

Designing Auctions for Coordination in Service Networks

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Abstract The evolving service ecologies show new ways of value co-creation through combinations of multiple service components which are described in service offerings. An open issue in such a large service ecology is how to efficiently coordinate and price service offerings. Service offerings provide different functionality and quality. Customers need to distinguish their preferences on different combinations of service attributes. In this chapter we address this issue of service offerings allocation and introduce a structure design approach, Market Engineering, as an appropriate method to design such mechanism. In order to apply this approach to service systems we introduce a formal model and a definition of service value networks. Examples exemplify our approach and we show one possible step towards implementing such a mechanism.

Keywords: Market Engineering, Path Auction, Web Service Coordination, Service Value Networks, Mechanism Design

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1. Introduction

The way how the electronic service industry contributes to value generation has changed in recent years. Flexible service components are developed instead of large monolithic software applications on a licensed-based business model. Service components are described in service offerings and provide certain functionality, e.g. a specific part of a service process. Such service components enable business on a pay-per-use basis. Additionally, they can be easily adapted and extended

by additional services or a combination of service components can build up *complex* services.

This conceptual and technical change offers customers the opportunity to purchase service offerings on-demand. Thereby, they are not limited to purchase offerings from a single provider. A complex service can rather be composed from the offerings of different providers tightly focused on required features. Such modularity is one of the most promising answers to the question of how to face rising demands for sophisticated, customized products (Baldwin and Clark 2000). Once serving the whole value chain by what has become famous as vertical integration, service providers now tend to engage in networked value creation in ecology-like environments which we call service value networks (SVNs). This development enforces the economic trend to a horizontal specialization in service offerings which in turn calls for new cooperation forms in loosely-coupled configurations of legally independent firms. Though horizontal specialization can lower their risk of operating in a changing and uncertain environment.

This is why companies tend to engage in networked value creation which allows participants to focus on their strengths. Partners in such ecologies can leverage the know-how and capital assets of partners, at the same time spreading risk, sharing investment cost, and retain flexibility. In that way, the network has the ability to “rapidly pick, plug, and play” business processes (van Heck and Vervest 2007). By re-aggregating with partners, a company can broaden its range of customer attractions. Especially in complex and highly dynamic industries, forming agile SVNs, is more than an attractive strategic alternative.

From a customer’s point of view it is a challenge to find the best combination of service components in such a SVN and to determine prices for it. If it is clear which offerings technically can be combined in order to form a complex service, the following question remain: Which providers should I choose? What price should be paid for the complex service in total? Which price are the providers of the single components paid? Thereby, heterogeneity of service offerings and service requests is one problem in price determination. Another problem is preference elicitation which is crucial in the service sector where valuations for different kinds of service offerings are hardly determinable directly. Thus, we are interested in building mechanism for this pricing and allocation task.

Auction theory¹ has shown good results in eliciting preferences and efficiently allocating goods. But, auction design is a challenging task. The outcome of an auction does not only depend on the institutional rules of an auction but also on the specific characteristics of the resource to allocate, and on the behavior of the participants. Thus, auction theory which is an applied branch of game theory studies auction from a theoretical perspective regarding the efficiency of resource allocation, the bidding strategies, and the revenues. Economists often assume bidders to be fully rational. This is a rather strong assumption which does not hold in reality. Thus, auctions can show outcomes which were not expected theoretically since human decision making is influenced by various factors. Participants might have incomplete information, different risk attitude or a different reaction to uncertainty. Additionally, psychological or emotional effects can play an important role.

Therefore, it is not sufficient to design new auction mechanisms (for the allocation of offerings) and study them only from a theoretical perspective. It is also necessary to incorporate behavioral aspects. Laboratory or field experiments as well as simulations are possible approaches. Thus, suggest a structured approach to the design of coordination mechanisms which can be used in designing service value networks. Such an approach was introduced by Weinhardt et al. (2003) which was called Market Engineering.

The evolving service ecology with a business service choreography (Demirkan et al. 2008) calls for appropriate mechanism which allocate service offerings. As this chapter provides both a introduction to auction theory and mechanism design as well as an application to the field of service systems.

Thus the contribution of the chapter is twofold. First we introduce Market Engineering (ME) as a design approach for mechanism. Second, we apply Market Engineering exemplarily on service value networks. Therefore, we introduce our understanding of SVNs by conducting an environmental analysis in section 3. We develop a path-based auction mechanism and show a possible implementation in a web-service coordination. The chapter closes with a conclusion.

¹ Further literature on auction theory, see for example Klemperer (2004), Krishna (2002), Milgrom and Weber (1982), Wolfstetter (1999)

2. Market Engineering

Searching an appropriate structure for an economic system is not a new question for economists. But the optimal design of such a system is often unknown. Hurwicz (1973) argues on the question in what respect the structure of an economic system is unknown:

“Typically that of finding a system that would be, in a sense to be specified, superior to the existing one. The idea of searching for a better system is at least as ancient as Plato's Republic, but it is only recently that tools have become available for a systematic, analytical approach to such search procedures.”

The interest in studying electronic markets has increased in the last few years. It can be observed that the market outcome not only depends on the market participants and their valuations, but also on the market structure which stimulates strategic behaviour of the participants.

It has been more and more called for scientific support in designing and developing (electronic) markets (Roth, 2002; Varian, 2002). One approach for the design of markets has been introduced by (Weinhardt, 2003) as *Market Engineering* (ME). (Holtmann, 2004) remarks that it were McCabe (1993) who used the term Market Engineering for the first time, but since then the term was only used a few times. Therefore, Weinhardt (2003) picked up this term and provided a comprehensive definition of ME as a service oriented design approach to the development of electronic markets. An electronic market can be perceived as a service which enables electronic trading and which is provided by either a non-profit organization or profit oriented company. Holtmann (2004) and Neumann (2004) describe the idea of ME comprehensively.

