outcomes. Dependencies between services are also formalized, providing a mechanism for reasoning about which services must or may be part of a service bundle, and why. Using both ontologies together enables us to evaluate complex service offering scenarios.

2.3 Notes on Research Method

Hevner et al. [18] posit that the key point in design science research in information systems (IS) lies "in the identification of as yet undeveloped capabilities needed to expand IS into new realms not previously believed amenable to IT support". Studies we have performed in the health sector [8], in the energy sector [3] and in the music industry [31] show that a need exists for automated support – often online – for service bundling, a task that is traditionally performed in the minds of service personnel and business analysts/developers. Automation requires that knowledge be formalized, i.e., described in a machine-readable way. However, while service management and service marketing are mature areas of research in business schools, very limited effort has been devoted to formalizing this broad knowledge base with the aim to use such knowledge for the construction of information systems and software tools to support business networks in offering services via the world wide web. Service bundling, business design, business analysis and other typical business issues require understanding of the “ill-structured, fuzzy world of complex organizations” [1], and have been considered as unsuitable for automation because they are “highly unstructured and characterized by difficult-to-forecast activities linked by reciprocal rather then sequential dependencies” [33]. The research described in this article provides proof by construction that (1) service bundling can be automated, and (2) business analyses can be greatly supported by information systems.

To this end, our research does not attempt to develop new theories related to service bundling or business analysis. Instead, we rely on existing research, the fruits of decades of research in business schools, that captures a shared and accepted understanding on services and service bundling. Our contribution to the scientific knowledge base lies in the development of conceptual models – ontologies – that are the basis for developing information systems to solve organizational problems by designing and evaluating organizational artifacts such as business models and service bundles. We perform design and evaluation on a number of levels. First, our research is about *designing* formal conceptual models (ontologies), based on an existing knowledge base. We evaluate these models by applying them in various case studies in different industries and contexts, to ensure broad applicability. Second, our ontologies provide a conceptual model for the design of information systems to support solving organizational problems. Third, these information systems are tools in the hands of business analysts/developers, service personnel and end-customers, in the design and evaluation of desired organizational artifacts. In our case, these artifacts are service bundles and business models to realize bundled offerings.

As such, we employ formal ontology as a device for rigorous theory articulation. Ontologies as qualitative theories are formal conceptualizations of real-world domains such that they have a computational representation that is fit for automated reasoning [7, 15]. They represent a view that is shared by a community of practice in a domain. Being design research artifacts, ontologies should be generalizable. Hence, they reflect a consensual understanding of a domain, as typically found in textbooks. Ontologies do not attempt to express the latest debates in academic literature where there is no consensus. As far as the trade-off between relevance and rigor is concerned, the challenge of an ontology developer lies in making the ontology as compact as possible, to increase applicability, usability and understanding, and yet as complete as possible, to be a sound reflection of real-world conceptual structures shared within a domain.

The quality of an ontology is assessed in terms of computational adequacy, theoretical adequacy and empirical adequacy. Computational adequacy is proved when ontology-based software tools are designed and built. Theoretical adequacy (soundness, consistency, completeness) can partly be validated by computer tools, simulation and analysis, and partly by application in real-world situations. Empirical adequacy is validated in terms of whether the ontology is good enough to help solve organizational problems, and bring innovation in business and industry practice.

3 e-Services in the Energy Sector

3.1 Introduction to the Energy Sector

Since the deregulation of the electricity market in Norway in 1991, production and trade of electric energy have been liberalized, while the transmission and distribution are maintained as regulated monopolies. Nowadays, after evolving for 15 years of deregulation, the Norwegian power market has become mature. The electricity generation and supply sectors are characterized by a fierce competition, due to which the difference in electricity retail prices per kWh between different suppliers is diminishing. Also in other European countries power is shifting from suppliers to customers, and more and more end-user customers in Europe are able to choose a preferred electricity supplier.

Commercially, one of the disadvantages of the electricity product is that for power supply companies it is hard to distinguish themselves, due to the anonymous nature of this product: electricity from different suppliers is delivered according to the same standard, with the same physical characteristics, and is consumed through the same electricity socket in a customer's home. Therefore, companies face difficulties in competing with each other. Consequently, many suppliers are seeking for ways to improve marketing via differentiation of their product, to increase their market share. One way to differentiate is to offer additional services such as Internet access, (software) application service provisioning and home comfort management. Product differentiation can also be achieved by introducing substitutes as "green energy". Another way to improve marketing is to create more complex and elaborated electricity retail contracts, which are more beneficial to customers because they fit better to their needs. At the same time, choosing the best electricity contract becomes a demanding task for electricity consumers.

Many of the additional services can be ordered and provisioned via the Internet. Moreover suppliers can use existing infrastructure and/or available business processes to deploy such extra services, so bundling these services with the electricity product can be done with relatively modest effort. Experience however shows that the bundling of services without sound logical fundaments of the bundles design process and disregarding customers' demands may cause severe financial losses, as can be seen by the example of KanKan [9]. KanKan was launched on January 23rd 2001 as a new market offer of one of the biggest Distribution System Operators in Norway. It was marketed as an integrated bundle of services, including electricity supply and transmission, Smart Home features, home insurance, telephone and an ISP service. Despite the expectations and costly market campaigns, very few households showed interest in the new service offering. After several attempts to revise the concept, it was removed from the market [9, 24]. Several reasons for the failure were identified later; misunderstanding of customer needs and meeting them in product offers was the most visible one. Furthermore, the KanKan example highlights the necessity for evaluation methods for the feasibility of offering service bundles.

3.2 TrønderEnergi AS

Following the deregulation TrønderEnergi AS was reorganized into a holding company with various subsidiaries, including TrønderEnergi Kraft AS (electricity producer), two hydro power plants in Orkla and Driva, TrønderEnergi Nett AS (distribution system operator), Orkdal Fjernvarme AS (hazardous waste utilization), Loqal AS (broadband Internet), Nidit AS (IT services), SmartKonseptet (smart home solutions) and TrønderElektro AS (electrical installations). The company wants to use the new corporate structure in order to improve its position on the market. TrønderEnergi AS, however, is aware of potential financial risks related to implementation of a wrong bundling strategy. Although several of the subsidiaries within the holding company are economically independent (they are responsible for their own profit and loss), the corporate parent's interest is to utilize the various service offerings in order to offer service bundles where the electricity product (sold by one subsidiary) is differentiated by additional services (sold by other subsidiaries).

The example of KanKan along with several similar cases makes the corporate parent very cautious and skeptic when it comes to implementation of bundled offerings. We performed a thorough analysis of the services which can be offered by the holding company, including their pricing, possible composition of bundles, probable limitations and potential benefits. We also evaluated the financial feasibility of different compositions of bundles. The study presented in this article utilizes and exemplifies our service ontology, as well as a value ontology for business models design [11, 12].

4 A Four-step Method for Business Analysis

How to develop service bundles using the sketched ontologies? Our approach includes the following four steps:

1. Create an initial business model, using the e^3value ontology. The main purpose of this step is to elicit the actors involved and the elementary (single) services they offer each other. Thus the focus is not yet on (new) service bundles, but just on service providers and the single services that they offer. We identify these services in an initial model.
2. Describe the found elementary services in detail using the concepts of the *Serviguration* ontology. An important step is to express the service dependencies, which provide constraints for the bundling. Use software support to define (generate) service bundles by applying a configuration algorithm.
3. Reason about the identified service bundles using knowledge modeled in the *Serviguration* ontology, and choose a reduced set of *preferred* service bundles. This step requires knowledge that is typically possessed by domain experts.