2.1. Markets and Auctions

There are many views on the term *market* in economic literature. It can be generally stated that a market coordinates exchange, interactions that are mutually beneficial and hence, co-create value for the entities involved. For example, markets can be used to coordinate the exchange of service for service, or the exchange of resources, such as goods, information, (property) rights and/or money. It provides a mechanism to match demand and supply (resource allocation) and determines a market (or clearing) price. This mechanism can be either defined explicitly as e.g. in an English auction, or it can evolve during a negotiation process. Markets are understood as one form of coordination in economic interaction. In contrast to coordination by markets, Coase (1937) discusses hierarchical coordina-

tion as it is known from the organization of firms where the coordination of tasks and resources takes place through delegation and control. In their purest form, neither hierarchies, nor markets involve cooperation throughout the coordination process, although in reality mixed forms occur.² These two main forms of economic coordination span a continuum where many mixed forms for cooperation lay in between.

From an economic perspective, the study of markets is coined by the question, to which extent markets contribute (and can be optimized) to economic coordination. Smith (1982) developed the *Microeconomic System Framework* that clearly defines the core concepts of a market system. Foregoing work on that issue was accomplished by Hurwicz (1960, 1969, 1973) and Reiter (1977). Smith understands markets as economic systems that, basically spoken, consist of three main components, (i) *economic agents* acting in the market, (ii) *commodities* being exchanged (at least one), and (iii) a *set of rules* defining the *market institution*.

An *auction* is a specific type of market. Auctions are known as one of the oldest forms of trading used already at 500 B.C. in Babylon (c.p. Cassady, 1967). Nowadays, auctions are mainly used for three reasons: (i) speed of sale, (ii) information revelation of buyers' valuation, and (iii) prevention of dishonest dealing between the sellers and buyers (Wolfstetter, 1999). In auctions economic agents compete against each other on settling a trade by submitting bids representing their willingness to pay. Bertsekas (2001) states that auctions are an "intuitive method for solving the classical assignment problem." The auction rules determine the way of bidding (e.g. amount of bids, increments, start, end), the winner (and thus, the allocation of the good), and the price to pay. McAfee (1987) defines auctions as follows:

"An auction is a market institution with an explicit set of rules determining resource allocation and prices on the basis of bids from the market participants."

Bids can be specified in several ways, e.g. by raising the hand when an auctioneer calls a certain price, or explicitly in written form. Wolfstetter (1999) points to the information problem in economic trade, where an individual has incomplete information about the competitors' valuations. This is one of the main issues in auction theory and leads to the question of how to design auctions in order to reveal this information. There is no general answer to this question, since it depends on several factors. Therefore, auction need to be analyzed in the given context.

² Strategic alliances are a well established cooperation in e.g. the airlines industry. Airlines cooperate on selected routes but remain competitors on the other flight routes. The need for cooperation increases also in the service sector since companies offer more and more specialized services.

There are various auction formats depending e.g. on whether one single unit or multiple units are to be traded and whether there are single or multiple sellers or buyers. Auctions with just one seller and multiple buyers (or vice versa) are called single sided auctions. Double sided auctions have multiple buyers and sellers. Klemperer (2004) names four standard single sided auction types: (i) ascending (e.g. English auction), (ii) descending (e.g. Dutch auction), (iii) first price sealed-bid, and (iv) second price sealed-bid (e.g. Vickrey auction). Wurman (2000) propose a classification of five classic auctions by differentiating the attributes (i) single vs. double sided, (ii) open (cry) vs. sealed, and (iii) ascending vs. descending. This classification is also depicted in Figure 2.1.

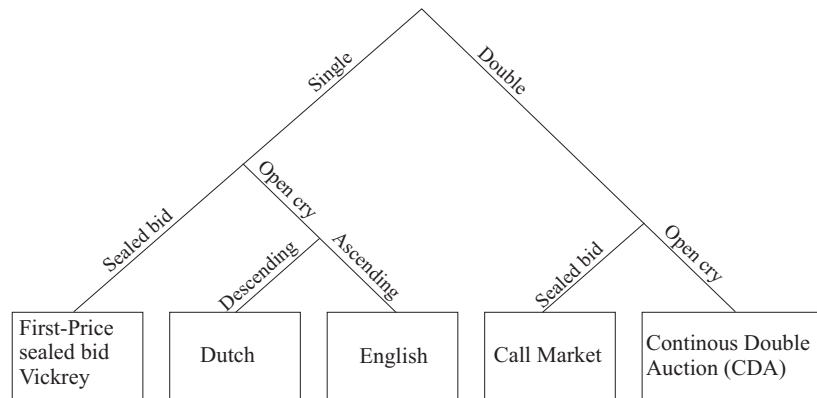


Figure 2.1: A classification of classic auction types (Source: Wurman, 2000)

2.2. Structured design approach

The terms *market design* and *mechanism design* are often used in economic literature to describe the conceptual development of market rules as defined by Smith (1982) comprising the information exchange rules (the language), adjustment process rules, allocation rules, and cost imputation rules. For electronic markets such mechanisms have to be implemented and operated on an Information Technology (IT) infrastructure. The operator of an electronic market can be understood as a service provider for economic trades. This service concept includes also some kind of fee in order to cover at least the costs for service providing. These additional requirements for designing electronic markets are picked up by the ME methodology and lead to the following definition, which summarizes the work of Neumann (2004).

Market Engineering subsumes the systematic approach to development, analysis and design of electronic market service integrating theory from the scientific areas of economics, business administration, computer science and law. ME focuses on the three core activities (1) design, (2) operation, and (3) research of electronic markets.

In order to appropriately design electronic markets, it is essential to base the design on research results of electronic markets and to study new mechanisms comprehensively. There is also a need for successful business models and powerful technologies. The ME process includes these different aspects according to the service engineering process and engineering design approaches and is described in the following. Figure 2.2 depicts this approach.

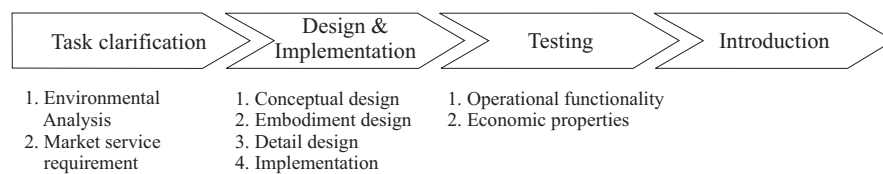


Figure 2.2: The market engineering process

The ME process consists of the four stages (1) Task Clarification, (2) Design and Implementation, (3) Testing, and (4) Introduction. These stages are subdivided into several phases.

(1) Task Clarification

At the very beginning of the ME process, it is important to conduct an environmental analysis and to elaborate the market service requirements.

- Environmental analysis
The environmental analysis starts with (i) the market definition, including the determination of the trading objects, potential customers and their endowment, preferences of customers and other constraints. Once the market is defined (ii) a market segmentation (regarding e.g. customer or product groups) is examined. Finally, (iii) a market target is determined, meaning that it has to be decided which of the market segments to focus on for trading.
- Market service requirements
The environmental analysis serves as starting point to identify basic requirements of the electronic market. It comprises the socio-economic environmental aspects such as the (potential) number of agents, their preferences (private or common values), and resources. Additional service offerings to meet customers' expectations are elaborated and also legal aspects are analyzed. Important requirements regarding the business process (e.g. cost coverage), incentives for participation, or computational requirements are defined.

(2) Design and Implementation

The second stage is structured into four phases:

- Conceptual design

At the beginning the market system is defined with abstract descriptions regarding the market rules, the infrastructural requirements and the business rules as identified in Stage 1.

- **Embodiment design**
The abstract descriptions of the conceptual design phase are redefined into semi-formal description of the institutions such as trading protocols. Often there are diverse trading protocols (or descriptions) for one and the same trading mechanism. The descriptions of the embodiment design phase abstract from implementation details.
- **Detail design**
Detail design starts with building the layout of the system, which is subsequently refined and which finally results in a complete and detailed system model, e.g. based on UML. This model also considers implementation details.
- **Implementation**
The predefined and developed software model is implemented using a standard software development process.

(3) Testing

The developed system is tested regarding its operational functionality and its economic properties.

- **Operational functionality**
It is important to assure that the implemented system works correct. Therefore, it has to be checked if the code maps to the specified requirements (verification). Common techniques such as unit testing can be applied. Additionally, it is necessary to verify if the requirements themselves are correct or if additional requirements exist (validation).
- **Economic Properties**
Electronic markets can be analyzed with respect to their economic performance either on an analytical basis, using experimental techniques or based on simulation. Theoretic analysis is not suitable for all markets and market environments. Especially the behaviour of human economic agents is not always obvious and hard to model. Therefore, game theoretic experiments can help to gain new insights. It is also possible to apply simulations for testing and evaluating electronic markets.

(4) Introduction

After comprehensive tests, the developed market service can be launched and operated. Market Engineering recommends permanently observing and reassessing the market. The gathered feedback helps to improve market service and facilitates the redesign of markets.

As pointed out auctions are one way of selecting and allocating goods or service. In order to find a good combination of service offerings it is necessary to design an auction mechanism with specific properties. Krishna (2002) is a very good ref-

erence for introduction to auction theory. He outlines different properties of mechanisms and describes efficient mechanisms. In the next section we construct an efficient mechanism for find efficient combinations of service offerings in service value network.

Having learned about auction design we now apply the concept of Market Engineering to service value networks in the next two chapters.

3. Environmental Analysis: Service Value Networks

Ever since the seminal work of Williamson (1985) at least three types of business governance structures have been identified: market, hierarchy, and hybrid forms. In pure markets all information is publicly and instantaneously observable via the price mechanism, which in turn provides a perfect incentive mechanism to align individual profit with economic efficiency. However, by this it is assumed that an effective price mechanism exists in the first place. This is a presumption which is generally not warranted for non-standard goods and service that involve a high factor of specificity (sunk costs), customization, low frequency of trade, or high uncertainty in demand or supply.

In a purely hierarchical organization, on the contrary, value is created strictly within the boundaries of the integrated firm. Here, by definition, opportunistic behavior of business partners is not feasible, and thus neither the revelation of knowledge nor the incompleteness of contracts poses impossibility constraints. However, such formal control usually comes at the price of inefficiency and inflexibility, which are both crucial in an increasingly competitive economy. Hybrid governance forms such as networks combine the advantages of market governance, in particular adaptability and incentive compatibility with those of hierarchies, foremost control.

Consequently, *business networks* have been proposed as the superior governance form for today's highly dynamic and complex business world (Miles and Snow 1985). Business networks evolve from a pool of potential horizontal as well as vertical business partnerships. In this respect they differ both from strategic alliances, comprising only horizontal business partners, and supply chains, denoting purely vertical relationships.

Likewise *service value networks* constitute a special type of business network, which, although frequently used, lack a generally accepted definition.

3.1. Definition and Characteristics

Definition 3.1: Service Value Networks. *Service value networks are business networks, which provide business value through the agile and market-based composition of complex service offerings from a steady, but open pool of complementary as well as substitutive standardized service modules by the use of ubiquitously accessible information technology.*

In the following, we will discuss each part of the definition in detail and thereby highlight the boundaries of service value networks.