4. Use the e3value ontology to assess profitability of the chosen service bundles.

In steps 1 and 4 we use the e3value ontology. The added value of using and applying the service ontology in steps two and three is that step four becomes manageable: we only assess profitability of service bundles that have been identified as interesting in steps 2 and 3. In the following sections we illustrate how these steps work out in a large scale case study.

******** Place Figure 4 approximately here *********

5 Step 1: A Value Model for Energy Services

A first step in creating a multi-enterprise business model is to understand the elementary services. In many cases, these services cannot be easily enumerated because stakeholders themselves do not have a clear view on such services. To this end, we construct an e3value model (see Figure 4) that shows the services enterprises are offering to customers, as well as what they request in return[2]. The construction of such a model involves eliciting services that exist in reality or that stakeholders want to develop. The e3value method has been discussed extensively in [11] and [12] so we only present the model itself. Due to model complexity and space limitations, we only present a fraction of the model here. Figure 4 shows a number of actors: an end-user customer and a number of actors, enterprises offering a range of services (e.g., TrønderEnergi Kraft AS and Smartkonseptet). Actors exchange *value objects*, objects of economic value such as money, electricity, the capability of remote control of devices such as heaters or coolers, and the capabilities for energy consumption control and temperature regulation.

[2] An e3value model can be visualized using the e3value software tool which can be downloaded from www.e3value.com.

Value objects are offered and requested via value ports. Ports are grouped into value interfaces, depicted by small rounded boxes surrounding two or more value ports. Such a value interface fulfills two modeling purposes. First, a value interface models economic reciprocity. For instance, it says that electricity is delivered only if a fee is paid in return, and vice versa. Second, a value interface may represent bundling, saying that two or more value objects are offered (or requested) only in combination. Figure 4 deliberately does not represent such a bundling case. In this article we discuss how to find such bundles for known elementary services.

The value model in Figure 4 shows actors, activities they perform, objects of value they offer and what they request in return, but not which meaningful bundles of value objects can be constructed. In a complex value model with many actors and value objects, finding these bundles is a far from trivial task. Although the notion of 'value interface' in e^{3}value models a bundle, the e^{3}value ontology cannot be used to reason about the various bundling options. To do this, we propose the *Serviguration* ontology that connects well to the e^{3}value ontology, with the aim to assist in finding such bundles specifically for services.

6 Step 2: A Service Model for Energy Services

The *Serviguration* service ontology formally describes a shared view on what services are with the aim to compose (or: configure) complex services out of more elementary services supplied by different enterprises.

Service elements are the building blocks of a service bundle. They represent what a supplier offers to its customers, in supplier terminology. It is what the business literature defines as service, an economic activity (performance) of mostly intangible nature.

Elementary services result from our initial value model, depicted in Figure 4. Value activities in the e^3value ontology correspond to service elements in the *Serviguration* ontology. Additionally, value objects in the e^3value ontology correspond to service inputs and service outcomes in the *Serviguration* ontology. We implemented these mappings of concepts in a software tool that uses the e^3value and *Serviguration* ontologies, so that the relevant constructs of an e^3value model can be exported to a *Serviguration* model and vice versa.

In this case study we modeled 14 elementary services that can be offered to customers in bundles that include energy supply: electricity supply, electricity transmission, hot water distribution (for room heating), broadband Internet access, IT services, sales and installation of electrical appliances (heat pump and energy control system, to reduce energy consumption and to regulate temperature), temperature remote control and more. Some services were modeled multiple times, as they can be provisioned in different forms (i.e., with different inputs and outcomes).

A list of services, described by their service inputs and by their service outcomes, is presented in Table 1 and visualized in Figure 5, where the symbols 'OB' mark a service dependency between the involved service elements: Optional Bundle. This service dependency can be interpreted as 'there is business logic in bundling these services, but they may also be provisioned independently' (other kinds of dependencies are supported also by the *Serviguration* ontology). Service inputs are depicted on the left hand side of a service; service outcomes are depicted on the right hand side thereof.

******** Place Table 1 approximately here *********

******** Place Figure 5 approximately here *********

Figure 5 is a visualization of seven of the fourteen services we modeled. Three service elements (electricity supply, electricity transmission and energy control system) were modeled twice because they are available for consumption in different forms, resulting in a set of ten services. This set serves us for the current discussion.

The ‘base’ e^3value model in Figure 4 does not consider dependencies between different service elements, and gives no guidelines on how to combine services into a service bundle. Theoretically, we could design and assess business models for any combination of one or more services, making the development of financial calculations for the model very time-consuming due to the multitude of possible solutions. With a set of n service elements, and assuming that a service bundle may include one or more service elements and (for simplicity) that no service is included more than once in a bundle, as many as 2^n-1 distinct service bundles are theoretically possible. Using a set of ten services, this yields 1023 possible bundles. Many of these bundles are not based on business logic, and therefore it is worthless to spend time analyzing their financial feasibility. The service ontology was applied to resolve this problem, narrowing the scope of our primary business model analysis:

1. Step 2 of our method: 1023 service bundles could theoretically be created. The service ontology identified those bundles that are driven by business logic, omitting all other theoretically possible bundles. We generated bundles for five different sets of bundling requirements (varying from very specific requirements to more general ones) that we matched with service benefits of the ten services in Figure 5. Using the service ontology and an ontology-based service configuration software tool, we reduced complexity to sets of only 2, 8 16, 17 and 28 service bundles for the five different

scenarios. Our software tool[3] was very helpful in this task, because generating these service bundles manually, with no tool support, is an error prone task.

2. Step 3 of our method: Providing knowledge on services, to facilitate reasoning about a choice between the bundles that were designed in step two.

Services of subsidiaries may be bundled due to various reasons, including an efficient use of common business processes, interdependencies between services and more. We modeled business rules concerning energy services as service dependencies (see Section 2.1.3), to be used as constraints in the software-aided service configuration. These are listed in Table 2. The most often used service dependency in this table is 'optional bundle', implying that there is business logic behind combining two services into a bundle but the separate services can also be consumed independently of each other. At the end of a business analysis, if a choice is made to market two services only as a package rather than also as elementary services, an 'optional bundle' dependency will be changed to a 'bundled' dependency, reflecting the new business decision. By applying service dependencies between service elements, we generated a set of service bundles, omitting bundles that have no business logic (from a supplier's point of view). Examples of possible bundles are:

1. Electricity supply and heat pumping
2. Electricity supply and hot water
3. Electricity supply, energy control system and remote control

No service dependency exists between the services *heat pumping* and *hot water*, because there is no business logic behind a bundle that includes only these two services (a heat pump

[3] A beta version of the software modeling and configuration tool can be downloaded from www.baida.nl/research/*Serviguration*.html.

reduces electricity consumption, but when hot water replaces all the use of electricity for heating, there is no electricity consumption to reduce). Consequently, this bundle is irrelevant, and was not generated. On the other hand, since a ‘bundled’ service dependency between *remote control* and *energy control system* requires that *remote control* not be sold without *energy control system*, all bundles with *remote control* but without *energy control system* are invalid, and were not generated. This knowledge does not exist in a value model.