Complex service. By a *complex service* we understand the composition of services components. In more detail, complex or composite service offerings typically involve the assembly and invocation of several service components offered by diverse enterprises in order to complete a multi-step business functionality (Papazoglou 2008) In turn, service *component* are either other complex service offerings or functionality that is provided via a Web service. The term *utility service* originates from the energy domain, denoting core service offerings such as the provisioning of gas or electricity. Adapted to the area of e-service, the term denotes infrastructure service offerings that provide enabling technologies for ecologies such as storage capabilities and the provisioning of computing power (cp. Section 3.3).

Standardized service modules. In order to be plug-and-playable, the utility service must provide standardized interfaces for interchanging machine-readable parameter values.

Steady but open pool of complementary and substitutive service offerings. Service offerings must register (or be registered) with the service value network in order to be eligible for composition. This set of registered service offerings form the steady pool from which a complex service is composed. However, the registration is open for any service which meets certain minimum requirements, such as modularity provided through a detailed interface specification. Moreover, it is also feasible that the service value network itself will actively browse the service landscape for eligible service offerings and register them automatically. In particular, in this context *steady* means that the SVN maintains a list of service offerings (including their interface descriptions) also if there is no current service composition request in the network. *Open* however, refers to the fact that no service can be excluded from the network, as long as it meets the publicly known minimum requirements.

Agile and market-based composition. *Agile* service composition refers to the network's ability to orchestrate a complex service ad-hoc and demand driven. At the

time of the request, the SVN will search for an optimal path through its network of registered service offerings. Here optimality is evaluated in terms of efficiency, i.e. the allocated complex service should maximize the sum of customer and provider welfare. This can only be achieved if the service orchestration is driven by a market-based approach, e.g. by means of a reverse auction.

Ubiquitously accessible information technology. Finally, the SVN must be run on and by ubiquitously accessible information technology, such as the Internet. This requirement comes as a direct consequence from the openness of the service pool and the call for efficiency. If any service meeting the requirements of the SVN shall be allowed and encouraged to register with the SVN, the SVN itself cannot rely on proprietary and protected information technology.

3.2. Formal Network Model

A service value network is described by means of a simplified state chart model (Harel and Naamad 1996) and is aligned with the representation provided by Zeng et al. (2003). State charts have proven to be the preferred choice for specifying process models as they expose well-defined semantics and they provide flow constructs offered by prominent process modeling languages (e.g. WS-BPEL) and therefore allow for simple serialization in standardized formalisms.

Hence, a service value network is represented by a k -partite, directed and acyclic graph $G = (V, E)$. Each partition y_1, \dots, y_k of the graph represents a *candidate pool* that entails service offers that provide the same (business) functionality. The set of N nodes $V = \{v_1, \dots, v_N\}$ represents the set of service offers³ with v, i, j being arbitrary service offers. Service offerings are provided by a set of Q *service providers* $S = \{s_1, \dots, s_Q\}$ with s is an arbitrary service provider. The *ownership information* $\sigma : S \rightarrow \mathcal{P}(V)$ that reveals which service provider owns which offering within the network is public knowledge⁴. There are two designated nodes v_s and v_f that stand for source and sink in the network. The set of edges $E = \{e_{ij} \mid i, j \in V\}$ denotes technically feasible service composition such that e_{ij}

³ The terms *service offer*, *service* and *node* are used interchangeably

⁴ The reverse ownership information $\sigma^{-1} : V \rightarrow S$ maps service offers to single service providers that own that particular service

represents an interoperable connection of service $i \in V$ with service $j \in V$ ⁵. If two offerings are not interoperable at all, they are not connected within the network.

A *service configuration* A_j of service $j \in V$ is fully characterized by a vector of attributes $A_j = (a_j^1, \dots, a_j^L)$ where a_j^l is an attribute value of attribute type $l \in \mathcal{L}$ of service j 's configuration. Attribute types can be either functional attribute types or non-functional attribute types (e.g. availability or privacy). A service's configuration represents the quality level provided and differentiates its offering from others. According to Lamparter (2007), a service configuration can be defined as follows:

Definition 3.2: Service Value Networks. *A service configuration A_j of a service $j \in V$ selects a value a_j^l for each attribute type $l \in \mathcal{L}$ of a service and thereby unambiguously defines all relevant service characteristics. The choice of configuration might affect the functional and non-functional aspects of a service and is a major determinant of the price.*

Furthermore let c_{ij} denote *internal variable costs* that the service provider that owns service j has to bear for that service being interoperable with service i and for the execution of service j as a successor of service i . The representation of a detailed cost structure of service providers is intentionally omitted which serves a better understanding and does not restrict the generalization of the model. It is assumed that the representation of internal variable costs reflects the service providers' valuations for their service offers being executed in different composition-related contexts.

The instantiation of a complex service is represented by a path from source to sink within the service value network. Let F denote the set of all feasible paths from source to sink. Every $f \in F$ with $f \subset E$ represents a possible instantiation of the complex service. Focusing on the presence or absence of a particular service $i \in V$, F_{-i} represents the set of all feasible paths from source to sink in the reduced graph G_{-i} without node i and without all its incoming and outgoing edges.

⁵ For the reader's convenience the notion e_{ij} is equivalent to $e_{v_i v_j}$ representing an interoperable connection of service $i \in V$ with service $j \in V$.

In contrary, let F_i be the subset of all feasible paths from source to sink that explicitly entail node i .

Definition 3.3: Service Value Network Model. A service value network model is an acyclic, k -partite and directed graph such that

$$G = (V, E)$$

with the set of nodes V representing service offers and the set of edges E that denotes technically feasible service compositions. G contains two designated nodes v_s and v_f representing source and sink such that every feasible path $f \in F$ connecting both nodes is a possible instantiation of the complex service.