******** Place Table 2 approximately here *********

******** Place Table 3 approximately here *********

7 Step 3: Service Ontology for Business Analysis

In step three we reason about theoretically feasible service bundles, and make a choice about preferred bundles. Our reasoning is based on the assumption that a supplier wishes to offer service bundles that satisfy its customer needs and demands. These are modeled in the service value perspective of our service ontology [3]. Table 3 presents a hierarchy of customer needs, wants and demands for the study at hand. We defined relations between customer demands and service outcomes, descriptors of available services (see Figure 6). These relations have the form of ‘IF demand X THEN service outcome Y’ and implicitly ‘IF service outcome Y THEN service element Z’, reflecting a logical correlation: service element Z provides service outcome Y, which can satisfy demand X. Demands and service outcomes can be described by quality criteria, such as productivity, availability and more.

******** Place Figure 6 approximately here *********

Applying these relations results in sets of service bundles per customer demand. Based on knowledge that the service ontology provides, business developers then reason about these bundles. Some bundles may appear to be redundant (because they compete with each other on satisfying the same customer demands). Others may be suitable only in certain circumstances (certain areas or customer types). A choice to offer certain bundles implies also a choice of business partners to work with.

To satisfy a customer demand for energy supply a bundle may theoretically include almost any combination of the following services: electricity supply, heat pumping and hot water (as well as other obligatory services that we do not discuss here). The service ontology provides extra tools to narrow the scope of our analysis:

1. Hot water (replacing part of the electricity consumption, for a lower price) is available in a limited geographic area only; hence, different service offerings are possible in different areas. This is modeled in Figure 6: a context switch triggers different relations (production rules) between the demand for energy supply and the service outcomes ‘energy of type electricity’ and ‘energy of type hot water’, based on the given zip code.
2. Customers would prefer bundling electricity supply with hot water to bundling electricity supply with heat pumping due to a lower price[4]. Consequently, where the hot water service is available, offering electricity supply with heat pumping may be less attractive. The difference in price is modeled by the pricing model concept that is attached to the fee input of commercial services.

Let us now take a new customer demand into consideration: temperature regulation, for indoor comfort. The following service elements satisfy this demand for commercial

[4] A lower price is achieved only over time, because customers who wish to consume the hot water supply service for room heating are required to invest in hardware.

customers: heat pumping, energy control system and remote control. Also here the service ontology provides extra information for our business analysis:

1. Manual and location-dependent (only onsite) temperature regulation requires two service elements: electricity supply and heat pumping. If a customer already consumes these services for his energy supply, manual energy regulation is available with no extra costs (see the top left service bundle in Figure 7).
2. Automated and location-dependent (only onsite) temperature regulation requires the following service elements: electricity supply and energy control system (see the top right service bundle in Figure 7). Unlike the first bundle, this one does not provide the outcome “air conditioning”.
3. Automated and location-independent (via a website) temperature regulation requires the following service elements: electricity supply, energy control system and remote control (it also requires an ISP service, but we omit this from the current discussion for brevity) (see the bottom service bundle in Figure 7).

Suppliers may then decide whether they want to offer all three bundles, or whether they want to profile themselves as online energy suppliers, and supply only the online temperature regulation version. If electrical appliances and remote control are offered by different companies, this implies also a choice of partners to work with. Although all three bundles satisfy the same customer needs and wants, as we have seen they are essentially different due to their service properties. For our example let us assume that the choice has been made to supply the third of these bundles.

******** Place Figure 7 approximately here *********

******** Place Figure 8 approximately here *********

8 Step 4: Value Ontology for Business Analysis

In the last step of our method we develop business models for the chosen bundles, and assess their profitability. Profitability assessment is not shown here (for an explanation see [12]), but only how found bundles can be fed back into an e^3value model. All feasible bundles that were not chosen in step three are discarded, so their profitability need not be assessed. Chosen bundles can be shown in a revised e^3value model (see Figure 8). In this case we restrict ourselves to bundle 3 as explained in the previous section. A customer demand as identified in the service ontology, e.g., automated, location independent temperature regulation, is represented by an e^3value consumer need. Such a need connects to one or more value interfaces of the actor that has the need. The actor then transfers objects of economic value to satisfy the need via one of the connected value interfaces. In our case, the need is connected to three interfaces via an AND-fork, saying that in order to satisfy the need, the actor must exchange objects via all three interfaces. Information elicited by using the service ontology was very useful when calculating profitability of the chosen bundles. For example: in the initial e^3value model it was difficult to define some value transfers, because domain experts had to make assumptions, e.g., about the demand. The service ontology-based model allows us to verify the existing financial formulas and create the missing ones because it captures more details such as service properties. Take for example the bundle that includes electricity supply and heat pumping: we can make a better assessment of electricity consumption (and thus the costs) during winter and summer for customers, because this information is modeled using the service ontology. We can derive very realistic figures, based on the composition of the bundle.

A found bundle in the previous section is represented in Figure 8 as a value interface for the composite actor TrønderEnergi AS that bundles ports exchanging a remote control service, electricity, and energy control. Additionally, the reciprocal value objects (fees, lock-in) are also shown in the value interface. Note that a value interface exactly models bundling: it is only possible to obtain the bundled services in combination, in return for the sacrifice stated. Other bundles can be modeled similarly. In the current study, step two generates at most dozens of feasible bundles, based on ten elementary services. In step three we choose only a subset thereof for profitability assessment. A recurring element in service bundles in step two is that the services 'electricity supply', 'remote control' and 'energy control system' are always bundled, while other services as 'heat pumping' and 'supply of hot water' are included in some of the bundles only. In accordance with these findings, business developers chose to investigate the financial feasibility of a business model where 'electricity supply', 'remote control' and 'energy control system' are marketed as a package, while 'heat pumping' and 'supply of hot water' may be sold separately. This choice is reflected in Figure 8. From a business development perspective, the choice to market several services only as a bundle is an important decision. Investigating this option was a direct result of our service configuration approach.

9 Analysis and Conclusions

9.1 Business Perspective

Developing a multi-actor business model for e-service bundles involves various potential partners, each offering a number of services; only a subset of these services has to be selected for a business model. However, why choose for one service or another? Assessing profitability of all possible scenarios is a very time consuming task. In this article we presented how we use a service ontology with a value ontology to tackle this business problem. When a broad spectrum of services is included in a business analysis, our ontology helps business developers design meaningful service bundles, and discard all other scenarios. As a result, the scope of financial feasibility studies remains manageable.

Our four-step method provides a means to reason systematically about the selection of one service or another for a service bundle, eventually resulting in feasible service bundles that satisfy certain customer demands. When multiple feasible service bundles satisfy the same customer demands, it is important to be able to reason about differences between the bundles, to make a decision about one or more bundles, reflecting one or more business models to develop. Since we choose only a subset of the possible bundles, our business analysis will have a much narrower scope than an analysis that takes all possible partners (and services) into consideration. The service ontology was applied to resolve the complexity problem of a business analysis in the energy sector by narrowing the scope of our primary business model. Consequently, significantly less effort had to be put into profitability assessment.

In our present study an energy supplier wishes to bundle electricity supply with other services, provided by a number of suppliers. The questions at hand are with which other services to bundle electricity supply, and whether the resulting business model(s) will be profitable. Past failures of similar initiatives show that these questions are far from trivial, and the competition in this sector requires a thorough analysis before a new business model is developed and a new service offering is marketed. Even with a limited set of only ten services, 1023 service bundles could theoretically be designed; assessing profitability for all service bundles would cost too much time. No mechanism was available for selecting bundles. By applying the service ontology in the energy domain, we managed to reduce the task complexity:

1. The number of service bundles for which profitability needs to be assessed was reduced by formalizing and applying dependencies between services, serving as rules for service bundling, or service configuration.
2. Knowledge on services was made available, to facilitate reasoning about a choice between feasible bundles.
3. Information on costs of and demand for services helps make a sound profitability assessment.

This knowledge is not available in the e^3value ontology, where no guidelines are provided for bundling services. With a set of ten services and 1023 different sets of these ten services, step 2 of our method reduced the complexity to a maximum of several dozens solutions per scenario. Step 3 of our method further reduced the complexity to a few (typically two to five) service bundles per scenario. All other theoretically possible service bundles are irrelevant, and their profitability need not be assessed in step 4 of our method.

9.2 Ontology Development Perspective

Goal: use the service ontology to reduce complexity of business analyses

In this article we focus on the service offering perspective of our ontology, where we describe services as acts of exchanging economic values, and also as components for configuration. In [3] we focus on the service value perspective, showing how we ensure that the generated service bundles provide a good solution for customer demands.

Similarly, the study we describe here served us mainly for developing and validating the service offering perspective of the ontology. We modeled energy services using our *Serviguration* ontology and software tool, and used our software tool to generate service bundles based on criteria given by our business partner. Applying our ontology provides business developers with the required tools for performing a structured business analysis, reducing the complexity of the analysis by narrowing the number of possible business models that have to be analyzed.

Ontology validation: in exploratory real-world studies a 'good solution' is not defined a priori

From the perspective of TrønderEnergi AS, a study like this is aimed at designing and exploring new business models; TrønderEnergi AS does not know in advance which bundles shall be selected as sensible. Therefore, business developers cannot say in advance which service bundles they expect to be generated, such that we can validate the service model and service configuration algorithm by comparing results to a list of expected bundles. Instead, the theoretical validation of our ontology and related software tool starts by modeling services and generating service bundles. These are presented to our business partner for assessment. In our case the generated service bundles were found sensible solutions by our business partner; our claim that service bundles can be configured by software when modeled using our service ontology proved to be correct in the energy study. The service ontology provided our partner with information and knowledge to continue the business analysis with profitability assessment of business models for offering service bundles.

Ontology development: real-world studies as a means to understand and generalize business logic

By modeling energy services and designing service bundles, we gained major insights into the service offering perspective of our ontology. First, we used the study at hand to sharpen the definition of ‘service inputs/outcomes’ in our service ontology, and to distinguish between a business value perspective on services and a process perspective. We model only service inputs/outcomes that describe the value exchange between involved actors. Yet, some inputs/outcomes represent an exchanged value, and are also a process element.

Second, energy services may have very complicated pricing models, allowing customers a high degree of flexibility in choosing a scheme that suits their needs best. This study was therefore very suitable for understanding how pricing models can be expressed as formulas, and how they can be modeled in the service ontology.

Third, due to the complex nature of this domain, many interdependencies exist between services. We refer not only to what we call ‘service dependencies’ in the ontology (determining which services can be combined into a bundle), but also to *how* one service influences another, assuming that they are bundled. For example, if customers have an energy control system next to their electricity supply, their electricity consumption is reduced by ten percent. The study at hand was used to develop the concept *conditional output* to model such constraints.

Ontology usage: discover the boundaries of an ontology

We used the study at hand to define an interface between our *Serviguration* ontology and the e^3value ontology for constructing business models, and implemented this interface in a software tool. By performing this analysis we learned the boundaries of both ontologies, and where they can fill in each other’s gaps. The e^3value ontology provides the means for constructing business models, but it does not allow reasoning on how services should be bundled. The *Serviguration* ontology provides a means to reason about service bundling, but does not describe the resulting business model or allow for calculating profitability of a business model. We showed how to use both ontologies together to perform a full analysis. The software-based interface between the ontologies allows for a computer-supported business analysis.

9.3 Concluding Remarks

The energy sector is growing horizontally, offering services which traditionally were not offered by this sector. Service bundles offered by energy utilities nowadays include non-energy related offerings, as a means to differentiate the energy product. This poses a challenge for business developers: criteria for including services in a bundle are sometimes still missing, and therefore an exploratory study is required, triggered by an understanding of customer needs as a key to designing new offerings. *Serviguration* focuses on customer demands as a starting point for service bundles design. It is this specific characteristic of our service ontology that makes it so suitable for business analyses as presented in this article.

The study at hand presents evidence of the feasibility and usefulness of software-aided composition of service bundles. At the same time it also demonstrates the boundaries of automation, the places where human intervention is required. The method we present for business analyses can help business developers reduce the complexity of business analyses, and pinpoint good candidates for new service bundles. Yet, the choice for one or more service bundles and related business models has to be made by humans. When our method shows that several service bundles actually compete with each other because they provide a solution for a same or similar customer demands, human intervention is required to decide on a course of action. Decision criteria may not always be clear-cut. For example, one may choose to offer a service bundle with modest financial perspectives because it involves a reliable business partner, while an offering which may promise higher revenues necessarily involves working with a business partner that has already let you down in the past.

A number of possible extensions for the *Serviguration* ontology provide fertile ground for future research. First, as mentioned before our service ontology does not model knowledge on strategic reasons for service bundling such as product differentiation, strategic alliances or cost effectiveness. A strategic-level software-aided reasoning will require that our ontology be extended with an ontology for modeling business strategies, based on which the business rules that we use are derived. A second area of future research is a better understanding of customer behavior. We describe in [3] how we reason about customer demands, and how we take the context of a given customer or customer group into consideration. We use the economic principle that a customer is interested in the value/benefits that a service provides, rather than in the service itself. In spite of the general applicability of this principle, marketing researchers have been publishing a wealth of research on factors that influence customer behavior. The means-end theory [17, 40] is a broadly accepted marketing theory for explaining why customers seek specific good/service attributes and benefits, by linking these attributes and benefits to customer values, defined as "consequences for which a person has no further (higher) reason for preference" [17]. We discuss this research direction in [3]. Third, service quality has been a very fruitful area of research for many years. At least two widely accepted generic models for defining service quality are used in business research: that of the Nordic school [13] and that of the North American school (SERVQUAL, see [41]). Other researchers investigated service satisfaction (which is influenced by the perceived service quality). With the rise of e-services, in recent years researchers have also been investigating e-service quality, compared to traditional service quality research. Embedding schemes for describing service quality may enable a richer understanding of customer behavior as a means for a coarse definition of customer requirements as input for the actual service bundling.