For illustration purpose, Figure 3.1 shows the model of a service value network with service offers $V = \{v_1, \dots, v_4\}$ and service provider $S = \{s_1, \dots, s_3\}$. Every feasible path $f \in F$ connecting source node v_s and sink node v_f represents a possible realization of the overall complex service.

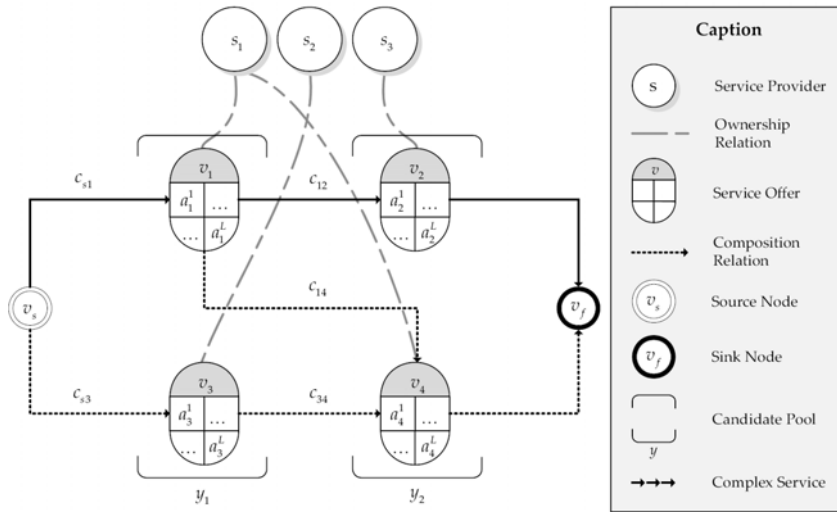


Figure 3.1: Service Value Network Model

3.3. Examples

Based on the characteristics presented in Section 3.1, we provide two extended examples how service value networks can be arranged and organized in real-world applications.

Example 3.1: Payment Processing. Consider a manager of a mid-size company that distributes flowers over the Internet. As payment processing is not a core competency of the company, the board decides on the integration of third-party service providers into existing business processes in order to decrease costs of operation and maintenance. The diagram in Figure 3.2 sketches an excerpt of the service components of an exemplary complex service that provides payment processing functionality.

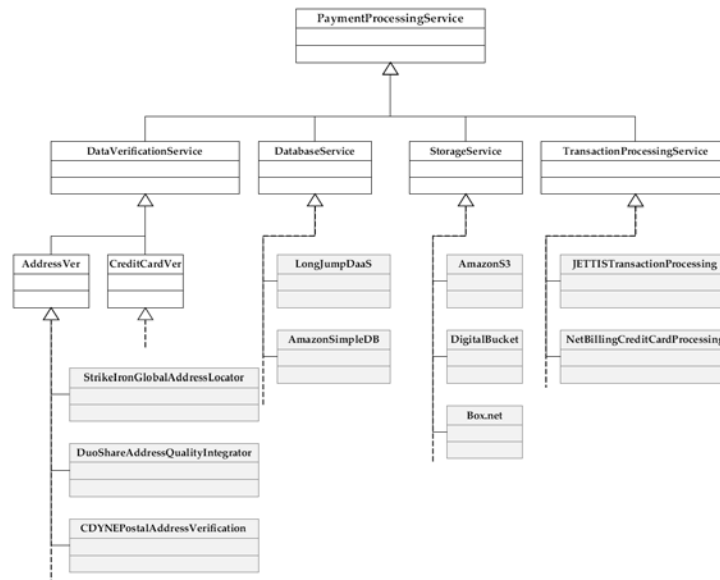


Figure 3.2: Payment Processing Service (Static View)

The `PaymentProcessingService` facilitates service components from StrikeIron⁶, Duo Share⁷ and CDYNE⁸ to verify the customer's address and credit card information. Customer data is stored and managed using a `StorageService` and a

⁶ <http://strikeiron.com/>

⁷ <http://duoshare.com/>

⁸ <http://cdyne.com/>

`DataBaseService` from third-parties. Exemplary service offerings from decentralized storage providers are Amazon S3⁹, Digital Bucket¹⁰ and Box.net¹¹. Service offerings for organizing and managing customer data are Amazon Simple DB¹² and Long Jump DaaS¹³. The actual execution of the financial transaction through the `TransactionProcessingService` is provided by JETTIS Transaction Processing¹⁴ and Net Billing Credit Card Processing¹⁵.

The process behavior of the payment processing complex service is depicted in Figure 3.3. Customer data is validated in the first step. After validation the actual transaction takes place and the customer's credit card account is charged by a transaction processing service. The change in state must be updated consequently in the internal database of the company. A database service updates corresponding customer data that is stored using a decentralized storage service. For each step of the complex service there is a potential pool of suitable candidates to fulfill required business transaction. The result of each transaction is passed sequentially to the successor service. In order to successfully instantiate the complex service the overall transaction requires a service candidate from each pool.