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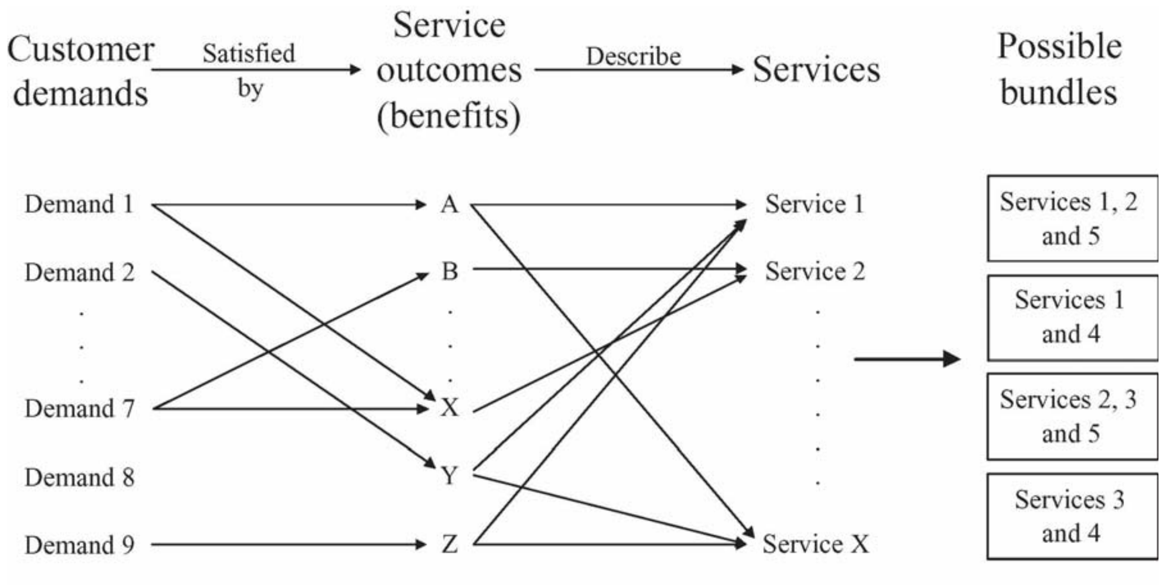

Figure 1: *Serviguration*: configuring service bundles based on customer demands

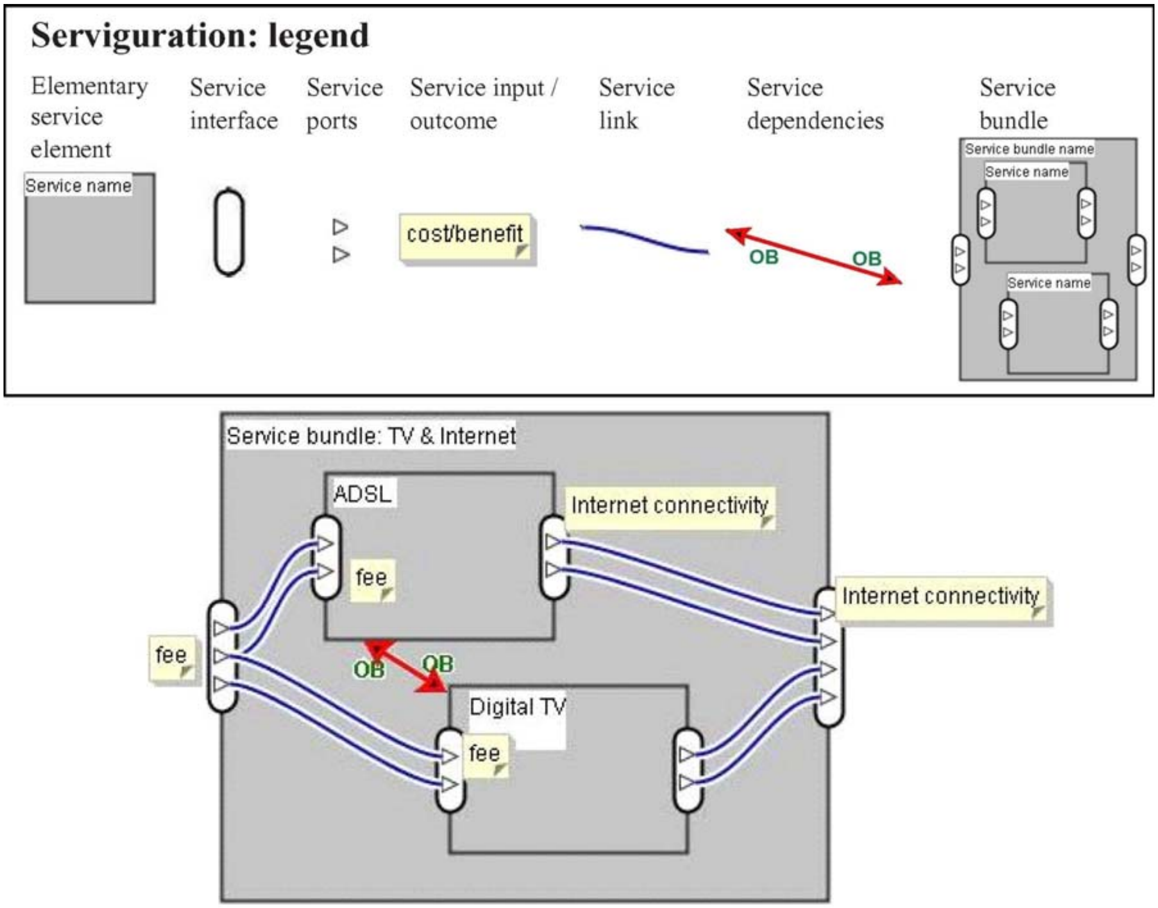

Figure 2: *Serviguration* service ontology: legend, along with an example service bundle (digital TV and Internet connection)