⁹ <http://aws.amazon.com/s3/>

¹⁰ <http://digitalbucket.net/>

¹¹ <http://box.net/>

¹² <http://aws.amazon.com/simpledb/>

¹³ <http://longjump.com/daas/>

¹⁴ <http://www.jettis.com/>

¹⁵ <http://www.netbilling.com/>

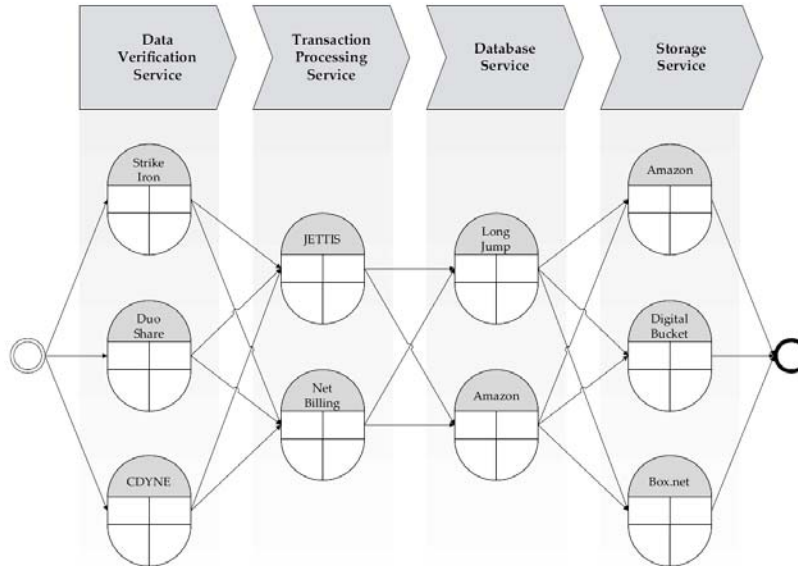


Figure 3.3: Payment Processing Service (Dynamic View)

Example 3.2: Realizing a Complex Service: Customer Relationship Management (CRM). This example shows the formation of a service value network that is ready to instantiate a complex service based on the requirements imposed by service request. A service requester requires a complex service that scans calendar entries within the upcoming week with regard to future meetings within a company. Based on the meetings' descriptions, the complex service queries soft skills of all meeting participants by browsing their profiles in social communities. Gathered information is then updated in a CRM data base that is stored by on-demand storage infrastructure (Figure 3.4).

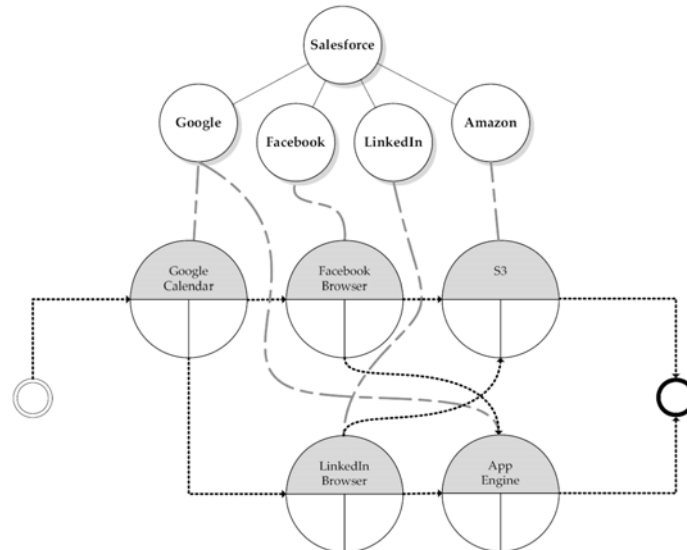


Figure 3.4: Example of a Service Value Network Realizing a Complex CRM Service

A set of service providers participates in the SVN by providing service offerings grouped in candidate pools. Google offers its Google Calendar service¹⁶ and Google App Engine¹⁷ which provides a scalable infrastructure for service development and storage. The social community platforms Facebook and LinkedIn¹⁸ provide service to browser profiles of registered customers. Amazon offers flexible storage capabilities through its Simple Storage Service (S3). As depicted in Figure 3.4 the requested complex service can be realized in four different versions by selecting feasible service combinations (e.g. Google Calendar, LinkedIn Browser and Amazon S3).

As described earlier the challenge in SVN is to determine the best combination of service offers regarding a customer's preferences and the price of this combination. Auctions are one concept for solving the allocation problem. The subsequent step in Market Engineering is to develop an appropriate auction design for the described allocation problem. We introduce such a mechanism in the next section.

¹⁶ <http://google.com/calendar/>

¹⁷ <http://code.google.com/appengine/>

¹⁸ <http://linkedin.com/>

4. Design and implementation: Coordination through Auctions in Service Value Networks

As introduced in Section 3, service value networks are ad-hoc formations of distributed service providers that offer modularized service components with the intention to realize a complex service to customers. Distributed scenarios with self-interested participants require a form of coordination in order to govern value creation. This section at hand discusses the need for auctions as a special form of coordination to manage the dependencies of distributed activities in service value networks.

4.1. Why Auctioning a Complex Service?

An adequate approach for allocation and pricing of complex service offerings has to account for special service characteristics in contrary to goods and products. In general, a service is not storable, production and consumption coincide in time and customers co-produce the final outcome which is fuzzy and hard to measure in terms of value for the customer. As stated by (Smith 1989) “*auctions flourish in situations in which the conventional ways of establishing price and ownership are inadequate*”. Smith concretizes the argumentation by briefly pointing out the main characteristics of such situations which are predestinated for the application of auctions by focusing on the roles and items involved: “*costs cannot be established, [...], there is something special or unusual about the item, ownership is in question, different persons assert special claims, [...]*.”

Although this statement is rather fuzzy, the characterization of the type of “item” which price is best established by the application of an auction mechanism opens up an analogy to the service concept. Recall, a service is characterized by the coincidence of production and consumption (uno-actu), it cannot be inventoried, value creation is dominated by intangible elements, customer co-production and fuzzy inputs and outputs.