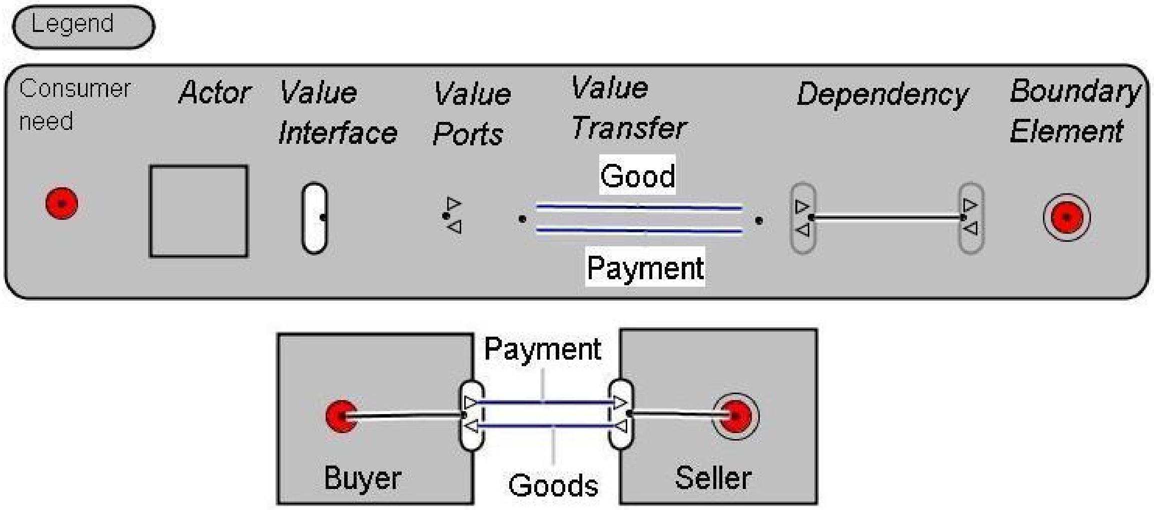

Figure 3: Example of an e^{3}value business model of a purchase of goods

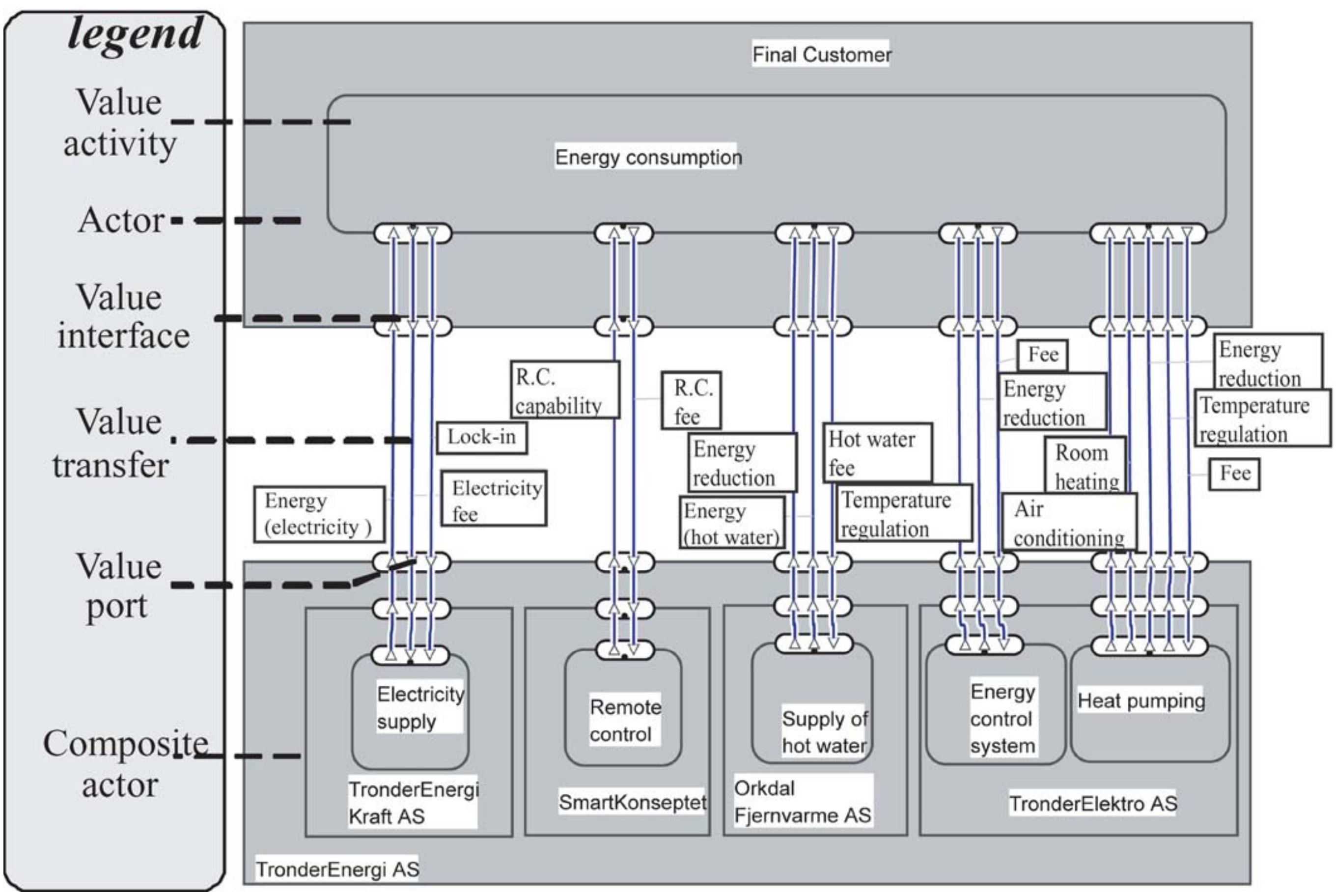

Figure 4: Initial value model for energy services

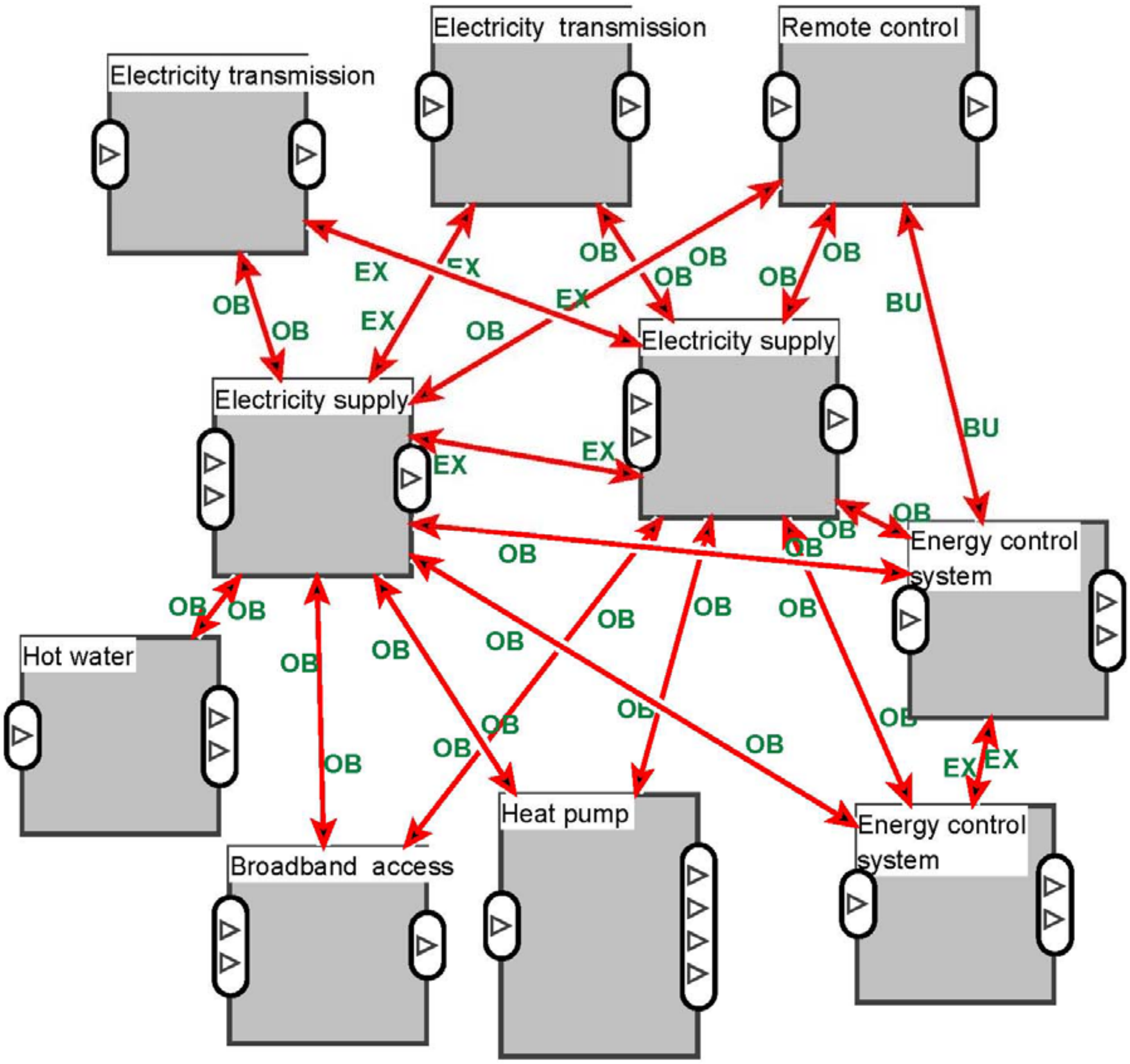

Figure 5: Service elements and their service dependencies

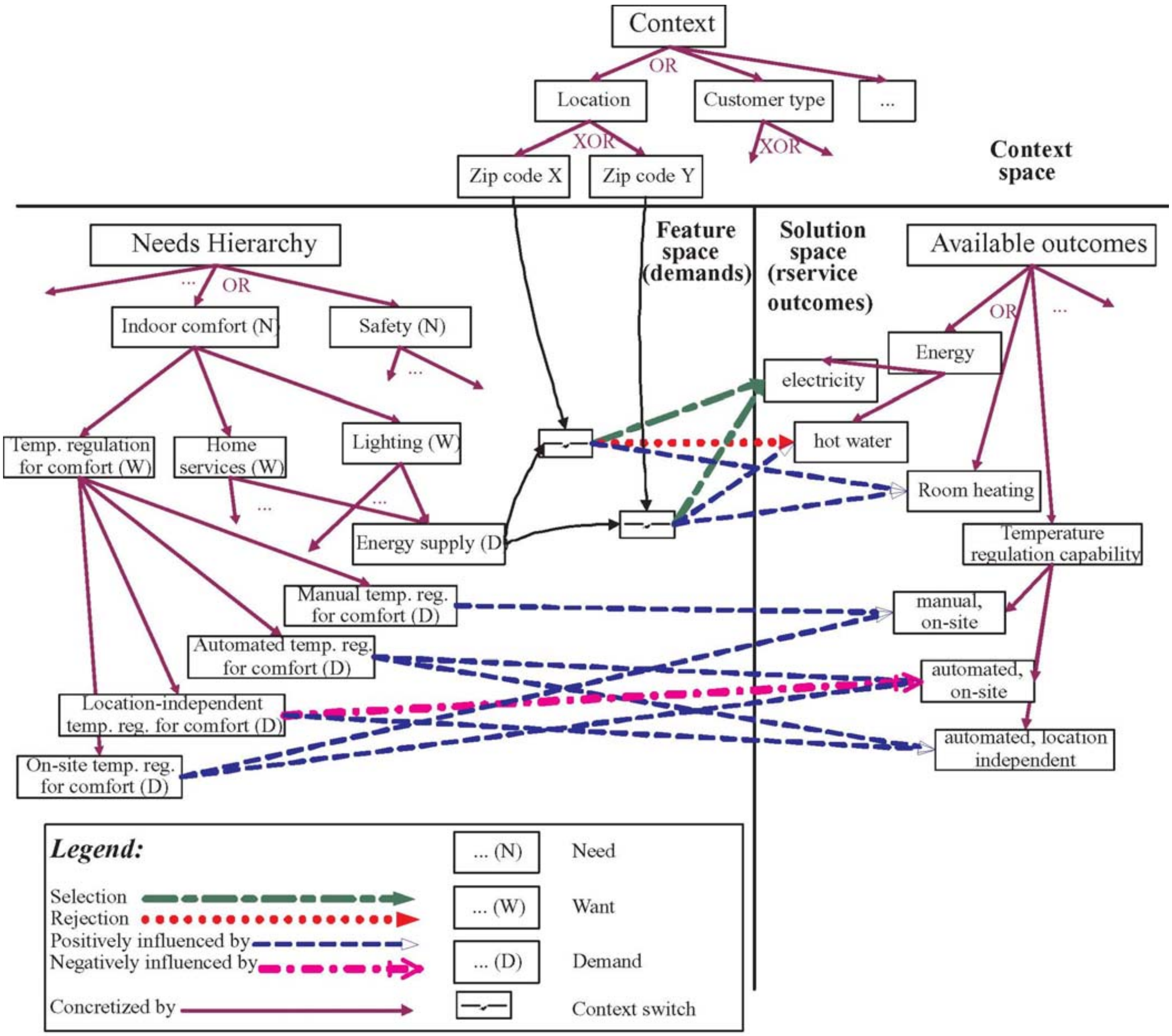

Figure 6: Partial graph of the energy study: production rules model how service outcomes satisfy customer demands.

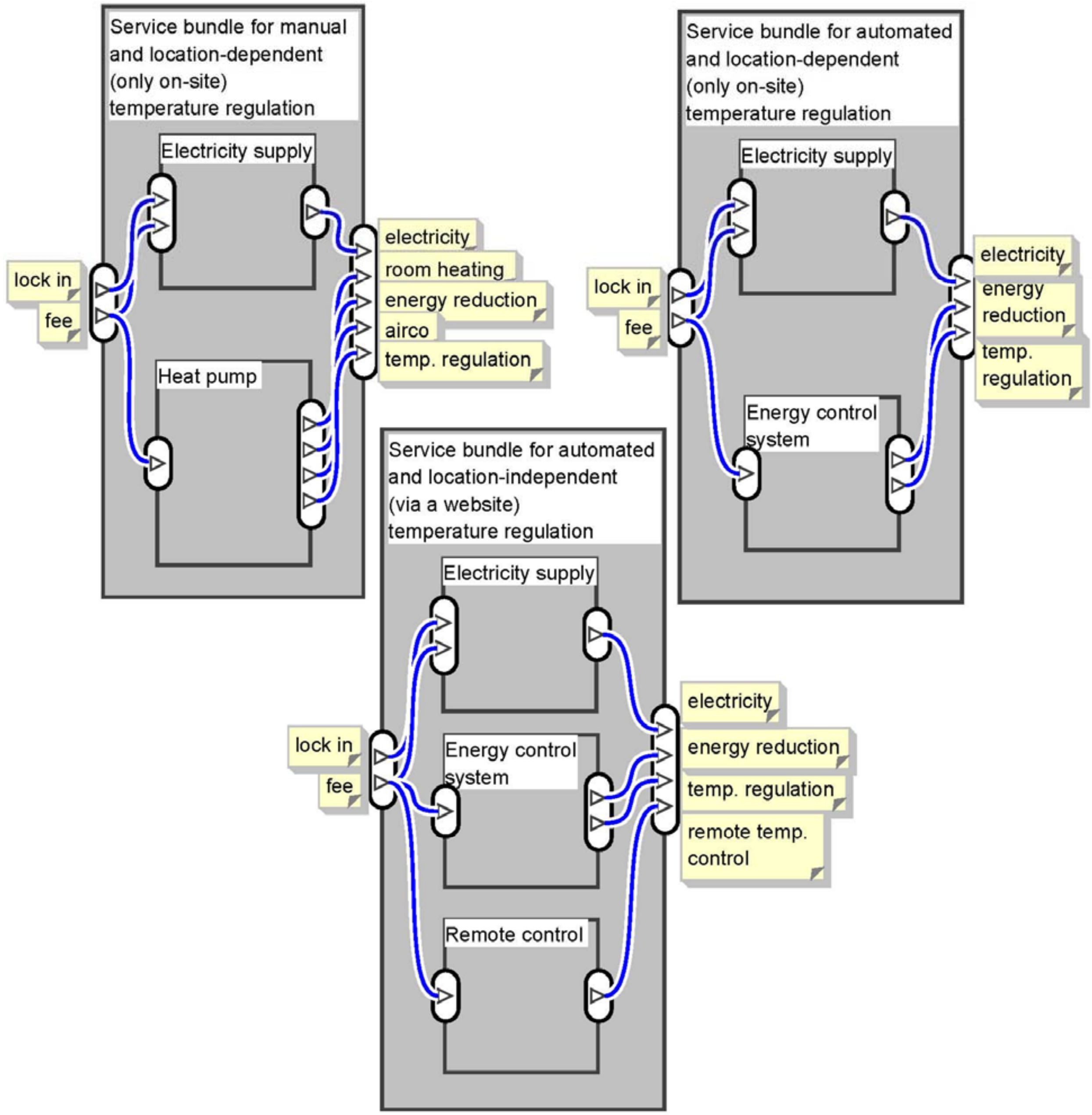

Figure 7: Step 3 of our method for performing business analysis yields three different service bundles for three similar customer demands