Smith points out that auctions are preferable in situation where costs cannot be established. From a microeconomic perspective such costs refer to internal costs that are *private information* to the one producing the item, i.e. the producer's individual valuation for the item. In the context of service, this argument also holds for the customer side. Based on the argumentation that value creation through service is mainly dominated by intangible elements, the value of the final outcome for the customer is hard to determine. An objective measurement of quality which might be an indicator for the customer's valuation is also hardly applicable due to a service's fuzzy inputs and outputs. The *complexity of value elicitation* and the prob-

lem of establishing adequate prices even increases in scenarios with joint value creation through service compositions (e.g. in service value networks where a complex service is produced). Analogue to Smith's argumentation, such problems can be addressed by the design of a suitable auction mechanism that induces incentives for service providers to report their private valuations truthfully. Auctions have proven to be the ideal instrument to *aggregate information* from distributed parties which results in an aggregated valuation (Jackson 2003; Pesendorfer et al. 2000). Without prior knowledge about the valuations of each participant, auctions can provide suitable incentives to make truth revelation an equilibrium strategy and therefore automatically *aggregate necessary information* from self-interested participants to determine adequate prices for a complex service.

Another criterion that is crucial to establishing a suitable approach for allocation and pricing according to (Smith 1989) is if the item subject to trade exposes special or unusual characteristics. The *uno-actu* implies that in the context of service value creation there cannot be a provider without a customer as *production and consumption coincides in time*. This service characteristic has fundamental implications on coordination aspects as service cannot be inventoried in order to balance demand and supply. Following the same direction, Lucking-Reiley enriches this argumentation by adding an economic perspective which explicitly focuses on the trade of service offerings by stating that “[...] in the future we may see much more auctioning of services [...]. Services are particularly attractive for auctions because they are in *relatively fixed supply* – unlike durable goods, *one cannot store surpluses or draw down inventory* in order to meet fluctuating demand.” (Lucking-Reiley). Market mechanisms such as auctions are preferable in situations with a *fast changing demand and supply ratio* as dynamic pricing smoothes high amplitudes. This property is crucial to success of *efficient allocation* and pricing especially when perishable service offerings are traded (Eso 2001).

The rapid growth of ICT has tremendously decreased transaction costs for service provision and consumption. Computing power and storage raises exponentially while prices drop anti-proportionally for hardware as illustrated by Moore's Law. This development directly leads to a tough *price competition* for service providers. In order to stay competitive, service providers have to *differentiate their service offers with respect to quality* and not to price (Berry et al. 1991; Dan et al. 2003; Devlin 1998; Liu et al. 2001; Matthyssens et al. 1998). *Quality is the main value-determining factor* in the context of service offerings as service customers experience a service activity mainly based on the quality provided. Quality is idiosyncratic to the individual and often determined by various factors and the interplay of multiple service components that are part of a service composition. Hence, it is unbearable for service customers to reason about all feasible combinations of single service offerings and the resulting quality provided by the service composition in order to meet their requirements. Therefore an auction mechanism is needed

which accounts for *different preferences of service requesters* defined for a *variety of quality characteristics* that are determined by each component that is part of feasible complex service instances. Especially in the context of a situational complex service provided by distributed parties in service value networks, a QoS-sensitive auction mechanism allows for the provision and pricing of highly customized short-term solutions to various types of customers leveraging the nature and benefits of situational applications and service mashups. As a consequence, service providers in service value networks are able to *address the long tail of business* by satisfying a great amount of individual service requests (Anderson et al. 2006). In these environments, it is assumed that service offers are under the control of distributed self-interested owners. In the absence of central control, non-performance or complete drop-outs of service components are inevitable. Auction mechanisms that are *computational feasible* allow for reallocation and price adaption during run-time enabling *dynamic failovers* in unreliable environments (Foster et al. 2002).

4.2. Mechanism Design Desiderata

When we get to mechanism design within the market engineering process we have to design the components it consists of: a set of possible messages to be exchanged, the allocation rule, and the payment rule. Additionally, we need to consider the desired properties of the social choice function. Typical properties are e.g. allocation efficiency, revenue maximization, incentive compatibility, individual rationality, fairness or budget balance. Note that some of the mentioned properties exclude each other. For further discussions and background on mechanism design we refer to Arrow (1951), Hurwicz (1973), Klemperer (2004), Krishna (2002), or Myerson (1981).

In the context of SVNs, allocation efficiency can be one desired property in order to find an optimal match between service requester's preferences and service offers. Auctions can be a good solution to that problem. On the other hand, a SVN platform provider might want to limit opportunistic and strategic behavior or to increase the variety of service offerings provided. Therefore, the platform provider could search for ways to also reward parties that are willing to contribute in niches. An adequate mechanism should be tailored to deal with coordination aspects in service ecologies in which participants are both, self-interested but also fully bound to the success of the whole system. In that case concepts from cooperative game theory like the Shapley-value might be appropriate mechanisms.

Another challenge that results from the characteristics of SVNs which should be addressed in the design stage is the stability of the network. An adequate mechanism implementation should provide incentives to on the one hand sustain partici-

pating service providers and requesters and on the other hand attract further candidates.

These consideration shows that it is essential to first define the objectives the mechanism should fulfill. The objectives might change during time, e.g. it the initial stage while the network is forming, the variety of service offers is more important which calls for a different mechanism compared to a later phase when the network is more stable in its service offer variety. The next section gives an examples for service network implementation and a possible coordination mechanism.

4.3. Web Service Coordination

Environments in which distributed units provide functionality in a loosely-coupled manner (according to the SOA paradigm) require some sort of process or set of rules to align activities in order to generate a desired outcome, i.e. they require *coordination*. The objective of coordination is to make a set of entities – either by providing incentives or establishing constraints upon them – pursue a common goal, e.g. producing a defined outcome.

In the context of Web services two specifications provide frameworks to implement coordination scenarios, WS-Coordination (Newcomer et al. 2007a) and WS-CF (Chapter et al. 2005). This section focuses on WS-Coordination as it is a finalized standard in contrary to WS-CF, which is still a public review draft. A detailed comparison of WS-Coordination and WS-CF can be found in (Little et al. 2003) and (Kratz 2005). WS-Coordination is based on concepts and roles that are represented by Web services. *Initiator*, *coordinator* and *participants* communicate using a common *context* that glues their interaction to the coordinated activity. The framework allows for different coordination protocols to be plugged in, in order to coordinate domain-specific work between clients, services and participants. Work is defined as activities performed by one or more distributed parties. Examples for specific transaction protocols are WS-AtomicTransaction (Newcomer et al. 2007c) and WS-BusinessActivity (Newcomer et al. 2007b). WS-AtomicTransaction specifies a rudimentary ACID¹⁹ transaction protocol focusing on ad-hoc short-term transactions in a general manner. In contrast WS-BusinessActivity defines transactions with relaxed ACID properties with the purpose to coordinate long-term business transactions.

¹⁹ ACID stands for *atomicity*, *consistency*, *isolation* and *durability*, which are properties that guarantee a reliable transaction.

Example 4.1 WS-Coordination compliant reverse auction

To illustrate the specification of a coordination model according to the WS-Coordination framework, an auction mechanism is introduced as a special type of coordination, i.e. a single item sealed bid reverse auction. There is one *buyer* who intends to procure a single good or service from multiple *sellers*. The auction conduction including the type of messages to be exchanged between the participants is specified by *auction rules* which are controlled and enforced by an *auctioneer*. The mapping between roles and entities in a reverse auction and a coordination model is depicted in Figure 4.1.

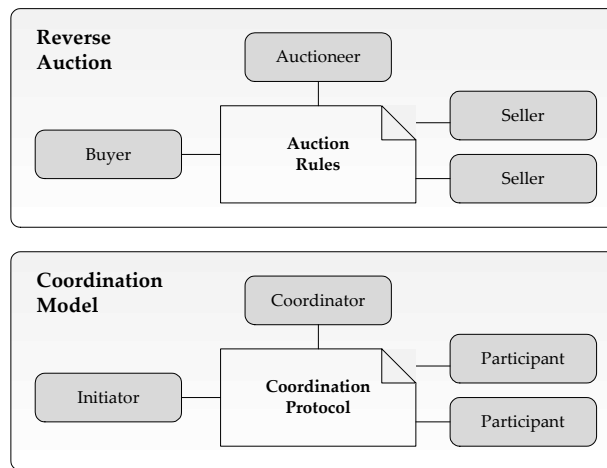


Figure 4.1 Mapping of a Reverse Auction to a Coordination Model

The buyer starts the auction by announcing a *request* for the desired good or service. The auctioneer receives sealed *offer* bids from the sellers by a public deadline. After the deadline the winner determination is performed by the auctioneer, the good or service is transferred and the winning seller receives its payment. Based on the WS-Coordination framework, the buyer is represented by the initiator and the sellers are instances of the participant role. The auctioneer as the coordinator is responsible for the coordination protocol, that is, the set of auction rules. The initiator starts the activation phase and receives a coordination context from the coordinator. The invitation phase is generally done by the initiator according to (Newcomer et al. 2007a). Nevertheless, this might not be practicable for the reverse auction scenario as the buyer is not necessarily responsible for the discovery and selection of potential sellers. As the WS-Coordination framework provides a generic coordination model independent of domain-specific application logic, a

tailored invitation process can be implemented on-top in order to shift responsibilities.

5. Conclusion

In this chapter we have introduced service value networks resulting from the possibility of combining single service offerings to a complex service. In order to find good combinations of offerings and to answer the question of determining prices we introduce an auction mechanism. Such auction mechanism need to be carefully design – especially in the context of service systems which rapidly become complex systems consisting of a large variety of service providers which offers an even larger number of service components. Consequently, Market Engineering proposes four steps starting with the environmental analysis which studies the environment of the service offerings traded and the agents which interact. This stage is followed by the design phase in which objectives of the mechanisms that is to be developed are determined and the mechanism itself is designed. Before the mechanism is implemented its properties need to be studied. Besides the theoretical analysis it might be useful to apply techniques such as experimental economics or computational approaches.

Since auctions are well known to allocate goods and service described by multiple attributes we discuss Market Engineering in the context of service value networks. Therefore, we study the environment for which the auction mechanism is to be developed and introduce our understanding of service value networks. Service providers offer their service within these networks. A service offering comprises all attributes which unambiguously define all relevant service characteristics. Service customers demand specific service offerings and might also combine offerings to a complex service. The choice of configuration might affect both, functional and non-functional aspects of a service.

We introduce a formal modal to cope with service offerings and possible combinations of them in a SVN. The practical use of this formal modal is exemplified in characteristic examples. The first example describes an online payment process which can be split in sub-processes. These sub-processes can be provided by different service providers. The second example realizes a customer relationship management task as a complex service.

In Section 4 we bring together the two presented fields of research, Market Engineering and Service Value Networks. The main questions a designer of systems for service networks has to answer is how an coordination mechanism can be defined. There might be different objectives for the social choice rule. One central

question in service value networks is how to efficiently match service offerings in order to satisfy customers' complex service requests and dynamically determine prices. Thereby, one can search for incentive compatible mechanisms that fulfill the efficiency criterion. On the other hand it might be valuable in networks not only to reward those service providers that deliver the service but also those providers that increase the value of the whole network. A starting point for such considerations might be the Shapley value (Shapley, 1953).

Besides the technical challenges, one key challenge of the still young field of service value networks is the creation of mechanisms that match supply and demand in appropriate manner. There is also need for creating formalisms which are understood by many disciplines. We have provided an attempt to a formal model, but still there is a need for further approaches and a common vocabulary. Much research needs to be done in that respect. Market Engineering is one approach to structure the design approaches and which we feel is a valuable contribution to the research in Service Systems.

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