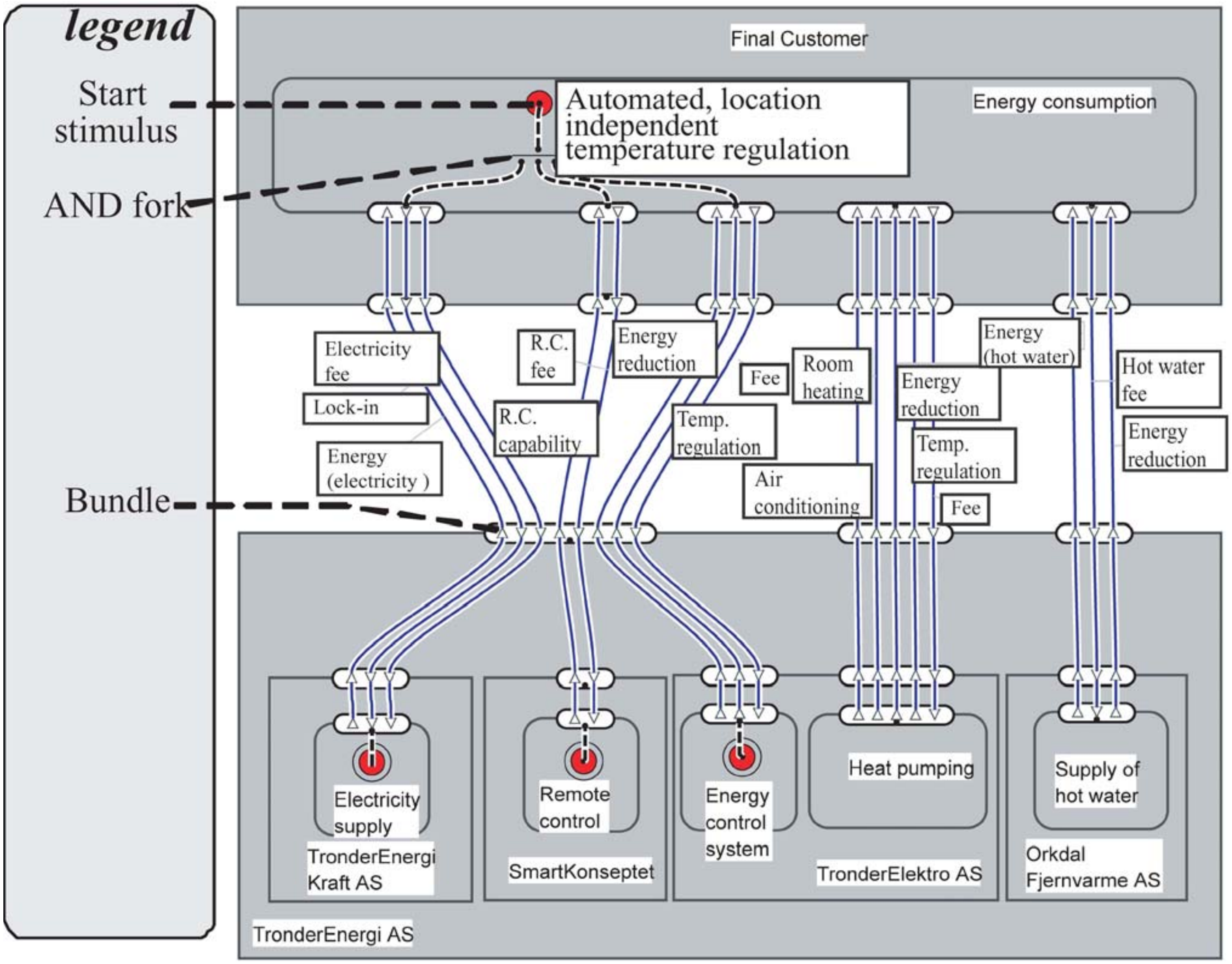

Figure 8: A revised e^{3}value model, reflecting bundling decisions

Table 1: Energy services described by their service inputs and by their service outcomes (type is mentioned in brackets)

ervice name	*ervice inputs*	*ervice outcomes*
lectricity supply	ee (monetary resource), ock-in (capability resource)	nergy of type electricity physical good resource)
lectricity ransmission	ee (monetary resource)	lectricity transmission state change resource)
ot water supply	ee (monetary resource)	nergy of type hot water physical good resource), nergy reduction capability resource)
eat pump	ee (monetary resource)	nergy reduction (capability esource), room heating capability resource), air onditioning (capability esource), temperature regulation capability resource)
nergy control ystem	ee (monetary resource)	nergy reduction (capability esource), temperature regulation capability resource)
emote control	ee (monetary resource)	emote temperature control capability resource)
roadband access	ee (monetary resource), ock-in (capability resource)	nternet connectivity (capability esource)

Table 2: Service dependencies in the energy study. A service dependency is a function with two arguments; the first argument is the service in the row, and the second argument is the service in the column. The abbreviations OB, EX and BU stand for the dependencies ‘optional bundle’, ‘excluding’ and ‘bundled’. Some services are modeled twice because they can be provisioned in different forms.

	electricity supply (1)	electricity supply (2)	electricity transmission (1)	electricity transmission (2)	hot water supply	heat pump	energy control system (1)	energy control system (2)	remote control	broadband access
electricity supply (1)		EX	OB	EX	OB	OB	OB	OB	OB	OB
electricity supply (2)	EX		EX	OB		OB	OB	OB	OB	OB
electricity transmission (1)	OB	EX								
electricity transmission (2)	EX	OB								
hot water supply	OB									
heat pump	OB	OB								
energy control system (1)	OB	OB						EX		
energy control system (2)	OB	OB					EX		BU	
remote control	OB	OB						BU		
broadband access	OB	OB								

Table 3: Customer needs, wants and demands for the energy utility TrønderEnergi. The notations H/I refer to the customer type: Household or Industrial.

Customer Needs	**Customer Wants**	**Customer Demands**
Indoor comfort (H,I)	Lighting (H,I) Home services (cooking, washing etc.) (H) Comfort temperature (H,I)	Energy supply (H,I) Hot tap water (H,I) Room heating (H,I) Air conditioning (H,I)
	Energy regulation for budget-control (H,I)	Energy regulation for budget control (H,I), with different characteristics (manual / automated, on-site regulation / location-independent)
	Temperature regulation for increased comfort (H,I)	Temperature regulation (H,I) with different characteristics (manual / automated, on-site regulation / location-independent)
Social contacts and Recreation (H) Business contacts (I)	Communication (H,I)	Telephone line (H,I) Mobile phone line (H,I) Internet (broadband) (H,I) Email facilities (H,I)
Safety (H,I)	Increased security (H,I) Reduced insurance premium (H)	Safety check of electrical installation (H) Internal control of electrical installation (I)
IT support for business (I)	IT-services (I)	ASP-services (I) Hardware (I) Software (I)